Sand: a review of its use in housed dairy cows
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1. INTRODUCTION TO SAND

Whether zero-grazed or brought in over winter, the housing of many dairy cows together can have a detrimental impact on the health and production (Haskell et al., 2006) of the herd. Innovations in barn and cubicle design have sought to minimise these problems (Cook & Nordlund, 2004) as well as ever-increasing options of inventive bedding materials (rubber mattresses, water-beds, straw, sawdust, composted manure), each attempting to solve the inherent problems of health, welfare and production loss. Favoured for decades by some of the largest dairies across the United States of America (Wisconsin, Wyoming, Ohio) and Canada (Ontario), sand has often by touted as the “gold standard” (Bickert, 1999) for housed cow comfort and health. Considered to be an economically viable option for large-scale enterprises that can afford not only to use large quantities of sand (25kg per cow/day) but also the labour and other costs that are implicated with its use, e.g. slurry management and erosion of farm equipment (to name only a few).

Why then, should sand be a feasible option for the more modest herds of the European farmer, when it has often been publicised as the most labour intensive (Rodenburg, 2000) bedding option? Sand, with its natural qualities of comfort, low bacterial count and ability to detract both heat and moisture away from the cow may be the best for both farming methods with some adjustment to housing management. This review will look not only at why sand is a good option for cubicle surfaces, but also at general and European constraints of using sand, many of which can be managed effectively, but some that must be tolerated in order to gain other critical benefits of sand. We will also look at the wide-ranging costs – economic, time and management.
1.2. Desirable Qualities

Why then should any dairy farmer, large or small, wish to use sand? Sand possesses many natural qualities that lend it to being an ideal bedding material for cows. Its merits enhance some of the most important characteristics of cow behaviour and health:

1. Provides comfortable surface for great “cow comfort”
2. Inorganic, less bacterial growth
3. Dry, reduces build up of moisture
4. Cool, does not insulate, reduces heat stress
5. Provides traction for cows, reduces slipping

The contemplation of these advantages will be briefly elaborated on in the following chapter; more complete discussions of the constraints and reimbursements of sand usage will take place in the housing, health, behaviour and production chapters.

1.2.1. Comfort

To claim that sand provides optimal cow comfort is firstly tricky to define and secondly hard to substantiate. Briefly described here, the report will later give more detail about these vital points of “cow comfort”

- Initially, the comfort factor of sand can be attributed to its innate qualities of dryness, coolness and traction as mentioned above.
- Additionally, there can be useful indicators of better cow comfort, e.g. increased lying times and lower incidences of leg lesions and other injury (Weary & Tucker, 2003).
- Also the tactile and physical qualities of sand, e.g. particle size and uniformity, have been shown to “cushion” the animal as it equalises its weight over the area of the cubicle (Stowell & Inglis, 2000) whilst lying down and standing up.

The loose texture and non-cohesive particles are seemingly lubricant under pressure; this eases the impact on the cow’s hard contact points and reduces hock lesions and hair loss (Stowell & Inglis, 2000). As long as the sand is kept dry (from urine, milk leakage or the elements on open sided barns) it will remain non-compactable. Preference tests have also been used to show that cows actively prefer sand to other bedding types (Tucker, 2003; Calamari et al., 2009) although data should be examined for scientific meaningfulness (Weary & Tucker, 2003) as there are many factors, e.g. prior experience, barn layout, that...
can account for disparity in results both for and against sand. Increased lying time can be another useful indicator of good comfort (Cook 2009), which in turn can reduce associated behavioural problems connected with lying in the gutter or perching in stalls. It may also reduce lameness caused by prolonged standing, e.g. sole ulcers (Weary & Tucker, 2003) and improve health through reduced stress (Cook, 2009). It can shorten the length of time for recovery from illness (van Eerdenburg, 2010), which is of great advantage to the overall welfare of the cow.

1.2.2. Inorganic
One of the main advantages of sand is that it is inorganic and as such, does not support bacterial growth (Bell, 2007). Although keeping it clean and contaminant free is management dependent. In this way sand is no different from any other bedding but relies on attentive and apposite farming practises. Cows naturally disturb and remove the top layer when rising from the stalls, which also keeps the bacterial count down (Stowell & Inglis, 2000). As sand is inert, it can be recycled and reused as bedding, although this is not current practice in the Netherlands or the UK due to cheap and abundant sand (van Eerdenburg, 2010). Sand is successfully recycled in other countries (e.g. USA, Canada) and in one study, maintained a low bacterial count for many years (Bernard et al., 2003), when recycling was well managed. In countries like the Netherlands sand can be reused onto fields and even give loamy soils some structure (van Eerdenburg, 2010) which contributes to it’s advantages as a low environmental impact bedding as it is not manufactured and is reusable.

1.2.3. Dry
Particle size should be 0.1-1mm and of uniform size (Schoonmaker, 1999). This is imperative not only for comfort, but also for the moisture content of the sand (Stowell & Inglis, 2000). Uniform particle size allows for proper drainage of urine or other moisture build up that allows bacteria to grow. Good drainage also prevents bacteria from forming colonies on the surface of the bedding, which is implicated in teat exposure when lying (Zdanowicz et al., 2004) and is a factor in the risks of environmental mastitis. Sand is also non-absorbent, which means that it does not retain or soak up urine, leaked milk or other fluids (Gooch & Inglis, 2010) whereas other beddings (e.g. straw, sawdust, etc.) may absorb moisture or
waste, which will support bacterial growth. Moisture on the surface of the sand has a very quick evaporation time (Stowell & Inglis, 2000) due to the way that moisture binds to single grains of sand. This leads to rapid drying of the top layer of sand, which inhibits bacterial growth and survival.

1.2.4. Temperature

Cows must maintain their body temperature between 38.6°C - 39.3°C (Cool Cows, 2008). When the environmental temperature rises above their thermoneutral zone, cows will have to expend energy to regulate their own body temperature. Sand does not insulate the cow despite the air present between grains in dry sand (Stowell & Inglis, 2000) and has much lower lying temperatures than other bedding materials.

The Temperature Humidity Index (THI) for dairy cows details the air temperature and relative humidity (RH) at which heat stress beings, it ranges from mild (THI 71-79 in yellow), moderate (THI 80-89 in orange) to severe (THI 90-99 in red), mild starts at 22°C at as shown in Figure 1 (Pennington & van der Deven, 2010).

| Deg C | 0  | 5  | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|     |
| 23.8  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 26.7  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 29.0  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 32.0  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 35.0  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 37.0  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 40.5  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 43.3  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 46.0  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |
| 48.9  | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |     |

Figure 1. Source: Pennington & van der Deven (2010).

The potential of heat stress in cows comes from (1) the external environment and (2) their internal metabolic process, which can increase when the cows lactate or ruminate (Kadzerea et al., 2002). Their heat load is determined by how much heat they can transfer back into the environment (Cool Cows, 2008) and despite disparity in thermoneutral zones for lactating and dry cows, heat stress in housed cattle is much more of the problem than cold and sand is ideal for helping the cow to expel excess heat.
1.2.5. Traction

In stalls sand provides traction allowing cows to stand up without slipping, which also increases use of stalls for lying time (Bell, 2007) as opposed to say, quarry belts which are notorious for being slippery when cows try to get to their feet. Cows can also get good leverage from the way that sand embeds their feet as they rise or lay down. This can also reduce their tendency to rock back and forth to find their momentum to stand which can reduce associated injuries to the knees and ankles (Bickert, 1999). Sand spread around the yard, in alleys etc, provides cows with extra grip during walking, so they express less fear of slipping which results in less compromised cow traffic. The traction also provides cow with enough grip to express natural behaviours, such as mounting or standing heat, which they may decline to do on a more slippery surface (Anderson, 2008).
2. COSTS

2.1. Sand Usage

In the first chapter the distinction was made between the American and European systems of managing sand. The tendency in these dairies is for high sand usage, sand is “deep bedded”, e.g. 15-20 cm on top the stall base (Schoonmaker, 1999). The advantage of this system is that cows will drag sand contaminated with faeces and other waste material out of the stall on a daily basis. It requires refilling with fresh sand every 12-14 days, with additional sand between these days to keep the curb from protruding (Schoonmaker, 1999).

However, in these “super dairies” for 1,000+ head of cattle, equipment like the The McLanahan Millennium Stall Filler (McLanahan, 2010) can fill 70 stalls in 2½ minutes, see Picture 1 (SBConsultancy, 2007).

In Europe, with only 11% of dairy herds in EU member states numbering above 50 cows (Arendonk & Liinamob, 2003), a drastic reduction in sand usage per stall is shown, because the smaller size of herd does not necessitate expensive cubicle filling equipment. However, it does mean that there are higher time and labour costs to managing sand compared to the American system.

American system: 20kg – 25kg per stall, per day is equal to 7.3t – 9.1t per stall p/a.
European systems: 5kg – 8kg per stall, per day is equal to 1.8t – 2.9t per stall p/a.
2.2. Sourcing & Types of sand

Sand can be sourced from a variety of locations: mason sand, dredged sand, beach sand and quarried sand (Stowell & Inglis, 2000; Bell, 2007; Gooch & Inglis, 2010). If, after separation from manure, the intention is to spread sand on the land it should be noted that some sources of sand can alter the pH of the land (Bell, 2007) therefore care should be taken in this regard when choosing the appropriate sand for the farm.

2.2.1. Fine & Natural Sand

Bell (2007) also raises concerns about the sustainability of sand sourced from beaches and river beds. Another concern with these types of sand is that they can contain pebbles, pieces of shell or other foreign objects, which can negate the comfort of the cow in the cubicle (Gooch & Inglis, 2010). Additionally there is a possibility that this sand can also be contaminated with organic material (Bell, 2007). Sand from these sources should be washed and sieved prior to use (Rodenburg, 2003). Advantages of this fine sand type is that it tends to stay in the stall longer and therefore less is required and of all sand types, it is possibly less abrasive on pumps and other farm equipment (Schoonmaker, 1999). Naturally sourced sand tends to have less uniform particle sizes (Stowell & Inglis, 2000) and is therefore is less porous (Gooch & Inglis, 2010), as small particles will fill and block the gaps between larger grains resulting in poorer drainage than other sand. Therefore fine, natural sand can become more compact and hard than coarse sand (Schoonmaker, 1999). Although fine, or natural sand is softer (Bell, 2007) the small particle size means that is hard to recover from slurry laden manure for recycling.

2.2.2. Mason & Concrete Sand

Mason or concrete sand has the advantage that if it is filtered for particle uniformity then it will have fewer pebbles or stones to cause injury or lameness (Schoonmaker, 1999; Gooch & Inglis, 2010). Furthermore, it has the lowest organic count prior to being used (Stowell & Inglis, 2000). It is less cohesive than fine or natural sand, which means that it remains looser (Schoonmaker, 1999) providing the “slipperiness” of particle on particle that prevents lesions and hard contact points on the cow’s body. The advantage of having uniform particle size is, as mentioned before, that it drains more quickly providing a dry bedding that does not support bacterial growth. Furthermore, it is easier to separate in manure handling systems then very fine sand particles (Schoonmaker, 1999), although recycling and reusing
this sand through washing can make the particle edges more jagged and abrasive to exposed skin, e.g. udder (Gooch & Inglis, 2010). There are some claims that mason or concrete sand are more abrasive on farm equipment and manure handling machinery (Schoonmaker, 1999), although in the big scheme of things, all sand causes wear and tear to farm yard appliances.

2.3. Price of sand

In this paragraph the differences in sand prices in countries will be discussed. In Table 1, the prices directly from the suppliers are shown.

