

THE EVALUATION OF BEDDING MATERIALS USED ON FREE-STALL RESTING SURFACES IN TERMS OF COW COMFORT

SERBEST DURAK DINLENME YÜZEYLERİNDE KULLANILAN YATAKMALZEMELERİNİN İNEK KONFORU AÇISINDAN DEĞERLENDİRİLMESİ

Suna Büyükkök¹, Kenan Büyüktaş^{2*}, Ahmet Tezcan², Cihan Karaca²

¹Akdeniz University Institute of Science, Antalya, Turkey

²Akdeniz University Faculty of Agriculture Department of Farm Structures and Irrigation, Antalya, Turkey

* Corresponding author: kbuyuktas@akdeniz.edu.tr

Geliş Tarihi / Received: 15.10.2020
Kabul Tarihi / Accepted: 26.12.2020

Araştırma Makalesi/Research Article
DOI: 10.38065/euroasiaorg.277

ABSTRACT

In this study, it was aimed to determine the most preferred bedding material in terms of cow comfort on dairy cattle barn in Antalya. For this purpose, 5 different bedding materials were applied in a total of 50 stalls. One hard plastic (rubber mat), two different types of soft plastic (soft foam mat and curly mat) and tartan rubber mat were placed on free-stall floors with 4 different application types. Thus, different bedding materials were evaluated in terms of preference time in different seasons. Then, the most preferred bedding material was determined using the preference conditions of the different bedding materials placed on the stall floor via measurements and observations made 24 hours a day for 6 months. Besides, the cow's preferences time recorded with cameras placed in the barn, the most preferred bedding material was identified. In addition, the preference times and usage periods of 4 different bedding materials used in the free stall floor were compared with the concrete floor. According to the result of the records and observations, it was determined that the cows are spending their time in soft foam mat with 237.14 min/day, hard rubber mat with 226.05 min/day, and soft curly mat with 216.28 min/day.

Keywords: Bedding material, comfort, freestall, lying time, preferences.

ÖZET

Bu çalışmada Antalya ilinde süt sığırcılığı ahırında inek konforu açısından en çok tercih edilen yatak malzemesinin belirlenmesi amaçlanmıştır. Bu amaçla toplam 50 durakta 5 farklı yataklama malzemesi uygulanmıştır. Serbest duraklı zeminlere bir adet sert plastik (kauçuk paspas), iki farklı tipte yumuşak plastik (yumuşak köpük paspas ve kıvrıkcık paspas) ve tartan kauçuk paspas 4 farklı uygulama şekli ile yerleştirildi. Böylelikle farklı yataklama malzemeleri farklı mevsimlerde tercih süresi açısından değerlendirilmiştir. Daha sonra 6 ay boyunca 24 saat yapılan ölçümler ve gözlemlerle durak zeminine yerleştirilen farklı yatak malzemelerinin tercih koşulları kullanılarak en çok tercih edilen yatak malzemesi belirlendi. Ayrıca ahıra yerleştirilen kameralarla ineklerin tercih süreleri kaydedilerek en çok tercih edilen yatak malzemesi tespit edildi. Ayrıca serbest durak katında kullanılan 4 farklı yataklama malzemesinin tercih süreleri ve kullanım süreleri beton zemin ile karşılaştırılmıştır. Kayıt ve gözlemlerin sonucuna göre ineklerin 237.14 dk / gün yumuşak köpük mat, 226.05 dk / gün sert kauçuk mat ve 216.28 dk yumuşak kıvrıkcık matta vakit geçirdikleri belirlendi.

Anahtar Kelimeler: Yatak malzemesi, konfor, serbest durak, yatma süresi, tercih.

1. INTRODUCTION

Cow comfort is a top priority for dairy farmers and the freestall resting surface material is a major contributing factor to the comfort of cows. The stall surface must be comfortable enough to attract a

cow to lie down in the stall rather than elsewhere (Boone, 2009). Many materials have been used for freestall resting surfaces, including: sand, straw, waterbeds, foam mattresses, rubber-filled mattresses, mattresses containing combinations of foam and rubber, and rubber mats. (Tucker and Weary, 2001; Gaworski et al., 2003).

Many researchers have studied the effects of different bedding materials on the overall behavior of the cows. O'Connell and Meaney, (1997) compared four treatments: 1) concrete and sawdust, 2) concrete and paper, 3) mattresses (Enkamat) and sawdust, and 4) mattresses (Enkamat) and paper, using 64 cows for sixteen stalls of each type. Cows preferred to lie down in the stalls bedded with mattresses and sawdust and were least likely to use the concrete stalls with paper. The results of Gebremedhin et al., (1985) illustrated a preference by cows for stalls with more bedding. They found that cows were more likely to lie down in stalls when these had more bedding (achieved by adding a bedding retainer), regardless of whether the stall base was concrete, mat or carpet.

