Facility and Climate Effects on Dry Matter Intake of Dairy Cattle

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Introduction

Performance of dairy cattle may be enhanced or hindered by environmental factors affecting feed intake. Feed intake is the single most critical factor of dairy production. As production levels increase, intake becomes a greater barrier to performance of dairy cattle. The environment of the modern dairy cow includes both physical facilities and climate. Physical factors associated with confinement facilities may have a greater influence on cow performance than climatic factors. Since confinement facilities generally last 20 years or more, design choices have long-term effects upon the dairy operation. Design of freestalls, feed barriers, housing pens, building, holding pens, and milking parlor combine to create the physical environment to which cattle are exposed. Physical facilities should provide adequate access to feed and water, easy access to a comfortable lounging area and provide a comfortable environment that provides adequate protection from the elements of nature. In addition, consideration of management factors related to the interaction of cow and environment should be considered. Correct design and management of facilities can create an environment that enhances the intake and performance of dairy cattle. Climate dictates what type of facilities is required for maximum production. The use of a cooling system or protection from winter conditions is determined by the location of the dairy. Since climate conditions vary widely, different facilities are required in different areas of the world. Choices made in facility design may reduce or increase the effects of climate.

On a day-to-day basis, the two most important numbers any dairy producer should know is the milk production and dry matter intake of each pen of cattle on the dairy. Roseler et al. (1997) utilized data from many studies conducted in four different regions of the United States to develop an equation to explain dry matter intake of dairy cattle. They concluded that milk yield explained 45% of the variability in observed dry matter intake of the cows studied (Figure 1). They also concluded that climate accounted for 10% and feed and management 22% of the variability in intake. Feed and management represented all the variability not explained by the other variables. This data clearly demonstrates that cows need to eat more to produce additional milk. Designing and managing facilities to increase milk production will increase feed intake. The goal of the system should be to provide adequate cow comfort which includes (1) adequate access to feed and water (2) a clean and dry bed which is comfortable and correctly sized and constructed and (3) based on climate appropriate facility modifications to enhance production potential.

Access to Feed and Water

One of the critical decisions that producers make is the type of freestall barn they build. The most common types are either 4- or 6-row barns and many times the cost per stall is used to determine which barn should be built. Data found in Table 1 represents the typical dimensions of the barns and Table 2 demonstrates the effects of overcrowding upon per cow space for feed and water. Grant (1998) suggested that feed bunk space of less than 8 in/cow reduced intake and bunk space of 8 to 20 in/cow resulted in mixed results. Even at a 100% stocking rate, the 6-row barn only offers 18 in/cow feed line space. When over crowding occurs this is significantly reduced. Four-row barns, even when stocked at 140% of the stalls, still provide more than 18 in/cow of bunk space. In addition, when water is only provided at the crossovers, water space per cow is reduced by 40% in the 6-row barn as compared to 4-row barns. Much of the current debate over the effect of 4- and 6-row barns upon intake is likely related to presence or absence of management factors which either reduce on increase the limitations of access to feed and water in 6-row barns.

Recommendations concerning access to water vary greatly. Current recommendations suggest a range of 1.2 to 3.6 linear inches per cow (Smith et al. 1999). In the Midwest, the typical rule is one waterer or 2 linear feet of space for every 10 to 20 cows. In the Southwest, the recommendation is 3.6 linear inches of space for every cow in the pen. Typically, water is provided at each crossover in 4- and 6-row freestall barns and generally a 4- and 6-row freestall have the same number of crossovers. Thus, water

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access in a 6-row barn is reduced by 37.5% as compared to a 4-row barn (Table 1). When overcrowding is considered (Table 2) water access is greatly reduced and the magnitude of reduction is greater in 6-row barns. Milk is 87% water and water intake is critical for peak dry matter intake. When building 6-row barns or overcrowding either 4-row or 6-row barns it is important to consider the amount of water space available. In warmer climates, it is necessary to modify building plans to provide 3.6 linear inches of waterer space per cow.