<table>
<thead>
<tr>
<th>Sand Type</th>
<th>Country</th>
<th>Quantity (tonne)</th>
<th>Quantity (m³)</th>
<th>Price (£GB / US$)</th>
<th>Price (£)</th>
<th>Approx cost per stall p/a, US system</th>
<th>Approx cost per stall p/a, European system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Sand</td>
<td>UK</td>
<td>1</td>
<td>0.67</td>
<td>£7.60</td>
<td>£8.50</td>
<td>£55-£69</td>
<td>£13.50-£22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>£62-£77</td>
<td>£15-£24.50</td>
</tr>
<tr>
<td>Mason Sand</td>
<td>UK</td>
<td>1</td>
<td>0.67</td>
<td>£13.00</td>
<td>£14.50</td>
<td>£95-£118</td>
<td>£23-£38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>£106-132</td>
<td>£26-£42</td>
</tr>
<tr>
<td>Mason Sand</td>
<td>NL</td>
<td>1.5</td>
<td>1</td>
<td>£9 - £18</td>
<td>£10 - £20</td>
<td>£66-£164</td>
<td>£16-£52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>£73-182</td>
<td>£18-£58</td>
</tr>
<tr>
<td>Cubicle Sand</td>
<td>USA</td>
<td>1</td>
<td>0.67</td>
<td>$8-10</td>
<td>$6-7.4</td>
<td>$58-$91</td>
<td>$14-$29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$44-$67</td>
<td>$11-$21.5</td>
</tr>
</tbody>
</table>

Weight: conversions between tonne and cubic metre vary (1m³ / 1.4t – 2t) due to the disparity in types of sand. Calculations made here at 1.5t per 1m³. Currency: calculations for £GB / € / US$ done on 22 March 2010. Price data for UK from (Cardigan Sand & Gravel Co., 2009) NL (van der Linde, 2008) and US (Rodenburg, 2009).

However, unless the farmer is picking up his own sand, haulage costs are also a factor which can make the overall price vary considerably (Bell, 2007). This is especially true to Europe, with greater number of small herd spread across the continent (Arendonk & Liinamob, 2003) as opposed to the fewer, larger dairies in the US and Canada. Therefore, there is a higher chance that some farms will not be located near to an accessible source of sand (beach, river, quarry, etc). This may mean that some farmers find recycling a more attractive option based on their local availability of sand. However, this has its own cost implications and careful consideration of how well managed the recycling could be should be weighed against other options of storing sand or even alternative bedding options. Investing in a recycling system may also see these farms being able to recoup their losses through re-use of their sand. Sand varies in quality cheaper versions (unfiltered, etc) should be avoided as they can
negate the benefits otherwise afforded by using sand by poor drainage and abrasive edges (Gooch & Inglis, 2010).

2.4. Cost analysis

A decision to use sand has to weigh up the costs (economic, housing / slurry requirements, labour, time) against the potential for investment in the herd (better health, welfare and production). Sand is not a salve or cure-all for poor housing design or bad management. The cost of sand does vary in price and delivery costs also contribute to this as sand is heavy and requires specialised transport for delivery to farms. This can be a significant factor for those farms living outside sand accessible zones. Currently in the UK and the Netherlands there is easy access to natural sources of sand (the coast, rivers, etc) and to manufactured mason sand at competitive prices. Other implications in cost are the natural wear and tear of sand on farm machinery which will need to be replaced more often. Steps have been made to reduce this, i.e. replacing slurry scraper chains with rope reduces the abrasion on the concrete, and metal scrapers with rubber ones. Sand does require specialised manure handling, which is often cited as the biggest challenge (Rodenburg, 2003) and modifying systems can be costly. Please see the chapter on housing for a review on slurry and manure handling with sand.

The Netherlands face additional challenges due to the lack of hills or inclines which lend gravity to the success of flush or sand trapping methods of manure handling (Hulsen, 2010). Sand can be more susceptible to blocking drains and pipes in the farm (Bell, 2007). In terms of slurry management, sand is also only really successful on solid floors. Updating barns could be expensive and solid floors have a risk of dirtier cows (versus slatted floors), although this is a constraint of using sand, rather than a disadvantage. Sand is also not suitable for calving as the sand sticks to calves (Stowell & Inglis, 2000). Sand stores can freeze solid in cold weather; therefore the use of sand may be restricted by geography – although there are ways of overcoming this, e.g. inside storage. If stored outside, dry sand can be obtained by sourcing sand from the middle of the heap. Dry sand is imperative to enhancing its natural benefits. Unlike the American systems, European farmers will also have to face doing much of the manual work on a day-to-day basis, meaning that sand will also have much higher time or labour costs for the farm.
Although, theoretically, the health and production benefits should outweigh these costs by providing greater cow welfare and longevity (Cook & Norland, 2010). Some studies support that sand reduces lameness by 42% (Cook, 2009) and significantly confirmed less environmental mastitis pathogens (Godden et al. 2008; Russel et al., 2002). Improved health and indications of better cow comfort should increase production both through a reduction in stress and disease. It is possible that farmers will wait to recoup the initial costs, but Schoonmaker (1999) provides several examples of small farmers who found that the overall benefits outweighed the initial and the long term problems.
3. HOUSING

In designing and managing cubicles for dairy cows, knowledge of cow measurements and their space requirements is fundamental because cubicle dimensions must be appropriate for standing, lying, rising and resting without injury, pain or fear (Anderson, 2008). Different studies showed that dairy cows prefer cubicles with softer surfaces (deep sawdust or sand rather than rubber-crumb-filled mattresses) and will lie in cubicles with rubber-crumb-filled mattresses longer when they are deep bedded with sawdust and surfaces that are level with the rear curb and/or 5 cm above curb rather than concave. Cows also exhibit a preference for cubicles without a brisket locator compared with those with a board 20 cm high. Cows will lie down faster in stalls with high neck rail and longer in wider cubicles (Fregonesi et al., 2007; Cook et al., 2008).

According to Cook (2010), in order to design cubicles for dairy cows we need to consider five main critical areas, these are:

- Adequacy of cubicle surface cushion
- Adequate lunging space and bob zone
- Appropriate position of neck-rail and brisket locator
- Appropriate resting area related to the size of the cows
- Appropriate curb height

3.1. Cubicle Surface

The most important factor determining cubicle usage of a dairy cow is cubicle surface cushion. Cubicle should be soft, free from pathogenic bacteria, should not be abrasive and slippery. To this regard, sand carries considerable potential benefits with regard to its use – giving cushion, comfort, support and traction without abrasion (Cook, 2010). Cook et al. (2008) suggested that deep sand bedding facilitates the rising and lying movements of dairy cows. In addition, sand allowed lame cows to maintain normal resting patterns. Another study also shows improvement in hoof lesion score after 21 weeks in cows bedded on sand compared with cows on straw bedding (Norring et al., 2008). Sand bedding may reduce the development of new cases of lameness (Cook et al., 2008; Cook, 2010). However, small resting areas, low divider rails (<0.34 m), limited lunge space, high brisket locators (>15 cm),
and high (>16 cm) or low (<15 cm) rear curbs were related to an increased risk of lameness or claw horn lesions though there is concern on the amount of manure contamination on cubicle beds associated with larger dimensions and greater freedom of movement (Tucker et al., 2004; Cook et al., 2008; Bernardi et al., 2009).

Poorly maintained sand stalls can be a disaster for cows, and the handling of sand laden manure is also problematic. Dug out stalls do not provide the necessary surface cushion to attract the cow (Cook, 2010). The keys to successful sand management are:

- Using washed, screened and graded sand – to remove soil and rocks and to make the particle size uniform
- Maintaining the sand level at an appropriate depth (5cm above the curb in an American styles and to the level of the curb in an European style) by adding fresh sand weekly and levelling daily
- Making sure that stall dividers are correctly mounted
- Providing a settling pit with easy tractor access to remove sand from the main lagoon

3.2. Cubicle Dimensions

The effective bed length for sand-bedded cubicles is the distance from the inside of the curb to the brisket locator. This is especially important if sand is maintained below the level of the curb. The rear curb is the fixed reference point for vertical measurements to locate neck rails. Neck-rail height changes with the height of sand stored at the front of the cubicle. A brisket locator can be mounted in a sand-bedded free stall. The soft resting surface of sand-bedded cubicles includes the space between the inside of the concrete curb and the brisket locator. This distance is the resting surface for the cow. The loop for the sand-bedded cubicle slopes downward at the curb side so that cows can swing their heads over it more easily when exiting the cubicle. The loop controls cow position and generally forces forward lunging. Ideally, the sand bed should be slightly sloped and filled to curb height in European systems, and above the curb according to the American system. Piles of sand stored in cubicle fronts are obstructions to lying, rising and resting behaviours (Anderson, 2008; Cook, 2009). Levelling sand on a daily basis should be avoided because of increased risk of mastitis (Zdanowicz et al., 2003; Russel et al., 2000). In Figure 2, dimensions for sand-bedded cubicles are shown.
3.3. Adequate Lunging Space and Bob Zone

Lunging space is the forward space required by the cows when lying down and rising up where as bob zone is the area at which the chin of the cow nearly touches the ground when the cow is rising up. The space needed for lying and rising motions (lunging) extends forward, downward and upward for head lunge and bob, vertically and forward for standing, and laterally for hindquarter movements as shown in Figure 3. Knowledge of this space is essential for properly positioning neck rails and provision for social space in open-front for head-to-head stalls (Anderson, 2008; Cook, 2010). Estimates of space used by the head while lunging, based on the longitudinal movement of the nose, ranges between 58 and 66 cm (Anderson, 2008).
Some of the biggest cubicle disasters usually observed are where a narrow loop divider, with a low rail around 46 cm above the cubicle surface, is used in a short cubicle. Cows commonly become entrapped as they shuffle forward on the bed and attempt to rise over a lower section of side rail though it is not the only reason for the cow entrapment. A similar problem may be present when sand cubicles are poorly maintained and the relative height of the divider rail increases as the surface erodes away (Anderson, 2008; Cook, 2009; Cook, 2010). Therefore, there is a need for close follow up and levelling of bedding surfaces (especially in sand bedding). Heifers that are not familiar with sand and/or the design of the dividers and pipes, will have to learn how to lie down, stand up and will easily panic and move forward (Hulsen, 2010).

3.4. Location of the neck rail and brisket locator
The cow should have enough room to rise behind and below the neck rail unhindered (Cook, 2010). Frequently, the neck rail in most sand cubicles is placed with the width of the rear curb closer to the back of the cubicle than it is for mattress cubicles. This neck rail location forces cows to perch in the cubicle rather than stand with their rear feet in the sand bed or on the concrete curb. This neck rail location aims to prevent cows from urinating or defecating in the sand bed (Anderson, 2008). Behaviour studies have shown that by moving
neck rails higher and forward, cows can stand with all four feet on the cubicles more easily (Gaworski et al., 2003 cited in Cook, 2010).

The best position of neck rail is 112-132 cm above the bedding and 163-183 cm forward from the rear curb (Cook, 2009). If the rail is incorrectly located, the cow rubbing the rail every time they rise in the cubicle can indicate this. More cows will be observed perching in the cubicles, with only two feet located on the platform. A brisket locator restricts the forward location of a cow lying in the stall. It defines the forward limit of the bed length measured from the rear curb. The best position for brisket locator is from 7-10 cm above the bedding (Cook, 2009). Cook (2010) suggested that diagonal lying results from cows lunging diagonally across the cubicle to rise and lie down which can be due to one of the following factors:

- There is a bob zone and lunge space obstruction in front of the cubicle
- There is a cow in the cubicle in front
- The neck rail is located too near the rear curb. Large cows must stand diagonally on the bed to lie down
- When there are many empty cubicles and the divider give the cows enough space, some cows will lie down diagonally. Especially when they are not familiar with the stalls (Hulsen, 2010)

3.5. Appropriate resting area related to the size of the cows

Kinematic analysis of the standing up movements indicates that dairy cattle use between 244 and 280 cm of total longitudinal space (from the nose to the most caudal point of the cow) (Anderson, 2008), and that lateral displacements during this movement range from 60 to 110 cm at the hips (Ceballos, 2003 cited in Tucker, et al., 2004); and estimates of space used by the head while lunging, based on the longitudinal movement of the nose, range between 58.4 and 60 cm (Anderson, 2008).

Due to variation in cow size between herds, the first step in planning cubicle size is the measurement of heifers and mature cows in your herd. To ensure that cubicles fit the majority of your cows, measure the larger representatives in a group (Anderson, 2008).
### Table 2. Body dimensions and estimated space requirement for mature Holstein cows. (Source: Anderson, 2008; Cook, 2009).