Rodenburg et al., (1994) and Visser, (1994) reported that various material used as bedding material decrease lay time and stress of cows, increase milk yield. In addition, the better hygiene of the freestalls allows the cows to be cleaner and less injured. Herlin, (1997) compared cow preferences for concrete, rubber mats (15 mm thick), and comfort mats (21 mm thick), by offering 18 cows 18 stalls, 6 stalls of each type. He found that cows were more likely to spend time lying down on comfort mats than on the rubber and they were more likely to use the rubber than the concrete. Haley et al., (2000) compared with high comfort mattress and concrete bedding materials and he expressed that cows spent more times in comfort mattress than concrete. He also reported that cows spend more time by waiting stand in concrete while they lie down more time in comfort mattress.

Zhao et al., (2012) compared with different bedding material such as dry sand, soft foam, rubber mat, waterbed in terms of softness. They determined that the softest resting surface material was the soft foam (1.07 CIV/L) followed by dry sand (moisture content <0.75%) (1.57 CIV/L). The hardest material was the rubber mat (64.23 CIV/L). The softness of the waterbeds varied with the change in water pressure and volume in both the small and large chambers of the waterbeds. Mitev et al., (2012) used three types of bedding materials for the preference test - rubber mats, manure-straw bedding and sand. They reported that the installed soft rubber mats on concrete floor mitigated the adverse effects on cow behavior at rest. The lying time (iFA-0.4133) on the rubber mats and the number of lying down (21.2) during the day showed that rubber mats are more comfortable for cows than manure-straw bedding and sand. When using a small amount of straw bedding, the cows preferred to lie longer on soft rubber mats.

As can be seen from the literature, the bedding materials used in the studies are generally similar materials. However, this study is different from other studies because soft curly mats and tartan rubber mats used in this study have not been tested before.

For this reason, the main objectives of this study is to compare five different bedding materials in terms of cow comfort and find out interaction between season and bedding materials. It is also very important that soft curly mats and tartan rubber mats used in the study have not been tested before in any study as bedding material in terms of cow comfort. So, this could bring innovation to the studies done in this area.

2. MATERIAL AND METHOD

The study was carried out in the dairy cattle barn located in Akdeniz University Experimental Research Area of Agricultural Faculty in Antalya. The two-row free-stall barn is a naturally ventilated dairy cattle barn with an north-south orientation and with the curtained north wall. The free-stalls were 110 cm width and 210 cm length with neck rail (110 cm above free-stall surface). The bases of the stalls of barn were made of concrete (C) material. In order to determine cow preference and comfort, four different bedding materials such as hard rubber mats (HRM), tartan rubber mats (TRM), soft curly mats (SCM) and soft foam mats (SFM) were applied to the concrete

stall floors in the barn (Figure 1). Some physical properties belonging to the bedding materials used in the study was given in Table 1. Four different bedding materials used were laid in equal numbers on concrete-based stalls and 5 different free stall floors were created. Cow behaviors were recorded 24 h/d using 2 cameras (Lg LCU5500R 700 TVI 2.8/12 mm). For a complete view, one camera was placed east side and one camera was placed west side of the barn. Cameras were placed 2.5 m height from the ground. Two cameras recorded a full view of each of the free-stalls. The cameras were attached to a video multiplexer and time-lapse recorder. Night video recording facilitated due to the fact that it was the night vision feature in the cameras. Video recordings were scanned at 5-min intervals; during each scan, it was recorded the general activity patterns of each cow on all recorded days. These activities were frequency, number of cows of standing and lying in each free-stalls. It could be determined the number of cows used the free-stalls having different bedding materials with this sampling method.



Figure 1. Bedding materials used in the study

Table 1. Some physical properties belong to the bedding materials used in the study

Bedding materials	Dimensions (cm)	Weight (kg/m ²)
	Width-Length-Thickness	
Hard rubber mats (HRM)	50*50*1.2	9.6
Soft foam mats (SFM)	50*50*3.2	1.2
Soft curly mats (SCM)	50*50*1.4	4
Tartan rubber mats (TRM)	40*40*3.0	20

50 lactating Holstein cows (averaging 300 day of lactation) were used in the experiment. Mean body weight of the cows was 650 kg and the average body length (defined as top line length from nose to tail) was 150 cm. During the experimental period, ration consisting of three different feeds such as rough feed, concentrate feed and silage feed were given to cows. Each cow consumed an average of 40 kg/day of total mixed ration twice a day at 09:00 AM and at 04:00 PM (Table 2). Cows were milked twice a day (07:00 AM and 07:00 PM) in milking room located in a separate compartment. The average daily milk production of the cow groups was 28 kg before the experiment while it was 28.5 kg during the experiment.