If construction costs are going to drive the decision between a 4- or 6-row freestall barn, overcrowding must be considered. Typically, 4-row barns are overcrowded 10 to 15% on the basis of the number of freestalls in the pen. Due to the limitations of bunk space, many times the 6-row barn is stocked at 100% of the number of freestalls. Thus, comparing the two buildings based on a per cow housed rather than a per stall basis would be more accurate. This will make the 4-row more cost comparable to the 6-row and maintain greater access to feed and water.

Feed Barrier Design

The use of self-locking stanchions as a feed barrier is currently a debated subject in the dairy industry. Data reported in the literature is limited and conclusions differ. Shipka and Arave (1995) reported that cows restrained in self-locking stanchions for a four-hour period had similar milk production and dry matter intake as those not restrained. Arave et al. (1996a) observed similar results in another study, however a second study showed similar intake but 6.4 lb/cow/d decrease in milk production when cows were restrained daily for a four-hour period (9 AM to 1 PM) during the summer. Increases in cortisol levels were also noted during the summer but not in the spring (Arave et al., 1996b) indicating increased stress during the summer as compared to the spring. Another report (Bolinger et al., 1997) found that locking cattle for 4 hours during the spring months did not affect milk production or feed intake. All of these studies compared restraining cows for four hours to no restraint and all animals were housed in pens equipped with headlocks. The studies did not compare a neck rail barrier to self-locking stanchions nor address the effects of training upon headlock acceptance. However, some have drawn the conclusion that self-locking stanchions reduce milk production and only the neck rail barrier should be used. The data indicates that cows should not be restrained for periods of four hours during the summer heat. The argument could be made that four hours of continuous restraint time is excessive and much shorter times (one hour or less) should be adequate for most procedures. These studies clearly indicate that mismanagement of the self-locking stanchions, not the stanchions resulted in decreased milk production in one of three studies with no affect upon intake in all studies.

Another study (Batchelder, 2000) compared lockups to neck rails in a 4-row barn under normal and crowded (130% of stalls) conditions. Results of the short-term study showed a 3 to 5% decrease in dry matter intake when headlocks were used. No differences in milk production or body condition score were observed. It was also noted that overcrowding reduced the percentage of cows eating after milking as compared to no overcrowding. In this study, use of headlocks reduced feed intake but did not affect milk production.

The correct feed barrier slope is also important. Hansen and Pallesen (1994) reported that sloping the feed barrier 20° away from the cow increased feed availability because the cows could reach 14 cm further than when the barrier was not sloped. They also noted that when feed was placed within the cow's reach much less pressure was exerted against the feed barrier indicating greater cow comfort. However, the study did not indicate that intake was increased only that accessibility was increased. Pushing feed up more frequently could achieve the same affect. One disadvantage of sloping the feed barrier is that feeding equipment is more likely to come in contact with the barrier which may result in significant damage to both.

The feeding surface should be smooth to prevent damage to the cow's tongue. When eating, the side of the tongue, which is much more easily injured, often contacts the manger surface. The use of plastics, tile, coatings, etc. will provide a smooth durable surface reducing the risk of tongue injury.

Correct design of the feeding area will allow the cow more comfortable access to feed. Figures 2 and 3 demonstrate the typical design for post and rail as well as headlock systems. It is important to lower the cow standing surface relative to the feed table and to provide the correct throat height. Incorrectly designed feeding areas may limit feed intake and, thus, milk production.

Freestall Design and Surfaces

Freestall Design

Cows must have stalls that are correctly sized. As early as 1954 researchers demonstrated increases in milk production when larger cows were allowed access to increased stall sizes. Today, construction costs often encourage producers to reduce stall length and width. This may reduce cow comfort and production. Cows will use freestalls that are designed correctly and maintained. If cows refuse to utilize stalls, it is likely related to design or management of the freestall area. Table 3 provides data for correctly sizing the stall. In addition, the stall should be sloped front to back and a comfortable surface provided.