<table>
<thead>
<tr>
<th>Body dimension</th>
<th>Space requirement (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nose-to-tail length</td>
<td>244-280</td>
</tr>
<tr>
<td>*Imprint length (resting area)</td>
<td>172-193</td>
</tr>
<tr>
<td>Imprint width</td>
<td>123-137</td>
</tr>
<tr>
<td>Forward lunging space</td>
<td>58.4-66</td>
</tr>
<tr>
<td>Neck rail height</td>
<td>112-132</td>
</tr>
<tr>
<td>Neck rail distance from rear curb</td>
<td>163-183</td>
</tr>
</tbody>
</table>

*Imprint length extends from the folded fore-knee to the tail when cows are lying in the narrow position

A brisket locator of 7-10 cm above the bedding can be used to prevent the cow lying too far forward on a free stall bed. However, there needs to be room for the cow to put her front leg forward when she lies down and when she completes the rising motion, so the board must be no higher than 15 cm. In some herds with sand bedding and high neck rails, these boards have been completely removed with apparent little ill effect (Cook, 2010). When cows are used to specific lying down, lying and standing up behaviour, they will not easily change this. The available spaces (walls, cows in other stalls, etc) also influence behaviour (Jan Hulsen, personal communication).

#### 3.6. Curb Height

Cook (2010) suggested that too high a curb reduces cubicle use by heifers and stretches rear flexor tendons of cows standing half in and half out of cubicles. Both high curbs and perching behaviour have been linked with increased lameness in several studies. Curbs should be no higher than 20 cm above the alley, a height that includes the mattress surface. Depth of the sand should be at least 25 cm, and should be refilled as soon as sand level is 2.5-5 cm below the curb; and should be at least 5 cm above the curb. Typically cows kick out 20-25 kg of sand/day when the sand level is above the curb and 10-15 kg of sand when it is below the curb. The difference exists in American and European sand bedding style where in the former sand is filled to at least 5 cm above the curb where as in the later sand is filled to the
level of the curb. Furthermore, sand should be added every week (Anderson, 2008). However, failure to replace and refill sand can cause the rear curb to protrude and shorten the effective resting space, and can result in the cows refusing to use the cubicles.

3.7. Manure Handling

Manure handling is the biggest challenge in sand bedded barns (Rodenburg, 2000). According to Gooch and Wedel (2010) manure handling is not an obstacle when proper design, equipment and management are employed. In the barn, tractor scraping is the simplest option while there is more wear on the floor and scraper. On the other hand, there is not a serious concern with a rubber scraper. Mechanical alley scrapers will wear a track in the centre of the floor where the cable or chain runs (Rodenburg, 2000).

Sand-Laden Dairy Manure (SLDM) is a complex mixture of two greatly different materials – manure and sand. Raw manure is a combination of water and undigested feed. When manure, a material that is pumpable, is mixed with sand, a material that is stackable, the result is a mixture that can neither be readily pumped nor stacked (Gooch and Wedel, 2010). The relative flowability of manure has traditionally been used to predict potential manure handling methods. For instance, traditional flowability standards suggest manure at 35% solids content (bedded pack manure) is stackable and can be handled as a solid. However, at 35%, SLDM is not stackable nor is it readily pumpable. The difference in flowability between manure mixed with sand and manure mixed with organic bedding stems from the fact that sand does not absorb liquid. Organic bedding does. SLDM flowability depends on manure:sand ratio, moisture content of the excreted manure and slope of the floor. Manure with minimal amounts of sand can be handled using regular manure handling systems. However, from the standpoint of cow comfort, minimization of sand usage is not recommended (Gooch and Wedel, 2010)
3.8. Cleaning Alley Floor

Sand is readily dragged from and kicked out of free stalls by cows as they enter, use, and exit the cubicle. The best mechanical method to clean shelter alleys is with a rubber scraper blade mounted to a skid-steer loader or small farm tractor. The rubber scraper is durable and can withstand the abrasive nature of sand. It also creates less wear on the flooring surface than steel scraper blades. SLDM can be scraped to a conveyance device or directly outside to a storage tank (Gooch and Wedel, 2010). Alley scrapers are popular with many dairy producers because they can be adjusted to frequently clean floors and require minimal daily labour.

There are scrapers that have been designed to handle SLDM both from an increased load and erosion standpoint. Long barns with minimal drops to across-the-barn reception gutters result in large accumulation of SLDM being pulled by the drive equipment. From an erosion perspective heavy-duty scrapers that have less moving parts are preferable. Steel scraper blades can be modified by retrofitting it with reinforced hard rubber to interface with the alley surface. Producers have reported that rubber flooring has reduced the wear on alley scrapers that convey SLDM (Gooch and Wedel, 2010). There are companies with specific heavy duty scrapers and with a lot of expertise in handling SLDM. Therefore, a farmer should work with an expert on sand bedding when designing a barn and choosing and installing equipments (Jan Hulsen, 2008).
3.9. Flush cleaning
Flush cleaning the barn with a wave of water is also an option to consider for new facilities or those that are extensively upgrading their manure system. Flush water volumes need to be adequate to ensure proper removal of manure from the alley. Required water volumes are determined by three variables: length, width and slope of the alley as well as the size of the sand grains that must be cleaned from the alleys. Complete removal of the manure component of SLDM is essential to clean the shelter, but residual sand left in the alley is acceptable as it enhances traction (Gooch and Wedel, 20101; Holmes, 2010). Flushing should be done when the cows are out to be milked, i.e. when the stall is free.

Barn floors are sloped and water is delivered at a fast rate to remove sand and manure from alleys. The steeper the alley, the less water is needed. Use of 2.5-4% (3% optimal) alley slope is advisable to obtain a good result. Water can be pumped from a second or third stage storage at high rate (greater than 5 feet per second) directly to the alley or at a lower rate to a flush tank (high head pressure). The flush tank is emptied by gravity at high rate (greater than 5 feet per second) into the alley. Flushing requires a large amount of added water and is prone to freezing in the alleys. Downstream handling systems must be designed to handle manure without settling sand until it is desired. Recycled manure storage water can cause odour problems in the barn and community (Holmes, 2010).

3.10. Sand Separation Methods
Sand separation systems can be broadly classified in to mechanical and non-mechanical. In non-mechanical separators the sedimentation process (the process of utilizing water as a media to separate various materials based on their specific weight and size) is applied to separate sand from manure. The other non-mechanical sand separation method is a sand trap. A sand trap is a separation means that is used exclusively with flush systems. Sand traps function by slowing a flush wave to a velocity of less than one foot per second for a retention time of approximately one minute, thereby allowing sand grains to settle. At this velocity, most sand grains and some manure solids settle. It was suggested that the effectiveness of a sand trap is limited by how it is managed because as sand accumulates in the trap, separation efficiency is reduced. In order for a sand trap to function as it was
designed it must be emptied on regular intervals. However, the amount of sand captured depends on the type of sand used. Sand with large quantities of fine particles is not recommended since fine particles tend to remain in suspension with manure that passes through the trap. The sand recovered from a sand trap contains some organic material and is generally not suitable for reuse (Gooch and Wedel\textsuperscript{1}, 2010; Holmes, 2010).

Mechanical sand-manure separators (SMS) separates sand from scraped or flushed manure. Mechanical SMS are different from mechanical manure separators in that sand-manure separators separate sand that is recyclable from manure and water whereas manure separators separate manure solids and some sand which is not recyclable from water. SLDM is usually delivered to a sand-manure separator by an inclined auger. Once in the separator, SLDM is mixed with air and recycled water which suspends the manure solids. Sand is allowed to settle in the separator and is recovered by a mining-duty auger. Sand is discharged at 10-12% moisture with less than 2% organic matter and can be reused for bedding. As with non-mechanical separators, sand with minimal amount of fine particles is preferred. Recovery efficiency of 90% or greater is attainable when an SMS is used in conjunction with the proper sand gradation which is also optimal for the cows (Gooch and Wedel, 2010\textsuperscript{1}; Holmes, 2010).

![Mechanical sand separator machinery](image.png)

However, according to van Eerdenburg (2010), it is economically not feasible to recycle and reuse sand in the Netherlands, because it is, at the moment, too expensive to recycle sand as compared to the price of sand. In addition, re-using sand is tricky and the major risks are E.coli infections causing severe cases of clinical mastitis. Sand separation leads to more coarse sand, as you recover the bigger particles easily whilst the small sand particles stay in the manure (Hulsen, 2010).

### 3.11. Conclusion

In order to design cubicles for dairy cows, adequate knowledge of cow measurements and their space requirements is crucial because cubicle dimensions must be appropriate for standing, lying, rising and resting without injury, pain or fear. In addition, cubicle dimensions have a significant effect on the resting time and cubicle using behaviour of dairy cows. Dairy cows prefer cubicles with soft surfaces, such as sand bedded cubicles, which improve their lying time. Small resting areas, limited lunging space, too high brisket locator and rear curb can increase risk of lameness claw lesion, which has direct effect on the productivity of the animal. In sand bedded cubicles, manure handling is a challenge. When manure is mixed with sand it can be hard to clean barns as the mixture is neither readily pumped nor stacked. However, there are mechanisms to aid the ease of the operations, such as flush cleaning and rubber scraping. In addition, the whole barn set up, constructions of the alley floors, manure handling systems and installations should be adapted to SLDM. Though it is possible to separate the sand from manure, reuse of the sand may depend on the context of the country, for instance in Holland, it is not economically feasible to reuse the sand as the price of the sand is cheaper than the separation costs. Furthermore, recycled sand can support pathogenic bacteria, especially E.coli which is the main cause of clinical mastitis.
4. BEHAVIOUR

The dairy farmer’s choice for using a certain type of bedding material in cubicles has a remarkable influence on the behaviour of cattle (Manninen et al., 2002; Nordlund and Cook, 2003; Drissler et al., 2005; Norring et al., 2008; Calamari et al., 2009). The bedding material used influences the ability of the animals to express natural behaviour. Behaviours that are directly influenced by the bedding material are lying, rising and standing behaviour. Bedding material should provide enough cushioning for the cows to lie on a soft surface and should provide enough traction for the lying and rising movements. The ability of cows to express natural behaviour influences the health and the production of animals (Manninen et al. 2002; Nordlund and Cook, 2003; Drissler et al., 2005; Fregonesi, 2007; Calamari et al., 2009; O’Driscoll et al., 2009). Important behaviours considering the life and production purposes of dairy cattle are choice behaviour, lying behaviour, standing behaviour, walking behaviour and stress (Drissler et al., 2005; Norring et al., 2008; Calamari et al., 2009). The advantages and disadvantages of cow behaviour when sand is used as bedding will therefore be described in this chapter.

4.1. Choice behaviour

Since the 1970’s, animal preferences for different housing conditions are studied by allowing animals to make choices between several alternatives (Tucker and Weary; 2001). In preference tests where cows were asked to make a choice for sand or alternative bedding materials, contradictory results have been shown.

In research conducted by Calamari et al. (2009) cows showed a preference for soft bedding materials. In a preference test, cows spent lying time mainly on soft surfaces, either sand bedding or a thick layer of straw. The results of this study are shown in Figure 5. The differences in lying and standing times between sand and straw were not significant. The differences between sand and rubber mats and mattresses were significant (Calamari et al. 2009).
In addition, cows kept in free-stalls with sand had a greater milk yield compared to cows kept on straw, rubber mats or mattresses. From these results sand can be considered the best lying surface for dairy cows (Calamari et al., 2009). These findings are supported by other recent studies that provide evidence that deep-bedded free-stalls, especially sand, provide advantages over other lying surfaces (Drissler et al., 2005; Cook, 2009).