Table 2. Amount of feed given to cows in the barn, feeding times and milking times

Number of cows	Amount of feed (kg/cow/day)			Feeding times		Milking times	
	Rough feed	Concentrate feed	Silage feed	a.m.	p.m.	a.m.	p.m.
50	8.5	8	25	09:00	16:00	07:00	19:00

Temperature and relative humidity measurements were made outside and inside of the barn during the study. Outside climatic data of barn were taken from the meteorological station next to the barn (Figure 3). Inside climatic data of barn were taken with TESTO 175-H1 temperature and relative

humidity dataloggers (-20 to +55°C temperature and 0-100% humidity measurement range) which was placed to different points and heights in the barn (Figure 4).

The study was carried out for a period of 6 months between June 2016 and December 2016 to determine the preference times of 5 different bedding materials and cow comfort. Preference time, usage time, standing and lying time of hard rubber mats (HRM), tartan rubber mats (TRM), soft curly mats (SCM) and soft foam mats (SFM) used in stall bases were determined and were compared with data obtained from concrete (C) base material. The 4 different bedding materials and concrete floor were applied to free stalls in 4 different placement schemes in a total of 50 stalls, each of the bedding material consisted of 10 stalls (Figure 2).

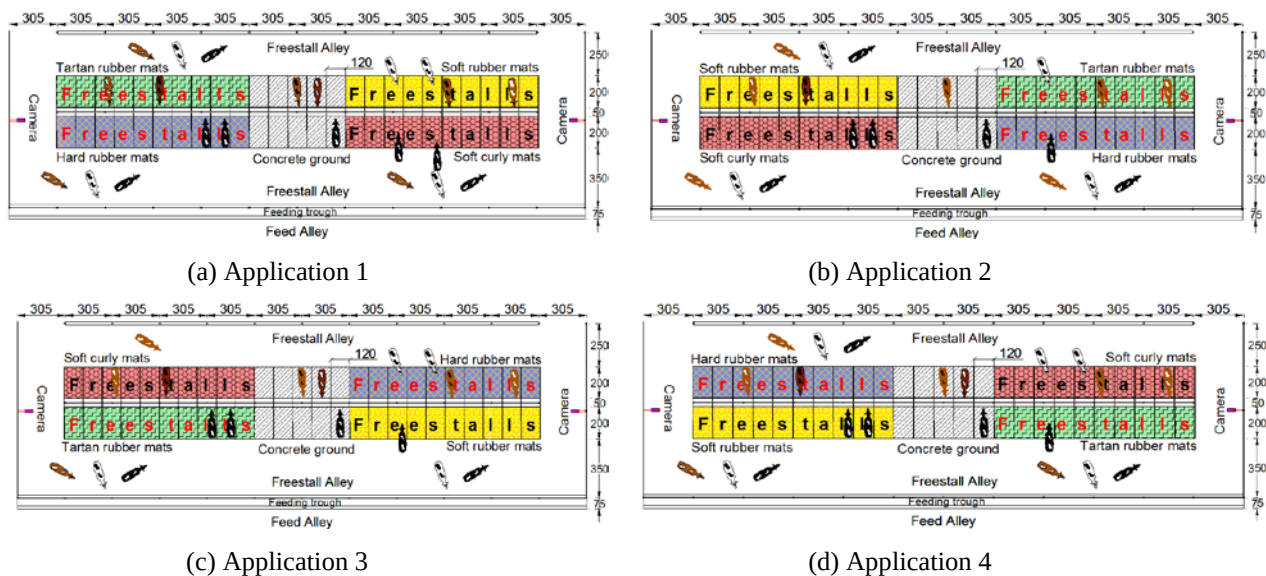


Figure 2. Application types of base materials to free-stall bases

Application date and times of application periods belonging to the bedding materials used were applied 40 days intervals and shown in Table 3. Additionally, the cameras were monitored continuously and the data were recorded by dividing the day into 4 time periods such as Morning-Noon (M-N), Noon-Evening (N-E), Evening-Night (E-N) and Night-Morning (N-M). Time periods were determined by dividing a day into 6 hours intervals (Table 3).

Table 3. Application date and times of application periods of base materials

Applications	Date	Application Periods	Times
Application 1	July 1 st – August 9 th 2016	Morning – Noon (M-N)	06:00 – 12:00
Application 2	August 14 th – September 22 th 2016	Noon – Evening (N-E)	12:00 – 18:00
Application 3	September 27 th – November 5 th 2016	Evening – Night (E-N)	18:00 – 00:00
Application 4	November 10 th – December 19 th 2016	Night – Morning (N-M)	00:00 – 06:00

Each of the five different bedding materials used as the material was laid on the base of 10 stalls and records were taken with cameras during 40 days. Each bedding material was applied in four different places on the stall platform provided that concrete floor remains stable and the four different applications were applied to the stall bases during 6 months and the preference time and durations of cows were determined. The distribution of locations of bedding materials in 4 different applications were determined randomly.