Freestall Surface Materials

Sand is the bedding of choice in many areas. It provides a comfortable cushion that forms to the body of the animal. In addition, its very low organic matter content reduces mastitis risk. Sand is readily available and economical in many cases. Disadvantages may include the cost of sand and/or the issues with handling sand-laden manure and separating the waste stream. Since 25 to 50 pounds of sand are consumed per stall per day, it should be separated from manure solids to reduce the solid load on the manure management system. In arid climates, manure solids are composted and utilized for bedding. Producers choosing not to deal with sand or composted manure bedding, often choose from a variety of commercial freestall surface materials. Sonck, et al. (1999) observed that when given a choice, cows prefer some materials (Figure 4). Occupancy percent ranged from over 50 to under 20%. Researchers suggested that the increase in occupancy rate was likely influenced by the compressibility of the covering. Cows selected freestall covers that compressed to a greater degree over those with minimal compressibility. Cows need a stall surface that conforms to the contours of the cow. Sand and materials that compress will likely provide greater comfort as demonstrated by cow preference.

Enhancing Production Potential Environmental Temperature

Mature dairy cattle generally have a thermal neutral zone of 41 to 68°F. This may vary somewhat for individual cows and conditions. Within this range, it is generally assumed that impacts upon intake are minimal. However, temperatures below or above this range alter intakes.

Effects of Heat Stress

Heat stress reduces intake, milk production, health and reproduction of dairy cows. Spain et al. (1998) showed that lactating cows under heat stress decreased intake 6 to 16% as compared to thermal neutral conditions. Holter et al. (1997) reported heat stress depressed intake of cows more than heifers. Other studies have reported similar results. In addition to a reduction in feed intake, there is also a 30 to 50% reduction in the efficiency of energy utilization for milk production (McDowell et al. 1969). The cow environment can be modified to reduce the effects of heat stress by providing for adequate ventilation and effective cow cooling measures.

Ventilation

Maintaining adequate air quality can be easily accomplished by taking advantage of natural ventilation techniques. Armstrong et al. (1999) reported that a 4/12 pitch roof with an open ridge resulted in lower afternoon cow respiration rate increases as compared to reduced roof pitch or covering the ridge. They also observed that eave heights of 14 feet resulted in lower increases in cow respiration rates as compared to shorter eave heights. Designing freestall barns that allow for maximum natural airflow during the summer will reduce the effects of heat stress. Open sidewalls, open roof ridges, correct sidewall heights and the absence of buildings or natural features that reduce airflow increase natural airflow. During the winter months, it is necessary to allow adequate ventilation to maintain air quality while providing adequate protection from cold stress.

Another ventilation consideration is the width of the barn. Six-row barns are typically wider that 4-row barns. This additional width reduces natural ventilation. Chastain (2000) indicated that summer ventilation rates were reduced 37% in 6-row barns as compared to 4-row barns. In hot and humid climates, barn choice may increase heat stress resulting in lower feed intake and milk production.

Cow Cooling

During periods of heat stress, it is necessary to reduce cow stress by increasing airflow and installing sprinkler systems. The critical areas to cool are the milking parlor, holding pen and housing area. First, these areas should provide adequate shade. Barns built with a north-south orientation allow morning and afternoon sun to enter the stalls and feeding areas and may not adequately protect the cows. Second, as temperatures increase, cows depend upon evaporative cooling to maintain core temperature. The use of sprinkler and fan systems to effectively wet and dry the cows will increase heat loss.

The holding pen should be cooled with fans and sprinkler systems and an exit lane sprinkler system may be beneficial in hot climates. Holding pen time should not exceed one hour. Fans should move 1,000 cfm per cow. Most 30- and 36-inch fans will move between 10,000 and 12,000 cfm per fan. If one fan is installed per 10 cows or 150 ft^2, adequate ventilation will be provided. If the holding pen is less than 24 feet wide with 8 to 10 feet sidewall openings, fans may be installed on 6 to 8 foot centers along the sidewalls. For holding pens wider than 24 feet, fans are mounted perpendicular to the cow flow. Fans are spaced 6 to 8 feet apart and in rows spaced either 20 to 30 feet apart (36-inch fans) or 30 to 40 feet apart (48-

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inch fan) (Harner et al, 1999). In addition to the fans, a sprinkling system should deliver .03 gallon water per foot^2 of area. Cycle times are generally set at 2 minutes on and 12 minutes off.