In contrast, research conducted in Finland by Manninen et al. (2002), showed that cows preferred straw and mattresses over sand as bedding material in an unheated building. In this experiment cows tended to avoid sand, and they often lay down in alleyways when only sand as bedding material was provided. However, there were several points of discussion in this research. The cows in this experiment were not familiar with the use of sand, which influences the choice behaviour whereas cows tend to chose for bedding materials that they are familiar with (Manninen et al., 2002; van Eerdenburg, 2010). In addition, the stall design was not optimal, cows showed difficulties in coming out of the stalls (Manninen et al., 2002). Therefore, it can be concluded that the research of Manninen et al. (2002) is not in accordance to the general trend in research, which shows that cows appreciate sand as much as other deep-bedded materials.
4.2. Lying behaviour

Several behavioural studies have been carried out to determine the preference for cows for a certain type of bedding material. The most important behavioural parameter for measuring cow preference is the time cows spent lying down on different types of bedding (Nordlund and Cook, 2003; Calamari et al., 2009; Cook, 2009), whereas cows have shown to be willing to ‘pay’ for lying time (Norring et al., 2008). The number of lying bouts can be considered as an important indicator of the quality of the bedding material provided (Manninen et al., 2002). Both research on lying times and on the number of lying bouts will be reviewed. In addition, the influence of the sand depth the lying behaviour of dairy cows will be discussed in this paragraph.

4.2.1. Lying time

Although research conducted by Manninen et al. (2002) showed that cows housed in unheated buildings showed a negative attitude towards sand used for bedding material, several other studies on lying times showed contradictory, positive results. Calamari et al (2009) found that cows prefer deep-bedded stalls with straw and sand compared to rubber mats and mattresses. In addition, lying bouts were longest in stalls with sand used as bedding. The lying bouts in sand stalls were on average 68.9 minutes, compared to 62.7 (straw), 62.5 (rubber mats) and 61.7 (mattresses). The lying time differed significantly between rubber mats and mattresses compared to sand, but straw and sand did not differ significantly. Furthermore, Calamari et al. (2009) found that free stalls with sand bedding were occupied significantly longer compared to straw, rubber mats or mattresses. Similar results were found in research conducted by Cook (2009) where the time cows daily spend on the most important activities in sand bedded stalls and stalls with mattresses were analysed. The result of this is shown in Figure 6. The minimum time spend lying down per
day should be at least 12 hours (Cook, 2009). Cows housed on sand spent on average 12.4 hours lying down, while cows housed on mattresses only spent 10.7 hours lying down on average (Cook, 2009).

![Figure 5. Daily time spent on different behaviours. Source: Cook (2009).](image)

Earlier research by Marin et al. (2007) found that lame cows preferred rubber mats with 2 inches of sand compared to mattresses. In both stall surface materials the locomotion score had a significant effect on standing behaviour. However, results show that the rubber mat covered with sand appears to be beneficial for lame cows, whereas they spent around 13 hours lying down and about 2 hours standing in the stall. In contrast, cows spent less than 12 hours lying down and more than 4 hours standing in the stall, which is considered insufficient for optimal recovery of lameness (Marin et al., 2007).

In addition to the preference tests where cows showed preference for a certain type of bedding, Fregonesi et al. (2007) conducted research to find out how bedding quality affects the lying behaviour of dairy cows. In this study, cows had the ability to choose between a dry and wet sawdust lying surface. Cows showed a strong preference for dry surfaces in both summer and winter, which proves that the choice for a wet or dry surface is independent of thermoregulation (Fregonesi et al., 2007). The use of sand was not incorporated in this research. However, the preference for dry lying surfaces can be seen as an important factor in cow preference for sand.
4.2.2. Sand depth

Drissler et al. (2005) found that the depth of the sand bedding has a great influence on the lying behaviour of dairy cows. In this research, the depth and the distribution of the sand bedding were measured 3, 6 and 9 days after adding the bedding to the cubicle. The results of this study are shown in Figure 7.

In this figure the change in distribution of sand during the first 9 days after adding sand to the cubicle is very clear. This change in distribution is caused by cows expressing natural behaviour, which involves digging in the soil to provide itself a soft lying area. In addition, the process of lying down and standing up moves the sand sideways and towards the rear and the back. Furthermore, some sand is lost from the cubicle if cows step backwards or as a result of cleaning (Drissler et al., 2005; van Eerdenburg, 2010). Drissler et al. (2005) found that lying times decreased if the sand depth decreased and the shape of the lying area became more concave. Daily lying times were 1.15 hours shorter in stalls that were used often, and therefore had the thinnest layer of sand. In addition, cows spent 11 minutes less lying down per day for every 1 cm decrease in bedding (Drissler et al., 2005).

Recent research conducted by Norring et al. (2010) shows similar results. In this study the preferences of dairy cows were measured for three stall surface materials with small amounts of bedding. Results of this study show that cows prefer rubber mats compared to concrete and a thin layer of sand on concrete (Norring et al., 2010). If the layer of sand is too
thin the sand does not feel soft and a thin layer of sand on concrete feels uncomfortable when moving. In addition, if the layer of sand on concrete is too thin, sand becomes abrasive and the risk of lameness and hock lesions increases significantly (Norring et al., 2010).

4.2.3. Cost of inadequate rest: lameness / hock lesions

It is very important for high producing dairy cows to optimise the time spent lying down (Manninen et al., 2002; Norring et al., 2008; Calamari et al., 2009; Cook, 2009). Reduced lying time is related to hoof health and lameness (Manninen et al., 2002; Norring et al., 2008; Calamari et al., 2009; Cook, 2009). Deep-bedded surfaces are associated with fewer and less severe hock lesions (could even be zero if well managed) compared with mattresses with small amounts of bedding (Drissler et al., 2005).

In research conducted by Norring et al. (2008), 52 dairy cows were kept on either straw bedded concrete stalls or sand stalls for a 21 week period. The cleanliness of the cows was scored during the experiment. At the end of the experiment the severity of hock lesions and the improvement of overall hoof health were scored. Cows were less dirty in sand stalls compared to the animals housed in straw bedded stalls. The severity of hock lesions was lower for cows housed on sand compared to those housed on straw. In addition, the overall hoof health improved significantly for cows housed on sand. Furthermore, cows suffering from hock lesions, claw diseases and lameness recovered more quickly if they were housed on sand compared to straw (Norring et al., 2008).

These findings are in agreement with Cook (2009), who stated that cows require a resting period of at least 12 hours a day, and lameness increases if lying times are reduced. Lameness is a disturbance of locomotion and is an important behavioural indicator of pain and is therefore an indicator of poor welfare. Lameness can be considered as one of the most important health and welfare issues in the dairy industry these days (Telezhenko and Bergsten, 2005; Cook, 2009), whereas lame cows have a decreased production and lameness is the primary reason for disparity in dairy cows (Cook, 2009). In 2004 Cook et al. found that cows housed on deep-bedded sand were significantly less likely to develop clinical lameness.
(11%), compared to those housed on geotextile mattresses (24%). In later research, Cook (2009) found on average 42% fewer lame cows in sand bedded freestall herds, compared to herds housed on mattresses. In addition, cows recovered more quickly from lameness if they were housed on sand (Cook, 2009).

4.3. Standing behaviour

As mentioned before, adequate rest and thus adequate lying times are very important for high producing dairy cows (Manninen et al., 2002; Norring et al., 2008; Calamari et al., 2009; Cook, 2009). Reduced time lying down has an increased standing time as a consequence. Longer standing times are related to lameness and claw lesions, whereas the cow spends more time standing or walking in alleyways which can be covered with manure and urine (Rushen and de Passillé, 2006; Norring et al., 2008; Calamari et al., Cook, 2009). In addition, cows that are not provided with comfortable lying areas spent more time standing, mostly in the cubicles, to obtain relief from concrete alleyways (Rushen and de Passillé, 2006; O’Driscoll et al., 2009; van Eerdenburg, 2010). Increased time standing can be seen as a direct production loss, whereas it decreases time spent ruminating and blood flow to the udder is less compared to cows that are lying down (Calamari et al., 2009; Cook, 2009).

Cook (2009) found that cows housed on mattresses spent significantly more time standing in cubicles compared to cows housed on sand. Sand housed cows spent on average 1.8 hours a day standing in the stalls and cows housed on mattresses spent on average 3.7 hours a day up in the cubicle, as shown in Figure 6 (Cook, 2009). Furthermore, cows housed on sand spent on average 2.2 hours in the alley (including drinking time), while cows housed on mattresses spent on average 2.5 hours in the alley, which is significantly longer (Cook, 2009).
Cows housed in deep-bedded cubicles show the longest lying times (Fregonesi et al., 2007; Calamari et al., 2009; Cook, 2009). The main reason for increased standing time if cows are housed on harder surfaces e.g. rubber mats, mattresses or concrete with sawdust is that cows have difficulties rising and lying down on a firm surface (Cook, 2009). Sand provides traction, support and cushion to facilitate rising and lying movements for (lame) cows. Therefore, lame cows are able to maintain normal patterns of rest which increases recovery and decreases pain and the loss of production (Cook, 2009).

4.4. Walking behaviour

Healthy cows that have access to a comfortable resting area rest enough, are active and will make several walks to the feeding fence and the water point. However, walking on stall floors induces some health and safety risks for the cows. Walking on concrete floors has been shown to increase the development of lameness (Cook et al., 2004; O’Driscoll et al., 2009) and increases the risk of sole haemorrhages (O’Driscoll et al., 2009). In dairy cow barns with sand bedded cubicles, floors are usually made of solid concrete (O’Drescoll et al., 2009; Cook, 2009). Solid floors can become slippery, especially if there is residue of manure and urine on the surface (Rushen and de Passillé, 2006; O’Driscoll et al., 2009). In general, slippery floors have shown to decrease locomotion (shorter strides) and to increase the number of strides, which indicates that this floor type may not provide the friction necessary for cows to walk in a natural manner (Rushen and de Passillé, 2006; O’Driscoll et al., 2009). More grip can be provided by using rubber on concrete alleyways (Hulsen, 2008).

However, the advantage of using sand as bedding material in combination with a solid concrete floor is that lost/spilled sand from the cubicles wears out the concrete and roughens the surface, which allows cows to make long, natural strides without slipping (van der Tol et al., 2005; Rushen and de Passillé, 2006; Hulsen, 2008; O’Driscoll et al., 2009). In addition, the ability of cows to express natural behaviour of mounting in the heat period is increased. A disadvantage of sand on the concrete floor and the increased friction is that claws can wear out quickly, which increases the risk of claw infections. However, there are several other factors that influence the wearing of claws, e.g. dragging legs and walking long distances (Burgi, 2005). To prevent claws from excessive wearing during the first period after
being introduced to the sand bedding husbandry system, healthy claws should not be trimmed in the last months before transition to sand (Hulsen, 2008; van Eerdenburg, 2010).

4.5. Stress
If housed in comfortable stalls, cows will lay down for at least 12 hours (Cook, 2009). They will only reach this minimum of 12 hours rest if the bedding material provides enough cushioning to feel soft, but also provides enough traction for supporting lying and rising movements (Hulsen, 2008; Cook, 2009). Cows that are not housed in comfortable stalls will experience stress, whereas the desire to lay down cannot be fulfilled. This negatively influences other desired behaviours e.g. feeding and drinking behaviour (Hulsen, 2008). Reduced lying times have been shown to have a negative impact on production and on the development of lameness and hock lesions. Furthermore, inadequate rest is suggested to have a significant stress response (Norring et al., 2008; Cook, 2009), whereas ACTH concentrations (Munksgaard and Simonsen 1996, cited in Cook, 2009), cortisol response to ACTH challenge and growth hormone concentrations (Munkgaard and Løvendahl 1993, cited in Cook, 2009) are negatively influenced (Cook, 2009). As mentioned in paragraph 4.2, lying times were longest in deep-bedded cubicles and especially in sand (Calamari et al., 2009; Cook, 2009), which indicates that sand reduces stress for dairy cows (Cook, 2009; van Eerdenburg, 2010).

Unfortunately, further research on the relationship between sand and (short and long term) stress has not been carried out yet. However, from our findings we can strongly suggest that sand reduces stress in dairy cows, which positively influences the overall well-being of the cow. In addition, the reduction in stress when using sand as bedding might improve social behaviour in de herd.
4.6 Vulnerable cows

As mentioned before, sand has shown to have a positive effect on the behaviour and well-being of both healthy and unhealthy cows (Marin et al., 2007; Cook, 2009). In addition, sand can have positive effects on particularly weak and lame cows. Lame cows have shown to maintain natural lying behaviour patterns if housed on sand, which enables them to recover more quickly (Marin et al., 2007; Norring et al., 2008). Weak cows will do better because they are provided with a soft and cushioning surface, whereas sand provides enough support and traction for rising and lying behaviour as well (Cook, 2009).