Statistical analysis of data obtained as a result of six months of measurements, recordings and observations were made using the Duncan test at 5% significance level. It has been determined whether there is statistical difference between the reasons of preference and the preference times of the different bedding materials used.

3. RESULTS AND DISCUSSION

For each application, some climatic data obtained from meteorological station located next to the barn was shown in Figure 3. When the daily average temperature values are taken into consideration, first application is the period that the temperature value is the highest and there is no rainfall. Fourth application is period that temperature value is the lowest, wind speed is the highest and has the highest rainfall. Additionally, climatic parameters recorded inside the barn was shown in Figure 4.

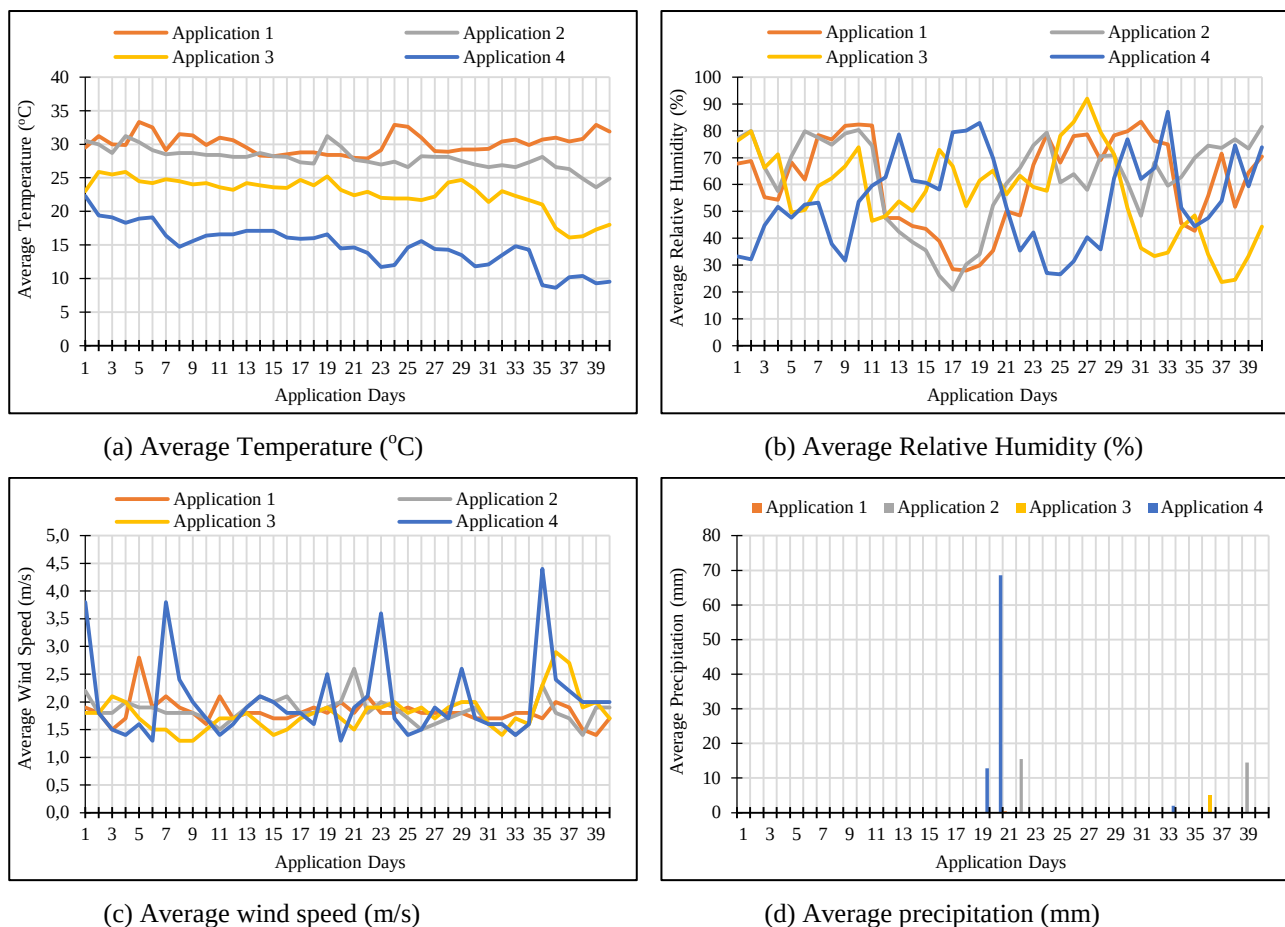


Figure 3. Outside climatic parameters taken during the study for each application