Freestall housing heat abatement measures should include feedline sprinklers and fans to increase air movement. Sprinkling systems should deliver water similar to the holding pen system except it should only wet the area occupied while the animal is at the feed bunk. The hair coat of the cow should become wet and then be allowed to dry prior to the beginning of the next wetting cycle. Fans may be installed to provide additional airflow that will increase evaporation rate (Harner et al. 1999).

Cold Stress

Dairy cows can withstand a significant amount of cold stress as compared to other animals. Factors affecting the ability of the cow to withstand cold temperatures include housing, pen condition, age, stage of lactation, nutrition, thermal acclimation, hairy coat and behavior (Armstrong and Hillman, 1998). Feed intake increases when ambient temperature drops below the lower critical temperature of the animal. Protection from wind and moisture will reduce the lower critical temperature and minimize the effects of cold stress. When feed intake is no longer adequate to maintain both body temperature and milk production, milk production will likely decrease.

Supplemental Lighting

Lactating Cows

Supplemental lighting has been shown to increase milk production and feed intake in several studies. Peters (1981) reported a 6% increase in milk production and feed intake when cows were exposed to a 16L:8D photoperiod as compared to natural photoperiods during the fall and winter months. Median light intensities were 462 lx and 555 lx for supplemental and natural photoperiods respectively. Chastain et al. (1997) reported a 5% increase in feed intake when proper ventilation and lighting were provided and Miller et al. (1999) reported a 3.5% increase without bST and 8.9% with bST when photoperiod was increased from 9.5 to 14 hours to 18 hours. Increasing the photoperiod to 16 to 18 hours increased feed intake. Dahl et al. (1998) reported that 24 hours of supplemental lighting did not result in additional milk production over 16 hours of light. Studies utilized different light intensities in different areas of the housing area. More research is needed to determine the correct light intensity to increase intake. In modern freestall barns, the intensity varies greatly based on the location within the pen. Thus, additional research is needed to determine the intensity required for different locations within pens.

Another issue with lighting in freestall barns is milking frequency. Herds milked 3X cannot provide 8 hours of continuous darkness. This is especially true in large freestall barns housing several milking groups. In these situations, the lights may remain on at all times to provide lighting for moving cattle to and from the milking parlor. The continuous darkness requirement of lactating cows may be 6 hours (Dahl, 2000). Thus, setting milking schedules to accommodate 6 hours of continuous darkness is recommended. The use of low intensity red lights may be necessary in large barns to allow movement of animals without disruption of the dark period of other groups.

Dry Cows

Dry cows benefit from a different photoperiod than lactating cows. Recent research (Dahl, 2000) showed dry cows exposed to short days (8L:16D) produced more ($P<.05$) milk in the next lactation than those exposed to long days (16L:8D). Petitclerc et al. (1998) reported a similar observation. Based on the results of these studies, dry cows should be exposed to short days and then exposed to long days post-calving.

Lot Condition

Mud can have a significant negative impact upon dry matter intake. Fox and Tylutki (1998) suggested that every inch of mud reduced DMI of dairy cattle 2.5%. Based on this assumption, feed intake of cattle in 12 inches of mud would be 30% less than those without mud. Based on our current knowledge of the impact of prepartum intake upon subsequent lactation performance. Dry cattle housed in muddy conditions may be at greatest risk. However, significant production losses may also occur in lactating cattle.

Summary

Environmental factors that affect feed intake can be divided into physical and climatic affects. On modern dairies, the physical factors may be more of a concern than the climate. Modern facilities provide the cow with protection from the natural elements. However, the same facilities that protect the cow from the climate may enhance or hinder dry matter intake. Facilities should provide adequate access to feed and water, comfortable resting area and adequate protection from the natural elements. Critical areas of facility design related to feed intake include the access to feed and water, stall design and surface, supplemental lighting, ventilation and cow cooling. The total system should function to enhance cow comfort and intake. It is important to remember that choices made during construction of a facility will affect the performance of animals for the facility life, which is generally 20 to 30 years. Producers, bankers and consultants too often view the additional cost of cow comfort from the standpoint of initial investment rather than long-term benefit.