4.7 Conclusions

The following conclusions can be formulated for this chapter:

- Cows chose for deep-bedded stalls, they prefer sand and straw above mattresses and sawdust.
- Cows have prolonged lying times if housed on sand compared to other bedding materials.
- Cows have more lying bouts and less standing bouts when housed on sand.
- Sand enables cows to express natural behaviour by digging in the sand.
- Adequate lying times decrease the risk of lameness or claw lesions, and enables faster recovery.
- Adequate lying times decrease stress.
- Sand makes the concrete in walkways rougher and cows slip less in alleyways. This increases the ability of the animals to express natural behaviour (heat), increases feeding and drinking times and reduces risk of lameness or claw lesions.
5. HEALTH

Bedding materials are classified in two separate categories, organic and inorganic. Sand is the predominately used inorganic bedding material, which does not support growth of bacteria, except when it is exposed to manure or moisture bacterial growth (Wallace, 2007). Organic bedding materials are characteristically byproducts of plants, which constitute mainly sawdust, wood shavings, hay, straw, crop residues, shredded paper and dried or composted manure solids. They are used for the reason that they absorb moisture, are easily available and manageable through existing manure handling systems. These materials have the major disadvantage of supporting rapid bacterial growth, which increases the likelihood of environmental mastitis pathogens. Within 24 hours these bacteria can multiply to great numbers (Wallace, 2007).

The particle sizes of bedding materials are major factors determining bacterial growth rates in organic bedding. Larger particles showed the least bacterial growth compared to very fine chopped bedding materials which favored rapid growth of bacteria. Plus, fine ground or chopped bedding materials have the tendency to stick to the cows more easily, which results in dirtier cows (Russel et al., 2002). The bacteria consume carbon that is contained in organic materials; bacteria also need a certain pH, warmth (body heat) and moisture (leaked milk, urine, faeces or wet claws). When one of these factors is not present bacterial growth will be limited. The most commonly occurring environmental pathogens related to bedding materials are streptococci and coliforms, e.g. E. coli, Klebsiella spp. Wood shavings and sawdust hold the highest risk of Klebsiella spp. because this bacteria originally occurs in the forest soils and can be transferred into these bedding materials. These organic bedding materials at the outset contain high levels of contingent pathogens that abridge the lifetime of the bedding material as a barrier of teat end contamination with bacteria (Smith et al., 1985; Wallace, 2007).
5.1. Mastitis & teat end exposure

Mastitis is caused by bacteria. They can be subdivided in contagious and environmental pathogens. Contagious pathogens are: Streptococcus agalactiae, Staphylococcus aureus and Mycoplasma species. Environmental pathogens are: coliform bacteria (e.g. Klebsiella pneumonia) and streptococci (e.g. streptococcus uberis) (Blowey and Edmonson, 1995; National mastitis council, 1997). Mastitis is caused by a broad spectrum of bacteria; some can survive in or on the udder and (almost) cannot survive in the environment. These bacteria spread in the act of milking (hands farmer, cleaning towel or cups) or cow to cow transmission and are called infectious bacteria. Using sand does not counter contagious bacteria and if sand bedded herds contain more of these bacteria it is not related to sand but due to cow to cow transmission or via milking (Hulsen., 2010). Another group of bacteria are environmental bacteria, which are distinctive to survive and multiply in the cow’s environment. Via feces and bedding materials the udder can be penetrated and cause mastitis (National mastitis council, 1997). Clinical mastitis cases cause an impaired milk production that result in economic costs for dairy producers plus reduced welfare and health of the affected animals. Mastitis is the most costly and infectious disease which affects dairy cows, even though there are many new developments to counter this disease (Andrews., 2000; Fetrow et al., 2002 cited in Godden et al., 2007). In addition, mastitis is one of the major causes of the involuntary culling of cattle (Smith et al., 1985).

The origin of all mastitis problems is teat end exposure. The probability of exposure of the teat ends with bacteria is minimal when the cows are standing. However, when cows find a place where they can lie down their teat ends become jeopardized. The bedding material used in cow stalls needs to be dry and clean to reduce potential risks for mastitis. Cattle originally evolved in pastures; therefore it is ideal to provide cows with a resting environment that simulates the cushioning of a pasture (Wallace, 2007). It is proven that bacterial populations which are found in bedding materials are closely correlated with those of teat ends. In research conducted by Zdanowicz et al. (2004) the bacterial populations on teat ends of dairy cows were compared between cows in stalls bedded with sand or sawdust. The bacterial counts that were found on the teat end swabs were moderately correlated between sand and sawdust bedding and there is a consistent relationship with previous literature reports (Rendos et al., 1975; Hogan et al., 1989; Hogan et al., 1999;
Hogan and Smith, 1997). Cows bedded with sawdust had higher counts of coliforms and Klebsiella compared with sand bedding. Sawdust bedding contained 2 times more coliform bacteria and up to 6 times more Klebsiella bacteria on teat end swabs. However, teat end swabs of sand bedding contained 10 times more Streptococcus spp. These results are in agreement with other studies (Bramley and Neave, 1975 cited in Zdanowicz et al., 2004; Fairchild et al., 1982; Janzen et al., 1982; LeJeune and Kauffman, 2005). On the other hand Janzen et al. (1982) found significantly (P<0.05) lower Streptococcus counts in sand bedding teat swabs compared to sawdust, which is in contrast with Zdanowicz et al.(2004). In addition, Klebsiella outbreaks are frequently associated with wood products used as bedding material and most commonly with sawdust bedding (Fairchild et al., 1982; Munoz et al., 2006). Cows spend 40-65% of the day lying down (Manninen et al., 2002; Tucker et al., 2003). During the time lying down there is a possibility for bacteria transfer between bedding and teats (Hogan and Smith, 1997; Hogan et al., 1999).

5.2. Bacterial counts

Bedding material can vary in its ability to support growth of environmental pathogens. Bacterial counts found in bedding materials are closely correlated to those on teat ends. Thus, when bedding materials contain high bacterial populations there is a reasonable chance that teat ends also contain high numbers of bacteria resulting in an increased chance of mastitis caused by environmental mastitis bacteria (Natzke and LeClair, 1976; Bishop et al., 1981; Janzen et al., 1982; Pankey, 1989).

Godden et al. (2008) studied different unused bedding materials in an incubation period from 0 to 72h and found significantly (P<0.05) lower bacterial growth (cfu/ml) of Enterococcus faecium and Klebsiella pneumoniae in clean sand in contrast to digested solids, recycled sand and shavings. In addition, clean sand also showed a favorable pH, C(%), N(%). However, shavings also had good results with bacterial growth and even got better results with Enterococcus faecium (Table 3 and Figure 8).
Table 3. Bacterial growth examined. Source: Godden et al. (2008).

<table>
<thead>
<tr>
<th>Bedding materials 0-72h</th>
<th>K. Pneumoniae (cfu/ml)</th>
<th>E. faecium (cfu/ml)</th>
<th>pH</th>
<th>C (%)</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean sand</td>
<td>1.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-1.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.15&lt;sup&gt;A&lt;/sup&gt;</td>
<td>0.28&lt;sup&gt;A&lt;/sup&gt;</td>
<td>0.01&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Recycled sand</td>
<td>1.91&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.37&lt;sup&gt;B&lt;/sup&gt;</td>
<td>1.13&lt;sup&gt;B&lt;/sup&gt;</td>
<td>0.04&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Digested solids</td>
<td>3.16&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.90&lt;sup&gt;C&lt;/sup&gt;</td>
<td>46.22&lt;sup&gt;C&lt;/sup&gt;</td>
<td>1.99&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>Shavings</td>
<td>1.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-4.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.27&lt;sup&gt;d&lt;/sup&gt;</td>
<td>53.02&lt;sup&gt;B&lt;/sup&gt;</td>
<td>0.35&lt;sup&gt;C&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a-c</sup> Different superscripts indicate a significant difference (P<0.05) in bacterial growth amid bedding types at an incubation period of 72h.

<sup>A-C</sup> Different superscripts indicate a significant difference (P<0.05) in biochemical characteristics amid bedding types.

K. Pneumoniae Growth

![Graph showing bacterial growth over time](image)

Figure 7: Comparison of growth of Klebsiella pneumonia amid bedding types at different incubation periods. <sup>a-d</sup> Different letters indicate a significant difference (P<0.05) in bacterial growth amid bedding types. Source: Godden et al. (2008).

The most rapid bacterial growth took place in the first 24h (Figure 8) after that it more or less stabilized. Enterococcus faecium and Klebsiella pneumonia were selected for the reason that these are two large common families of environmental bacteria. This study uses Enterococcus faecium and Klebsiella pneumonia and gives a good indication of which bedding type supports bacterial growth in which quantities. It is important to bear in mind is that other species of bacteria perhaps might have other growth requirements (Godden et al., 2008).

More on farm research was conducted by Kristula et al. (2005) and Bernard et al. (2003), who found similar results. The results of these studies suggested that bacterial numbers and
populations were similar for both clean sand and recycled sand in summer and winter. The outcomes indicated that either clean or recycled sand can be used without the risk of an increased incidence of somatic cell count or mastitis when stalls remain properly maintained. Consequently, the number of Klebsiella spp. and coliform bacteria remained below the limit of 1,000,000 cfu/g (bacterial count), which is the general accepted threshold for causing mastitis (Bernard et al., 2003; Kristula et al., 2005). Sand is from a bacteriologic point of view the best bedding material. Generally bacteria counts are lower than organic bedding, plus can put up with higher bacteria numbers and not significantly increase udder infections (Russel et al., 2002).

5.3. Mastitis prevalence

There is inconsistency in the prevalence of intra-mammary infections. In research conducted by Ferguson et al. 2007 a total of 18,711 milk samples were collected in a time period of almost 6 years. The milk samples were examined to find bacteria that cause mastitis. They found that cows with the highest milk production had the least mastitis pathogens prevalence (32.03L ⇒ 35.77% mastitis) compared to low producing cows (23.71 ⇒ 64.50% mastitis). The milk samples were examined for the subsequent mastitis pathogens; Staphylococcus aureus, CNS (Coagulase-Negative Staphylococci), Streptococcus spp, Coliform bacteria, streptococcus agalactiae and other bacteria. The best (lowest SCC) results were obtained with inorganic bedding. In addition, CNS and Streptococcus spp. were the most common mastitis pathogens found and therefore might be hazardous pathogens concerning dairy cows. Mastitis prevalence was similar to that reported in other studies conducted in the same area, assuredly, according to Ferguson et al., 2007. These findings are comparable to those of Cook (2009) who detected a mastitis prevalence of 45% in high producing cows (11.744L).

Picture 6: Mastitis infection
5.4. Lameness & Limb Disorders

Globally, protracted lameness is a serious welfare issue in the intensive production of milk; it is an intensely painful condition that also impacts greatly on the behaviour of the cow (O’Callaghan, 2002). Lameness is often an important contributory factor to loss in body condition and declining fertility rates (Garbarino et al., 2004; Collick et al., 1989). The physical limitation of lameness also decreases the cows voluntary visits to milking robots (Klaas et al., 2003). More commonly seen in loose-housed dairy cattle (Juarez et al., 2003; Klaas et al., 2003) disorders of the limb also influence the economics of production, often with serious cost implications. Most importantly it decreases milk production (Warnick et al., 2001; Green et al., 2002; Bareille et al., 2003; Juarez et al., 2003) but also causes financial loss because of expensive treatment (Blowey, 2008) and veterinarian care. Failing this first line treatment, persistent lameness also escalates the rate of culling (Enting et al., 1997; Booth et al., 2004) and the subsequent cost of replacement cattle (Sprecher et al., 1997; Booth et al., 2004). The major causes of lameness are solar hemorrhages, which are strongly correlated with insufficient lying times (Hulsen, 2010). Sole ulcers come up when soft tissues within the sole are injured and therefore no normal horn can be formed (see Figure 9). This damage can be caused by physical pressure and alteration of the composition and metabolism of dairy cows due to illness, diet and calving (Lameness control programme, 2007). In addition, due to laminitis or sole bruises, probably soft hooves are affected more easily (Hulsen, 2007).