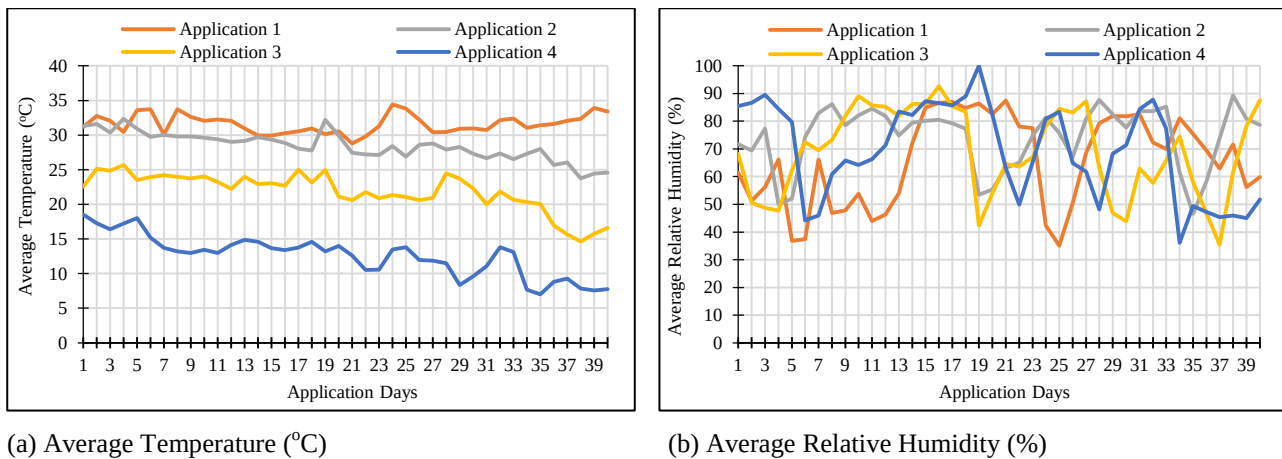


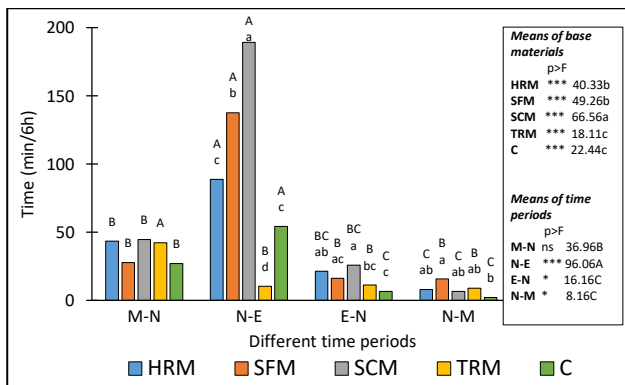
Figure 4. Inside climatic parameters taken during the study for each application

In order to measure responses of the behavior of cows in barn against different five bedding materials, the records and observations were made in 4 different applications and 4 different time periods during 160 days. For each material N=640 and in total N= 3200 observations were recorded. The statistical analysis based on the obtained measurements is given below. The average daily preference times at different application periods of different bedding materials were given in Table 4.

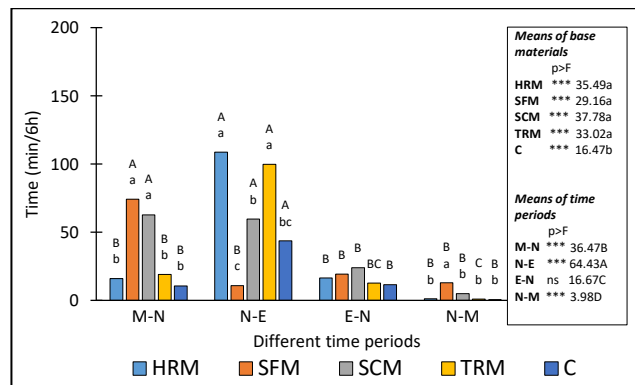
Table 4. Preference time at different application periods of different bedding materials