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Table 1. Average pen dimensions, stalls, cows and allotted space per animal.

					Per Cow		
Barn Style	Pen Width (ft)	Pen Length (ft)	Stall Per Pen	Cows Per Pen	Area (ft^2)	Feedline Space (linear in)	Water Space (linear in)
4-Row	39	240	100	100	94	29	3.6
6-Row	47	240	160	160	71	18	2.25
2-Row	39	240	100	100	94	29	3.6
3-Row	47	240	160	160	71	18	2.25

Adapted from Smith, J.F. et al., 1999.

Table 2. Effect of stocking rate on space per cow for area, feed and water in 4- and 6-row barns.

Stocking Rate (%)	Area (ft^2/cow)		Feedline Space (linear in/cow)		Water Space (linear in/cow)	
	4-Row	6-Row	4-Row	6-Row	4-Row	6-Row
100	94	71	29	18	3.6	2.25
110	85.5	64.5	26	16	3.27	2.05
120	78.3	59.2	24	15	3.0	1.88
130	72.3	54.6	22	14	2.77	1.73
140	67.1	50.7	21	13	2.57	1.61

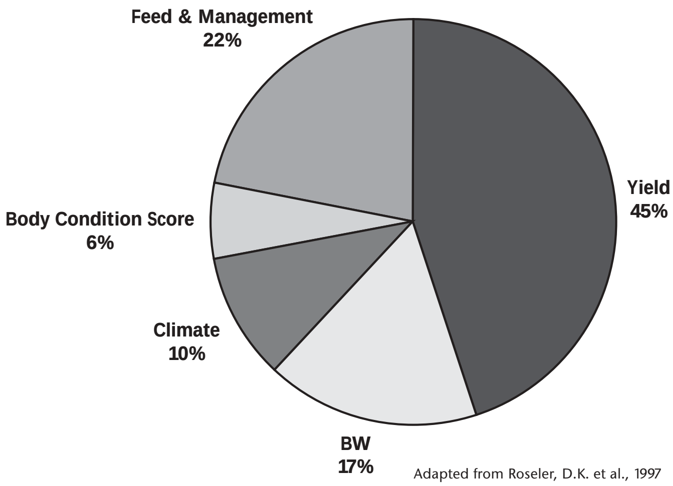
Table 3. Freestall dimensions for cows of varying body weight.

Body Weight (lb)	Free Stall Width (in)	Side Lunge (in)	Forward Lunge[a] (in)	Neck Rail Height Above Stall Bed (in)	Neck Rail and Brisket Board Bed, Distance from Alley Side of Curb (in)
800–1,200	42 to 44	78	90 to 96	37	62
1,200–1,500	44 to 48	84	96 to 102	40	66
Over 1,500	48 to 52	90	102 to 108	42	71

[a]An additional 12-18 inches in stall length is required to allow the cow to thrust her head forward during the lunge process.

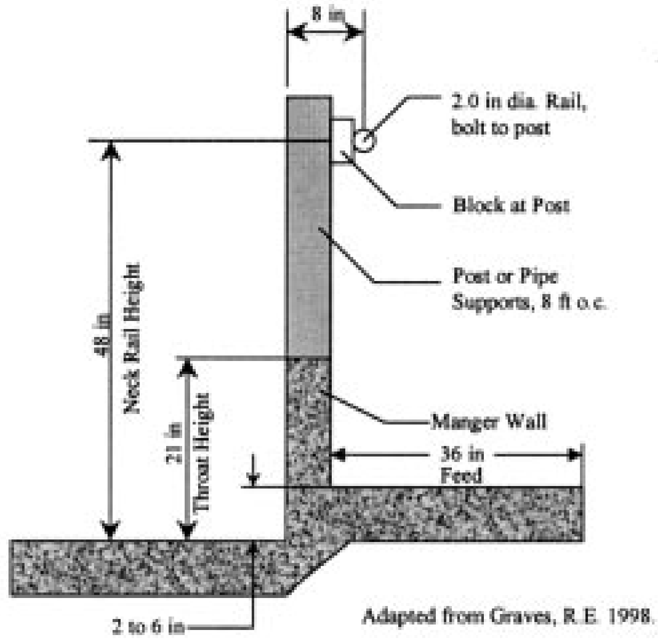
Adapted from Dairy Freestall Housing and Equipment, 1997.