![Picture 7: Sole ulcers; source Bell, 2007](image)

Cows bedded on sand are cleaner and have better hoof health than other bedding materials (Weary and Taszkun., 2000; Norring et al., 2008), the cleanliness of the beds depends on both
management and stall dimension aspects (Hulsen, 2010). Sand has the tendency to conform to the cow’s body shape, this is in all probability encouraging for improved healing because the cow can avoid pressure on her leg by changing position (Norring et al., 2008). Sand bedded free-stall herds on average have 42% less lame cows than cows bedded with other bedding materials (Cook., 2003; Cook et al., 2004; Espejo et al. 2006). Lameness prevalence was significantly (P<0.05) higher in sand bedded herds if hoof trimming is only performed on account of lameness or hoof overgrowth (33.7%) compared with farms were the feet were trimmed on a standard schedule once a year (22.9%) or two times a year (21.3%), which indicates that proper management is very important, even when sand is used as bedding material (Espejo and Endres., 2007).

Another positive aspect of sand is that claw disorders recovered more quickly than cows bedded in straw, rubber filled mattresses or concrete. Frank van Eerdenburg (2010) states that when cows lay down up to 50% more blood can flow within the body, resulting in improved recovery of the claw. When farms used more coarse sand that contains larger particles 7-11% of the knees were swollen. In addition, there was a significantly (P<0.04) higher number of cows with hairless knees than those who used new sand. Sand bedded herds had significantly (P<0.0001) lower percentages of leg lesions compared to waterbeds and rubber-filled mattresses. Sand scored lower on hygiene and therefore had significantly (P<0.0001) lower hygiene scores in relation to waterbeds and rubber-filled mattresses (Fulwider et al., 2007). Although sand scored significant lower in this research, hygiene is related to stall dimensions and management and therefore is not a viable factor (Hulsen, 2009).
Weary and Taszkun (2000) compared the severity and prevalence of skin lesions on the hocks of cows with different bedding types (Figure 10). In this research 73% had skin lesions on the hock. In total 89% of the cows with skin lesions have these on both legs, 76% on more locations on the hock, and 78% had lesions of moderate severity. Sand has a distinct advantage over mattresses and carries a minor risk of hock damage. In this study 91% of the mattress bedded cows and 24% of the sand bedded cows showed indications of hock damage. This indicates that sand beds show 74% less hock abrasions. Figure 11 shows that cows in stalls bedded with sand show overall significant less skin lesions. More research in this area is completed by Vokey et al. (2001) and Fulwider et al. (2007). Altogether they compared sand with rubber mattresses, sawdust, concrete and waterbeds, assuredly they were in agreement that cows housed in sand bedded stalls clearly suffer from less leg lesions (Weary and Taszkun, 2000; Vokey et al.,2001; Fulwider et al., 2007).

Figure 8: % of cows with lesions.
Picture 8: Sites of hock lesions and locations on the cow’s leg: (1) media (2) dorsal (3) lateral (4) medial (5) lateral.

Picture 9: Hock and knee lesions.
Figure 9: Rate of hair loss area (cm²) in a time period of 6 weeks. Source: Mowbray et al. (2003).

Figure 10: Lesions on tuber calcis and tarsal joint (cm²). Source: Mowbray et al. (2003).

Figure 12 obviously shows clear results of recessed mattresses being more abrasive to skin and causing more lesions. Especially on the tuber calcis there are more cm² of hair loss compared to the tarsal joint (Mowbray et al., 2003 cited in Weary and Tucker, 2003). Weary and Tazkun (2000) stated that mattresses are not that abrasive to cause lesions, when rising or lying down friction arises between the mattress and skin which builds up heat. The friction which cause heat reduces skin strength and causes hair loss and possibly also breakage of skin (Weary and Tazkun, 2000; Mowbray et al., 2003 cited in Weary and Tucker, 2003). Injuries can be used as a measure of cow comfort.
However, potential shortcomings of how injuries are assessed and how data is interpreted must be considered. Most of the time injuries are assessed by using qualitative assessment methods or using quantitative measurements, e.g. surface area of hair loss which are stated in Figure 12 above. The assessment method should be selected by means of how good this method reflects the way the wound/injury truly is affecting the cow. This can be in terms of experienced pain, or the way in which the injury predisposes the cow to other infections and physical injuries, like an abnormal gait. Regrettably, there is little or no research done yet to establish links between housing and hoof lesions. More work in this area is needed to understand housing mechanisms that can cause different diseases or injuries. A better understanding of development of injuries and which mechanisms are involved in this are needed to present more suitable advice (Weary and Tucker, 2003). When injuries are identified earlier, substantial costs as a result of mastitis and lameness can be reduced.
5.5. Costs of health disorders

Milk production decreases due to health disorders in dairy cows and have financial losses as a result. Bareille et al. (2003) studied the effects of health disorders on milk production and days of recovery. The results confirm that health disorders are long term and due to this long recovery time there is a large amount of milk loss, this makes health disorders costly (Bareille et al., 2003).

Table 4. Effect of health disorders on production of milk.
Source: Bareille et al. (2003).

<table>
<thead>
<tr>
<th>Health disorder</th>
<th>Days of recovery</th>
<th>Milk loss (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teat injury</td>
<td>63</td>
<td>154.6</td>
</tr>
<tr>
<td>Systemic mastitis</td>
<td>&gt;140</td>
<td>159.9</td>
</tr>
<tr>
<td>Local mastitis</td>
<td>&gt;49</td>
<td>13.1</td>
</tr>
<tr>
<td>Hock lesions</td>
<td>126</td>
<td>108.6</td>
</tr>
<tr>
<td>Foot lesions</td>
<td>112</td>
<td>76.7</td>
</tr>
</tbody>
</table>

5.5.1. Costs Mastitis

Mastitis costs money. This disease occurs at every dairy farm to a greater or lesser extent; also most farmers underestimate the actual costs of mastitis. In Holland the costs of mastitis vary between €17–€198 per cow/year. The standard costs for a clinical case of mastitis are estimated to be €210, varying from €164–€235 and is dependent on the month of lactation plus causational bacteria. The costs of clinical mastitis are, on average, €63 and those of subclinical mastitis are €77 per cow. The average costs of mastitis then come to a total of €140 per cow/year. The above stated values are reasonably in line with previous studies from Dutch and foreign studies. There is a calculation module developed (see link below) to calculate and estimate the overall costs of mastitis which is developed by the UGCN (udder health centre of the Netherlands), this site is only available in Dutch (Huijps et al., 2007).

www.ugcn.nl/nl/25222685%5BLink_page%5D.html?opage_id=3153817&location=18933516871759341,1086218
5.5.2. Costs Lameness

Lameness causes extensive costs on dairy farms. The costs can be divided into direct economic loss (costs of treatment and not delivering milk from treated cows) and indirect damage (lower milk production, reduced fertility and early culling). The costs per lame cow range from €100-300 (www.leidse-land.nl). Assuredly, the differences are remarkable among dairy farms that have a good and bad health management. The costs on dairy farms with low lameness rates (<5%) per year is about €10 per year/cow. However, the costs are much higher on farms with numerous lameness cases (>20-25%), whereas the costs are €25 euro per cow/year. Improving claw health certainly can be lucrative and good hoof health also contributes to the cow’s welfare and makes working on farms easier (www.leidse-land.nl).
6. PRODUCTION

The production of dairy cows is influenced by several factors e.g. genetic background, feeding regime, production stage and health status (Calamari et al., 2009; van Eerdenburg, 2010). The farmer’s choice for bedding material influences the ability of the animals to express natural behaviour, which in addition influences the health and the production of animals (Manninen et al. 2002; Nordlund and Cook, 2003; Drissler et al., 2005; Fregonesi, 2007; Calamari et al., 2009; O’Driscoll et al., 2009). In this chapter the advantages and disadvantages of using sand as bedding material on production of dairy cows will be discussed.

6.1. Advantages

Cows housed on sand have longer lying times compared to cows housed on other bedding materials (Calamari, 2009; Cook, 2009), as described in chapter 3. Increased laying times have several positive influences on milk production of dairy cows:

Firstly, increased lying times increase rumination (Hulsen, 2004). Furthermore, the blood flow through the external pudic artery to the udder is significantly higher if cows are lying down, which has favourable effects on milk synthesis and milk yield (Calamari, 2009; Cook, 2009). The increase of blood flow to the udder when lying down lies around 24-28%, compared to standing up (Cook, 2009). This can lead to a total increase of 0.9 to 1.6 kilograms of milk per day (Grant, 2004). However, the main reason for increased milk production of cows housed on sand will be the increased lying time, which influences feeding and drinking behaviour positively, and reduces stress (Hulsen, 2008). In research carried out by Calamari et al. (2009), milk yield was measured in four groups of lactating dairy cows housed on different bedding materials (straw, sand, rubber mats, mattress). During this 10 week experiment the milk yield decreased in all groups in accordance to the advance in the lactating phase. The reduction in milk yield from start to end of the experiment was 14.1%, 17.2%, 1.4% and 13.3% in straw, rubber mats, sand and mattresses respectively (Calamari et al., 2009). In addition, the highest lying times in this study were measured on sand (see also chapter 4), which proves that longer lying times have higher milk yield as a result (Calamari et al., 2009).
Secondly, if cows are able to achieve adequate rest, this has a positive influence on hormone levels (Drissler et al., 2005; Calamari et al., 2009; Cook, 2009). Adequate rest influences the ACTH concentrations and increases the cortisol (stress hormone) response to abnormal ACTH levels, which increases the ability of the animal to cope with stress (Drissler et al., 2005; Calamari et al., 2009; Cook, 2009). In addition, adequate rest has a positive influence on growth hormone concentrations (Drissler et al., 2005; Calamari et al., 2009; Cook, 2009). These facts indicate a significant reduction in stress if cows are housed on sand compared to other bedding materials e.g. rubber mats with sawdust and mattresses, which has a positive influence on the production, as described in chapter 4.

Thirdly, the inorganic characteristic of sand has a positive influence on the prevalence of mastitis. In addition, the non-abrasive characteristics of sand increase udder health (Calamari et al., 2009; Cook, 2009). Mastitis is a very common health issue on dairy farms, especially at the onset of the lactation (Andrews, 2000). Cows that suffer from mastitis have a reduced production at the beginning of the lactation, but they will not make up this reduction in the rest of the lactation. Cows who have had mastitis closely after parturition will not reach their expected peak in lactation, so the total milk yield in the whole lactation will be reduced as a result of the mastitis infection (Bareille et al., 2003). As shown in chapter 4, teat injury can cause a loss of 154.6 litres of milk, and systematic mastitis can cause a loss of 159.9 litres of milk in total (Bareille et al., 2003). A decreased prevalence of mastitis can therefore increase production significantly (Bareille et al., 2003; Cook, 2009).

Furthermore, the increased lying times and decreased time spent standing in cubicles or alleys, decreases the prevalence of lameness (Drissler et al., 2005; Cook, 2009). Lameness is the main reason for disparity in multiparous cows, and decreases fertility rates. Therefore lameness is of great influence on milk production (Cook, 2009). As discussed in chapter 4, lameness influences milk production on dairy farms in three ways: lower milk production of the lame cow, lameness is the primary reason for disparity in multiparous cows and lameness is an important reason for culling of cows (Enting et al., 1997; Booth et al., 2004). Cows suffering from lameness show decreased feed intake, have longer standing times and have less lying bouts, because lying down and standing up causes pain (Calamari et al., 2009;
Cook, 2009). Lame cows recover more quickly if they are housed on sand, because sand supports the cow with standing up and lying down, and provides a soft and cushioned lying surface (Calamari et al., 2009; Cook, 2009). In addition, the longer lying times decrease the recovery time, because of the increased blood flow into the claws when cows are lying down. Furthermore, the softness and the supportive characteristics of sand decrease the risk of developing lameness. Sand has shown to decrease time standing and walking in alleys, which decreases the risk of developing lameness and sole ulcers as well (Calamari et al., 2009; Cook, 2009).