Bedding material type	Applications				P > F	Bedding Mat. Type Average
	Application 1	Application 2	Application 3	Application 4		
Hard rubber mats (HRM)	161.30 <i>Cb</i>	141.98 <i>Ca</i>	250.68 <i>Ba</i>	350.25 <i>Ab</i>	***	226.05 a
Soft foam mats (SFM)	197.05 <i>Bb</i>	116.63 <i>Ca</i>	152.05 <i>BCb</i>	482.83 <i>Aa</i>	***	237.14 a
Soft curly mats (SCM)	266.25 <i>Aa</i>	151.13 <i>Ba</i>	125.63 <i>Bb</i>	322.13 <i>Ab</i>	***	216.28 a
Tartan rubber mats (TRM)	72.45 <i>Cc</i>	132.08 <i>Ba</i>	117.03 <i>BCb</i>	321.3 <i>Ab</i>	***	160.69 b
Concrete (C)	89.60 <i>ABc</i>	65.88 <i>BCb</i>	25.35 <i>Cc</i>	114.18 <i>Ac</i>	***	73.75 c
P > F	***	**	***	***		
Application period average	157.33 B	121.54 C	134.15 BC	318.12 A		
Importance level	Bedding material type (MT) : *** Application period (AP): *** MT x AP: **					
[†] : In the section written in <i>italics</i> ; the capital letters show comparison of the averages given along the horizontal (along the row) at the 5% significance level according to the Duncan test.						
^ψ : In the section written bold , the small letters given in vertical (<i>along the column</i>) and the capital letters given in horizontal (along the row) show comparison of the averages at the 5% significance level according to the Duncan test.						
* , ** , *** %5, %1, %0.1 it is important at the level of probability, respectively.						
ns: not significant.						

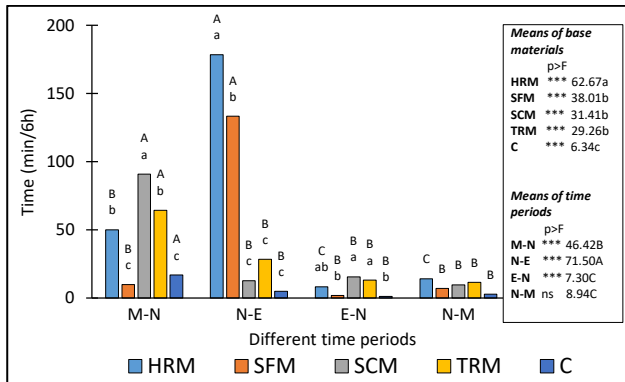
As can be seen from the Table 4, differences at %0.1 significance level were determined between bedding materials, application periods and their interactions. In addition, it was determined that cows prefer different base types at different durations during different application periods. When all application periods are taken into consideration, the longest time preferred bedding materials are SFM with 237.14 min/day, HRM with 226.05 min/day and SCM with 216.28 min/day, while the shortest time preferred bedding materials are C with 73.75 min/day. In addition, the longest time preferred bedding materials were determined as SCM in Application 1, SCM, HRM, TRM and SFM in Application 2, HRM in Application 3 and SFM in Application 4. Furthermore, the concrete was the shortest time preferred bedding material in all applications. (Haley et al., 2001) tested the effects of two types of stall floorings which are concrete and mattress flooring and two tie stall



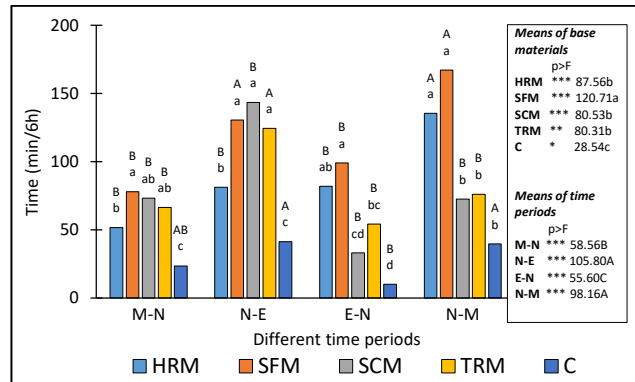
(a) Application 1



(b) Application 2



(c) Application 3



(d) Application 4

Morning-Noon (M-N): Between 06:00 and 12:00 AM
 Evening-Night (E-N): Between 18:00 and 00:00 PM
 AM

Noon-Evening (N-E): Between 12:00 and 18:00 PM
 Night-Morning (N-M): Between 00:00 and 06:00 AM

* The capital letters above the bars show comparison of the averages of same bedding material in each time period at the 5% significance level according to the Duncan test. The small letters above the bars show comparison of the averages of different bedding materials in same time period at the 5% significance level according to the Duncan test.

Figure 5. The preference times of different bedding materials for different application periods at different time periods of the day.