Figure 1. Description of factors that affect DMI in lactating dairy cows and the amount of variability explained by each factor.



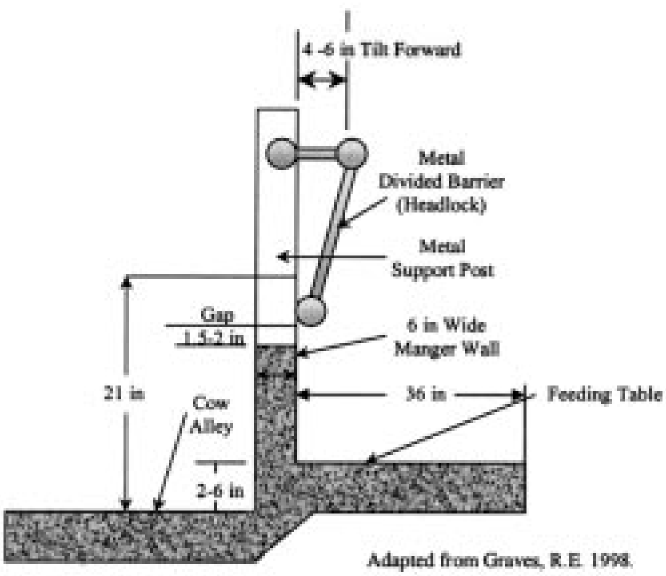
Adapted from Roseler, D.K. et al., 1997

Figure 2. Post and Rail Feeding Fence for Cows.



Adapted from Graves, R.E. 1998.

Figure 3. Divided Feed Barrier (Headlock)



Adapted from Graves, R.E. 1998.

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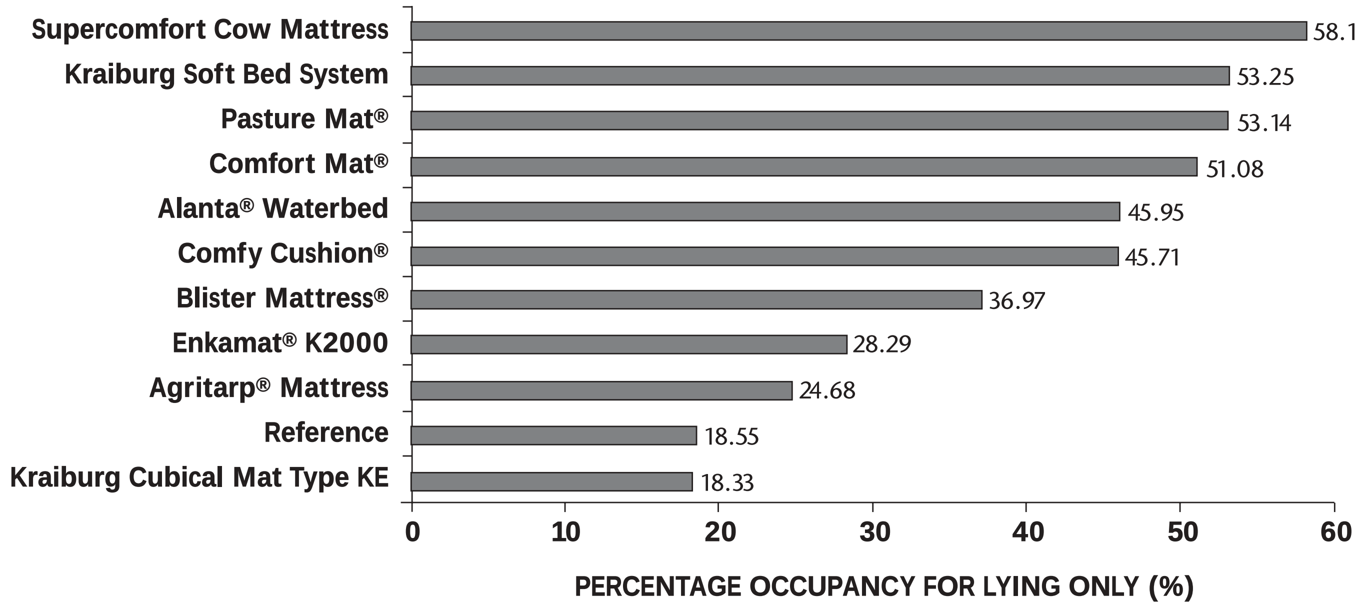
Figure 4. Classification of the 11 freestall surface materials, based on the average percentage occupancy for lying only (%).