Finally, sand has shown to have a positive effect on the longevity and the replacement rate of cattle. The main reasons for culling and replacing cows are low production, problems with reproduction and injuries (Cook and Nordlund, 2004). Especially prolonged suffering from lameness or mastitis are very common reasons for replacing dairy cows (Cook and Nordlund, 2004; Cook, 2009). Sand has shown to have a positive effect on the prevalence of lameness, environmental mastitis and hock lesions or abrasions (Cook and Nordlund, 2004). Furthermore, cows housed on sand will experience less stress and discomfort compared to harder bedding materials and will have longer and more productive lives, which can decrease the replacement rate of the herd (Cook and Nordlund, 2004). In conclusion, housing dairy cows on sand influences milk production in several ways.

6.2. Disadvantages

Cows are likely to show a preference for bedding materials that they are familiar with (Manninen et al., 2002; Tucker et al., 2003; Cook, 2009). Cows that are housed on sand when they are used to solid, hard surface cubicles before (concrete with straw/sawdust or rubber mats) may be a little hesitant to lay down or stand up at the beginning, because sand moves and is unstable compared to the bedding materials they were habituated to (Calamari et al., 2009; Cook, 2009; van Eerdenburg, 2010). In research conducted by Manninen et al. (2002) cows preferred other materials over sand, which was most likely due to unfamiliarity with sand in combination with a non-ideal stall design. In other research, cows tended to be hesitant towards sand as bedding material at first, because they were unfamiliar with this material (Tucker et al., 2003). However, cows prefer sand if they have had the opportunity to
get used to this type of bedding (Tucker et al., 2003; Norring et al., 2008; Cook, 2009). A period of adjustment should be at least 30 days, like Calamari et al. (2009) did before their research started. Thus, if the farmer chooses to use sand for bedding material, a slight loss in milk production can be expected during the transition period. However, the increase in production after cows familiarised themselves with sand will make up for this previous loss (Cook, 2009).

6.3. Conclusions

From this chapter it can be concluded that sand has a positive influence on the production of dairy cows because it provides a comfortable lying surface, which enhances overall cow health because of the following findings:

- Increased lying time increases rumination and blood flow to udder, which enhances milk production.
- Increased lying time decreases stress hormone release, which improves overall health and well-being of the cow, and increases production.
- Increased lying time reduces stress on feet, and thus reduces the risk of lameness and the prevalence of claw lesions.
- Increased lying time in combination with soft and cushioned (sand, straw or deep-bedded sawdust) bedding increases recovery from lameness and other health problems, and therefore production.
- The inorganic characteristic of sand reduces risk of mastitis caused by bacteria in the bedding material, and therefore production losses are less compared to other bedding materials.
7. LEGISLATION

There are several mechanisms for implementing welfare improvements on farms, where legislation has been the most important mechanism in Europe for years. At this moment there is no specific legislation on welfare of dairy cattle. However, there is general legislation on health and welfare of (farm) animals. Furthermore, legislation on emission and spreading of manure might cause limitations for using sand as bedding material. Both types of legislation will be discussed in this chapter.

7.1 Legislation on housing and welfare

7.1.1 Europe
Animal welfare has recently gained interest in Europe. Increased public awareness and pressure of animal protection organisations have resulted in the introduction of the Article 13 in the Lisbon Treaty. According to the Treaty, member states of the European Union should accept animals as sentient beings, and therefore have to pay full regard to the welfare requirements of animals, while respecting the legislative, administrative provisions or customs of the member states which relate to religious rites, cultural traditions and regional heritage (European Commission, 2007). Furthermore, the European Commission formulated basic regulations for farm animals in member states, which focus on humane treatment of animals and prevention of suffering, in the European Convention for the protection of animals kept for farming purposes, enacted in 1987 (European Commission, 2007).

Legislation in the form of laws and regulations has been the main mechanism for improving farm animal welfare in Europe. However, market-led initiatives have emerged in recent years in countries like the Netherlands and the UK. In these market-led initiatives, assurance schemes make sure that the quality of life of animals is addressed. The European Union followed the example of the marked-led initiatives and formed the Action Plan on Animal Welfare (2006-2010). The plan is to introduce a welfare labelling scheme based on a harmonised standard for all European Union states.
Welfare is a multidimensional concept that comprises both physical and mental health. It includes several aspects such as physical comfort, absence of hunger and disease, possibilities to perform motivated behaviour, etc. Animal welfare is increasingly considered as an essential of high quality food production chain. Consumer perception of food quality is not only determined by overall nature and safety but also by the welfare status of the animal from which it was produced. Thus, animal welfare is part of an overall food quality concept (Welfare Quality® consortium, 2010).

Towards the improvement of animal welfare, a research program known as ‘Improved strategies in animal welfare for improved food quality integrated Project’ is designed to develop European standards for on-farm welfare assessment and product information systems as well as practical strategies. The aim of animal welfare monitoring system is to assess the level of farm animals on individual farms which is believed to be scientifically valid and practically feasible. The important attributes considered in this welfare monitoring system are the five freedoms (such as freedom from disease, fear, hungry and thirsty, pain and injury, and freedom from discomfort). In legislation and quality control system animal welfare considers four welfare principles such as good housing, good feeding, good health and appropriate behaviours. Based on the Welfare Quality project in combination with economic surveys, the EU will come up with a proposal for a new EU directive on farm animal welfare (Welfare Quality® consortium, 2010).

7.1.2 The Netherlands
As mentioned before, there is no specific legislation on dairy cattle welfare, and certainly not on using sand for bedding in the Netherlands. However, legislation on health and welfare does influence farmers, also when using sand. The only general form of legislation regarding welfare is applicable to all production animals and describes general rules for husbandry and care of animals. In the Gezondheids- en Welzijnswet voor dieren (GwwD), which is in enacted in 1992, general information about health and welfare of animals can be found. Subjects that are mentioned in this law are:
- Prevention and protection against infectious diseases (art. 15), on transport/import of animals, possibilities of the minister of agriculture to prohibit transport and markets during outbreaks.
- It is illegal to hurt/injure an animal or treat the animals in a way that health and welfare are deteriorated (art. 36).
- The owner/caretaker of the animal is responsible to provide reasonable care for the animal (art. 37).
- It is illegal to make physiological changes to an animal where part(s) of the body are removed, except for neutering purposes, surgery of veterinary importance and surgery that is allowed by law (art. 40).
- Humane culling and slaughtering of animals (art. 44).
- Housing systems are only permitted if with reasonable certainty can be said that the husbandry system does not have harmful effects on the welfare of animals, to an extend that it is not acceptable (art. 47- art. 54).
- Transport of animals (art. 58).
- It is not permitted to change genes of animals if this prohibits reproduction, and it is not permitted to use biotechnological techniques on animals or embryo’s without a licence (art. 66).

In addition, there is a directive on the welfare of production animals the Besluit Welzijn Productiedieren, which is in use since 1999. In this directive, general regulations are presented on the following subjects:
- The freedom of movement of production of animals should not be restricted to that extent that animals suffer or get injured. Furthermore, animals should have enough space to meet their physiological and ethological requirements (art. 3).
- Animals should be offered shelter and protection from prey animals (art. 3).
- Animals need care from enough caretakers that have sufficient knowledge and skills on handling these animals and should be checked at least once a day (art. 4).
- Animals should be fed suitable feed and should be fed with intervals that meet physiological requirements (art.4).
- Sick animals should be treated immediately in a proper way (art.4)
- Housing facilities should provide safe and cleanable enclosures, fresh water, sufficient ventilation (art. 5).
- Medical treatments should be registered (art. 6).

At this moment, a new law on animal health and welfare (Wet Dieren) is under construction. This new law will be a clustering of the Gezondheids- en welzijnswet voor Dieren and four other laws on veterinary care, veterinary medicine, protection of animals and on animal feeds. In this new law, the intrinsic value of the animal will take a central role (Ministerie van Landbouw, Natuur en Voedselveiligheid, 2010).

**7.1.3. United Kingdom**

In the UK, the Farm Animal Welfare Council reviews farm animal welfare and advises the government for legislative requirements, using the five freedoms as basis (Defra, 2010). The on-farm welfare is regulated in The Welfare of Farmed Animals Regulations 2000 (Defra, 2010). These regulations require that everyone that takes care of farm animals should be familiar with the welfare codes for the specific animal species. These codes aim to reach the highest standards of husbandry, and contain guidelines for handling, caring, housing and treating animals (Defra, 2010). In addition, the Health and Safety Executive (HSE) contains a safety guide on handling and housing cattle in a safe way for both animal and keeper (Defra, 2010).

**7.1.4. USA**

Compared to the European Union, there are few laws and limited enforcement mechanisms for farm animal protection in the United States. Farm animal welfare has not been a priority for animal protection organisations in the United States in the history. The USA has a very strong lobby for the agricultural producers in the country. Furthermore, there is low public awareness of farming practices. This combination has led to little pressure in politics, and therefore not much regulation has been formed (Matheny and Leahy, 2007). Animal welfare and farming are governed by two federal laws:
The Humane Methods of Slaughter Act (HMSA), enacted in 1958.

The Twenty-Eight Hour Law, enacted in 1877.

A third, ambitious animal-protection law in the USA is the Animal Welfare Act (AWA). However, this law is not valid for farm animals, except when farm animals are used for testing, research or teaching purposes. This means that the law is not valid for about 90% of all farm animals in the country. Although the HMSA and Twenty-Eight Hour laws are there for the protection of all farm animals, they do not have much influence on farms in practice (Matheny and Leahy, 2007).

7.2. Legislation on emission

7.2.1 Manure on land

When sand is used as bedding material, sand will adhere to the manure and will be mixed with the slurry. In the Netherlands, slurry should be put on or in the soil immediately. However, farmers are allowed to spread solid manure on grassland, without injection until the year 2013. On arable land, solid manure should be spread and worked into the soil at once (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2010).

In the UK, there are no restrictions on how to apply solid manure or slurry on the land. However, Defra (2001) recommends usage of a system that reduces the gaseous NH3 emission from application of slurry on grass or arable land. According to Defra, use of appropriate field application techniques reduces the NH3 emission, and increases the amount of N in the soil that can be used by crops or grass to grow (Defra, 2001).

In the USA, regulations on how to apply manure to land differs per state. In general, manure should be applied to land in such manner that it will not result in discharge of waters of the state during the process of application. Furthermore, manure may not be applied to land if using practices are known to cause water pollution (Pollution Control Agency, 2004). In addition, the United States Environmental Protection Agency (2010) shows that applying manure to land is allowed in several ways (spreading, surface application of solid manure, liquid manure pit agitation and injecting), however, it is recommended to not use odour-causing methods in populated areas.
It should be kept in mind that spreading sand on grass or arable land might become a constraint if regulations on applying sand to land change in the future.

7.2.2 NH$_3$ emission

The emission of ammonia (NH$_3$) is considered to be one of the most harmful gasses, because it creates odours and it negatively affects water and air quality, and thus is a treat for the environment (Becker and Graves, 2005). According to the new emission norms in the directive ‘Regeling Ammoniak en Veehouderij’ (RAV), dairy farms should have a maximum of 9.5 kg of NH$_3$ emission per cow/year. Whereas most housing systems that use sand as bedding material have a solid, concrete floor, sand housing systems can be considered as low-emission systems. This is in agreement with the table in the RAV, that shows that cows housed in stalls with a solid floor have about 7.5 of NH$_3$ emission if grazed in summer, compared to 8.6 kg of NH$_3$ emission if housed indoors year round (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2009). Both grazed and zero-grazed sand-housed cow emissions are lower than the threshold of 9.5 kg of NH$_3$ per cow/year, and are therefore approved as low-emission system (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2009).