In Figure 5a, it was observed that cows spend the most of time in free stalls in Noon-Evening time period. The preference of the bedding material for cows was not statistically different at Morning-Noon time period in Application 1. In addition, it was observed that cows the longest time preferred to SCM bedding material in Noon-Evening time period, SCM, HRM, SFM bedding materials in Evening-Night time period and SFM, TRM, HRM, SCM bedding materials in Night-Morning time period. In Figure 5b, the longest time preferred bedding material by cows was determined to be SFM and SCM bedding materials in Morning-Noon time period, HRM and TRM bedding materials in Noon-Evening time period and SFM bedding material in Night-Morning time period also. However, for cows, the preference of the bedding material was not found statistically important at Evening-Night time period in Application 2. The reason for this is thought to be due to the connected that milking time of cows coincide with this time period (Table 2). In Figure 5c, it was determined that Noon-Evening time period became the longest preferred time period by cows.

During the Application 3, the longest time preferred by cows was determined to be SCM bedding material in Morning-Noon time period, HRM bedding material in Noon-Evening time period, SCM, TRM and HRM bedding material in Evening-Night time period. However, there was no significant difference among time spent of cows on the different bedding materials in Night-Morning time period. It is thought that cows are preferring to stay in padock during the night because of the convenient climatic conditions such as temperature, relative humidity, wind speed, rainfall (Figure 3). It is also understood that the cows prefer the bedding materials for very short time in the Night-

Morning time period. In Figure 5d, it was determined that Noon-Evening time period became the longest preferred time period by cows as become in the other three applications. It is thought that cows prefer to stay inside the barn because outside climatic conditions are unfavorable. When this period (Fig. 5d) compared with other periods (Figure 5a, b, c), it is seen that the sum of preference time to bedding materials of cows in Application 4 are much more than other periods. It is also similarly thought that this situation is caused by climate conditions and cows use more bedding materials because they prefer to stay inside the barn more in cold, windy and rainy days (Figure 3). When viewed to Figure 5, the longest time preferred bedding materials are SCM in Application 1, SCM, HRM, TRM and SFM in Application 2, HRM in Application 3, SFM in Application 4. As can be seen from Figure 5, soft bedding materials were the most preferred bedding material by the cows in all applications.

Previous work has shown that cows tend to spend more time lying on softer surfaces (Tucker and Weary, 2001). Lying time has been affected by different types of bedding material and the cows' previous exposure to these different materials (Tucker et al., 2003). Lying times are also lower and standing times higher when dairy cattle are forced to use hard surfaces, specifically concrete (O'Connell and Meaney, 1997; Haley et al., 2000; Haley et al., 2001). Cows also have longer lying times on rubber mats than on concrete (Rushen et al., 1998; Chaplin et al., 2000). These results agree with other literature suggesting that cows prefer to lie on softer surfaces (Fulwider and Palmer, 2004). However, softer flooring deforms under pressure which increases the contact area and dampens the force impact on the knees (Dumelow, 1995). Similarly, in our study, soft foam mats were easily deformed due to its softness. So, our study results show similarity with this aspect. For each application periods, preference times for different base materials of cows were shown in Figure 6.