Adapted from Sonch, B. et al., 1999.

Supercomfort Cow Mattress of R. De Cleene (Belgium) consists of a soft and elastic supporting layer of rubber tiles (30 mm thick) made from small rubber crumbs, combined with a top water-tight layer (6 mm thick) of polypropylene and a PVC back (weight: 3.8 kg/m^2). The latter is the same top layer as the Blister Mattress.

Kraiburg Soft Bed System of Gummiwerk Kraiburg Elastik GmbH (Germany) is a mattress consisting of a rubber mat with a hammered finish (a thickness of 8 mm and a weight of 9.5 kg/m^2) as nonporous top layer. The mat is combined with a 25 mm polyurethane foam underlay (weight: 3.5 kg/m^2). An all-round insulation strip prevents dirt from penetrating the foam.

Pasture Mat® type CS of Pasture BV (The Netherlands) is made by filling rubber crumbs (4-7 mm in size) in twelve independent cells of a bag (57 mm thick and 26 kg/m^2 weight), made from polypropylene and nylon. The independent cells are covered with a non-woven polypropylene top sheet of 3.5 mm thick and 1.9 kg/m^2 weight.

Comfort Mat® of Alfa Laval Agri Belgium: is a soft rubber mat with a thickness of 20 mm and a weight of 4 kg/m^2.

Alanta® Waterbed of Dunlop-Enerka (The Netherlands): is an individual double-sided rubber mat (Styrene-butadiene rubber) filled with water. Thickness of the mat is 9 mm unfilled and 50 mm filled with 50 liters of water. The weight of the unfilled mat amounts to 10 kg/m^2.

Comfy Cushion® mattress of Mac Farm Systems (Belgium) is made by stuffing rubber crumbs in independent cells of a bag of 70 mm thick, made of polypropylene. The weight of this underlayer amounts to 28 kg/m^2. Two tubes spaced 16 cm apart are fastened onto a polypropylene sheet forming an element. Elements are linked to each other by placing them alternately facing up and facing down. The tubes are covered with a white woven polyester sheet with a thickness of 1 mm and a weight of 0.5 kg/m^2.

Blister Mattress® of Brouwers Stalinrichtingen BV (The Netherlands) is made from a combination of a soft supporting layer (20 mm thick) and a top water-tight layer (6 mm thick) of polypropylene and a PVC back (weight: 3.8 kg/m^2).

Enkamat® K2000 of Vape BV (The Netherlands) is a compact mat consisting of 5 thin layers: a wear resistant top layer, an impermeable coating, a reinforcement textile, a second impermeable coating and a polyamide curling underlay.

AgriTarp® Mattress of Agriprom Stalmatten BV (The Netherlands) is made by stuffing rubber crumbs in independent tubular cells of a bag of 60 mm thick, made of polypropylene. The weight of this underlayer amounts to 28 kg/m^2. The tubes are covered by a non-woven polypropylene top sheet of 1 mm thickness and a weight of 0.8 kg/m^2.

Reference: a concrete floor littered with sawdust.

Kraiburg Cubicle Mat Type KE of Gummiwerk Kraiburg Elastik GmbH (Germany) is a classic rubber mat with a hammered finish (18 mm thick and 20 kg/m^2 weight).