The UK has set a national maximum of 297 kt of total NH$_3$ emission per year from 2010. Research is going on about measuring the yearly NH$_3$ emission through agriculture, from past and estimate future emissions, to be able to submit the annual emission data to the EC under the National Emissions Ceilings Directive (Defra, 2008). In addition, research is conducted to find out how animal welfare legislation influences the NH$_3$ emission in the country (Defra, 2008).
In the USA, some concerns have arisen about the impact of NH₃ emission from animal agriculture on the quality of the environment (Becker and Graves, 2005). Cattle and calves are responsible for 43.4% of the total NH₃ emission from livestock production facilities and other human activities, and therefore this sector has received increased attention from regulating institutions (Becker and Graves, 2005). However, to date there are no specific rules for maximum emission of NH₃ per cow/year.
8. ETHICS

The presence of many options of milk in the market (organic, grass fed, etc.) shows that there is a consumer demand for produce that has come from different farming methods. Farm animal welfare groups (CIWF, FAWC, Dierenbescherming, RCPSA) inform the public as to what options they consider the most ethical in terms of animal welfare, and occasionally, in the case of Dierenbescherming and the RSPCA endorse animal products as welfare friendly, as well as working with certain supermarkets to improve the welfare quality of their food. The “Good Food Shopping” guide (CIWF, 2010) lists the type of milk labeling which indicates the highest welfare for cows, naming the Soil Association Organic milk as the most ethical option. The justification behind promoting organic milk as welfare friendly (OMS-Co, 2010) mentions good access to grass, contrasts the housing and health implications of pasture fed cows to that of zero-grazed cows and the talks of low use of antibiotic treatment in organic herds. It would be superfluous to enter into the zero-grazed ethical debate for this report, suffice to say that the use of sand is not central to it, although there should be a wider appreciation that the vast majority of all herds are housed as some point during the calendar year (OMS-Co, 2010). A consideration for those marketing their milk as welfare friendly is; should there be a minimum standard of housing for these different methods of production and does sand have role here? As discussed in the rest of the report, sand certainly pertains to being the “gold standard” (Bickert, 1999) of cow comfort (Weary & Tucker, 2003) with considerable health benefits (Bell, 2007). Some dairies, including the controversial Nocton Dairy (The Guardian, 2010; The Times, 2010) in the UK are touting their use of sand as a sign that they are complicit with the highest possible welfare standards (Nocton Dairy, 2010) for cow health and comfort. Given that sand can be used as marketing device to promote a producer’s welfare credentials there could be a risk that sand facilitates in covering up poor practice. According to opinion sought (van Eedernberg, 2010), the use of sand as bedding is unlikely to be able to be used on milk labels as an indication of good welfare because the benefits of using it are so management dependent.
8.1. Food Ethics – the dairy herd and sand.

There is a growing trend for more ethical acceptability and consideration in agricultural practices and developments as they have implications for the environment and society and in the case of using sand we need to consider the consumer, the producer and the cow. The now common phrase “from plough to plate”, used when describing food, is reflective of an increasing desire of the consumer to know the origin and production management of their food. There are thoughts that call for a more holistic approach to farming is a cultural rebound of the post-WWII need for Taylorism, or scientific management by increased efficiency and decreased waste, with an emphasis on following empirical research rather than having room for ethical considerations. Mepham (2000) uses the bovine spongiform encephalopathy epidemic to illustrate how harmful the reductionist approach to farming can be and draws parallels with the efficient and yet ethically questionable intensive factory farming methods. The ethical considerations about milk (and other food) have been established as a separate branch of applied ethics, whose features (Adapted from Mepham, 2000) for consideration include:

1. Food is vital to human survival whereas other production industries aren’t.
2. Food production depends on the exploitation of living resources.
3. Sustainable food supply necessitates ecological and environmental stability.
4. Agricultural productivity involves use of extensive land.
5. Farming is a way of life which contributes to the numbers actively engaged in it; it also safeguards skills which might prove of inestimable value in the event of military or environmental crisis. (Mepham, 1998)

To make a practical application of the use of sand and its ethical considerations we must look at the points outlined above and at the social contract we have with our agricultural world. The “social contract” as defined by Mepham (2000) is the unspoken, yet accepted, agreement between members of a democratic society, which are the basis for governance and social cooperation. The purpose of this social contract is to find an equitable balance of liberties in order to have a strong social structure for all. In essence, these are informed by our Western ethical theories, namely utilitarianism and deontology.
The utilitarian view of ethics evaluates what decisions are better or worse (Sandoeet al., 1997) for the greater good. Whereas deontology is more involved with our moral obligations to others (Mepham, 2000) for example, the maxim “do unto other as you would have done unto yourself.” Animal rights campaigners believe that ‘the others’ in deontology include all sentient life forms, which here would mean cows. We will consider then the viewpoints, in conjunction with food ethics and our groups of concern; consumers, producers and cows.

8.2. Consumer ethics & sand
In Europe a correlation was found between the number of times an adult had visited a farm and calls for tougher legislation (Matheny & Leahy, 2007) suggesting that public education and awareness are central to consumer demand. A poll also indicated that the majority of the European public believes that farm animal welfare should carry more weight in legislation (Matheny & Leahy, 2007). Yet a poll of consumer concerns about farm animal welfare found that dairy cows were at the bottom of bovine issues (Miele& Parisi, 2001) with beef (BSE, feeding) and calves (veal crates) being thought of as the most compromised in welfare. Other reports show that the consumer is mostly concerned with food safety (Wells et al., 1998) rather than the housing conditions that would involve consumers taking a stance on the use of sand. Arguably, sand is also neither a more or less sustainable bedding option, because it is dependent on farm location. Neither utilitarianism or deontology would persist on marketing sand as an ethical choice, since other bedding types can also be well managed and provide good cow welfare.

8.3. Farmers, ethics & sand
The humaneness of intensive dairy farming raises concerns about the genetic health and sustainability of cows bred to have high milk yields, the treatment of male calves and whether or not it is right to house grazing animals for most of the year. Farming retorts to these methods of production have come in the form of criticizing the pressure of the milk quotas and the threat of cheap imports, with farmers often feeling that intensive farming is the only means to protect their industry. An oft-cited argument is that indoor methods of
dairy farming are better managed in the EU with tighter legislation than they are in non-EU member states where milk is sometimes imported. However, The British Veterinary Association has called for farmers to be better educated about the welfare of cattle, in particular they cite “housing the modern dairy cow can be a significant challenge to UK dairy farmers; however much can be done to existing buildings to achieve the high welfare standards which good housing can provide” (BVA, 2009) and states that housing is one of the main concerns that they have not seen recent improvement in. It is possible then sand can be a solution here, for both farmers and vets. Although not a resolution for poor cubicle design, it’s health and production benefits may be able to increase the farmer’s revenue and improve the mastitis and lameness that the vets are concerned with in this report. From an ethical viewpoint, sand would for both the vets and the farmers provide greater good, as it would address the health issues, whilst in the forum of food ethics, the improved welfare of cows by appropriate housing would help safeguarding of jobs in the EU. However, an ethical considerations might be, does sand facilitate an inhumane method of farming? Is the emphasis on increased production sustainable and welfare friendly?

8.4. Sand & cows
As mentioned in the applied food ethics, we exploit cows for milk production and internally pacify our unease of this exploitation in our social contracts by providing good welfare for the cows. Sand can be considered a great deontological solution from a cow’s point of view, as it is considered the highest level of cow comfort outside of pasture. In this instance, the costs, both economic and time are of little influence, for the ethical philosophy here requires us to treat the cows as we ourselves would wish to be treated. Again from the perspective of the cow, if sand really is, and can be proved to be, the best for health and comfort than the utilitarian ethics would also demand the use for sand in housed dairy cattle. The utilitarian view would consider the costs of the farmer to be less important the quality of life and welfare of the cow.
8.5. Conclusions
Sand can be considered important in the field of applied for ethics, it provides both customer satisfaction of doing the best by the animals that we use for food, as well as the potential to help farmers sustain their livelihoods through reduced health problems. Although currently not a vogue topic in farm animal welfare issues, the housing of all dairy herds should be considered important and consumer awareness will be able to influence public policy to make cubicle surfaces an important ethical issue in the production of dairy.
# 9. CONCLUDING TABLE

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Advantages</th>
<th>Constraints</th>
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<tbody>
<tr>
<td>Sand</td>
<td>- Comfort</td>
<td>- Heavy</td>
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<tr>
<td></td>
<td>- Inorganic</td>
<td>- Freezes in cold weather</td>
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<td>- Dry</td>
<td>- Labour intensive</td>
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<td>- Cool</td>
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<td>- Traction</td>
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<td></td>
<td>- Cheap if readily available</td>
<td>- More expensive in areas further from beaches/rivers</td>
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<td></td>
<td>- Financial costs can be recouped by well managed investment</td>
<td>- Costs dependent of lorry transport</td>
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<tr>
<td>Costs</td>
<td>- Soft bedding</td>
<td>- Manure handling</td>
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<tr>
<td></td>
<td>- Sand on concrete increases grip</td>
<td>- Wearing of machinery</td>
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<td></td>
<td>- Reusable if recycled</td>
<td>- Recycling is expensive</td>
</tr>
<tr>
<td>Housing</td>
<td>- Lying times &gt; 12 hours</td>
<td>- Each 1 cm less sand = - 11 minutes lying time</td>
</tr>
<tr>
<td></td>
<td>- Standing times &lt; 2hours</td>
<td>- Cows digging – loss of sand</td>
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<td></td>
<td>- Sand provides cushioning and traction for rising and lying down</td>
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<tr>
<td></td>
<td>- Increased walking behavior (increased feeding and drinking)</td>
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<td></td>
<td>- Less stress</td>
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<tr>
<td>Behaviour</td>
<td>- Significantly less environmental mastitis</td>
<td>- Sand can be abrasive if layer is too thin</td>
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<td></td>
<td>- Lower bacterial counts in bedding</td>
<td>- More lesions on dorsal tuber calcis (one study)</td>
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<tr>
<td></td>
<td>- 50% Less coliform bacteria compared to sawdust in teat swabs</td>
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<tr>
<td></td>
<td>- 85% less Klebsiella compared to sawdust in teat swabs</td>
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<tr>
<td></td>
<td>- 42% less lameness</td>
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<td></td>
<td>- 75% less hock abrasions</td>
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<tr>
<td>Health</td>
<td>- Increased lying times $\rightarrow$ increased rumination + increased blood flow</td>
<td></td>
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<tr>
<td></td>
<td>- Less stress = more production</td>
<td>- Takes time for cows to get used to sand</td>
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<td></td>
<td>- Lame cows recover faster (less production loss)</td>
<td>- Slight production loss possible during transition possible</td>
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<tr>
<td>Production</td>
<td>- Solid floor is low NH$_3$ emission system</td>
<td>- Legislation due to change about spreading waste on fields.</td>
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<td></td>
<td>- Improved housing is part of regulations to improve dairy cow welfare</td>
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<tr>
<td>Legislation</td>
<td>- Sand approved by both utilitarian and deontological views for providing cow with good comfort and improved health</td>
<td>- Potential for sand to be marketed as high welfare and mislead public as to poor management practices.</td>
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<tr>
<td>Ethics</td>
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REFERENCES


behavioural, productive and metabolic parameters in dairy cows’, Applied Animal Behaviour
Science 120 p.9-17.

www.cardigansand.co.uk/ pricelist.html (Accessed 19 February 2010)

and fertility’, Veterinary Record, 125, No. 5, 103-106.


housing type and stall surface, Journal of the American Veterinary Medical Association 223
(9) p.1324-1328.


activity patterns in dairy cows with relevance to lameness prevalence, Journal of Dairy
Science 87 (9) p.2912-2922.

Zone-Design Free Stalls: Do They Influence the Stall Use Behaviour of Lame Cows?, Journal of
Dairy Science 91 p.4673-4678.


Cook, N. B. (20093) Big sand stalls: Best thing ever or bad idea? [www document]

Dairy Operations’ www.vetmed.wisc.edu/dms/fapm/publicats/proceeds/
Troubleshootingcowcomfortandfreestalls.pdf (accessed on 05 March 2010)

Cool Cows (2008) Dealing with Stress in Australian Dairy Herds; Cows & Heat [www
March 2010)

Defra (2001) Managing Livestock Manures. Booklet 3: Spreading systems for slurries and
solid manures. Mansfield: ADAS Gleadthorpe Research Centre.


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Mepham, T. B. (2000) Symposium on ‘the ethics of food production and consumption’- The role of food ethics in food policy, Proceedings of the Nutrition Society 59pp. 609-618