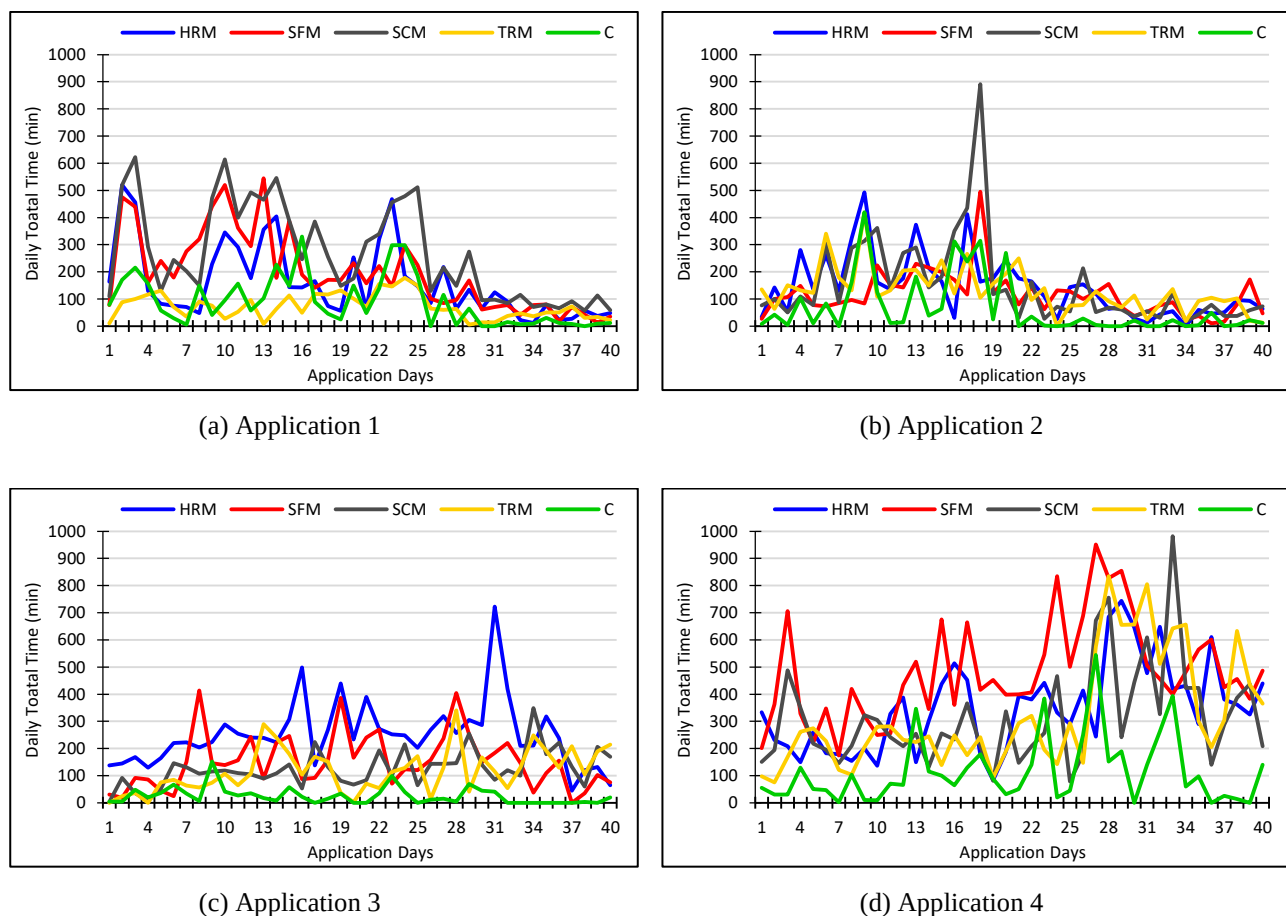


Figure 6. Daily preference times of different base materials according to application periods

When figure 6 is examined, it was seen that the preferring time of bedding materials by cows in Application 1, in which outside temperature is high, and in Application 4, in which outside temperature is low, are higher than that of the other two periods. Sum of preferred times of SCM, SFM, HRM, C and TRM bedding materials during the Application 1 were found 10650 min, 7882 min, 6452 min, 3584 min and 2898 min, respectively. These values for SCM, HRM, TRM, SFM and C bedding materials during Application 2 were found as 6045 min, 5679 min, 5283 min, 4665 min and 2635 min, respectively. On the other hand, HRM, SFM, SCM, TRM and C bedding materials during Application 3 were found as 10027 min, 6082 min, 5025 min, 4681 min and 1014 min, respectively. Lastly, SFM, HRM, TRM, SCM and C bedding materials during Application 4 were found as 19313 min, 14010 min, 12849 min, 12575 min and 4567 min, respectively.

In addition, the bedding materials were preferred the most in the Application 4. Furthermore, soft bedding materials were preferred more than hard bedding materials and concrete surface in all applications. When all applications were examined, the highest sum of time of bedding materials preferred was found as SFM with 19313 min in Application 4, while the lowest time of bedding material was C with 1014 min in Application 3.

When it is looked to the similar studies in the literature, results of those studies in literature show similarities with this study performed. Herlin, (1997) compared cow preferences for concrete, rubber mats (15 mm thick), and comfort mats (21 mm thick), by offering 18 cows 18 stalls, 6 stalls of each type. He found that cows were more likely to spend time lying down on comfort mats than on the rubber and they were more likely to use the rubber than the concrete.

Haley et al., (2000), compared with high comfort mattress and concrete bedding materials and he expressed that cows spent more times in comfort mattress than concrete. He also reported that cows spend more time by waiting stand in concrete while they lie down more time in comfort mattress. Greenough, (2007), reported that cows increase their lying time by 1.8-4.0 hours per day on a soft bedded stall compared to concrete surfaces.

Concrete became the least preferred bedding material in the all studies in literature similarly this study. In addition, soft bedding materials preferred the most time by cows in other studies like this study. As can be also understand from this situation, results show highly similarities with other studies.

4. CONCLUSION

Data taken with camera were recorded during 24 hours in 6 months period by lying 5 different bedding materials to surface of freestalls and bedding material preferences of cows were observed. In addition, this study is important because bedding materials such as soft curly mats and tartan rubber mats used for the first time as a bedding material in research like this and effects of different bedding materials to cow comfort were determined. According to combined results, the longest time preferred bedding materials are SFM with 237.14 min/day, HRM with 226.05 min/day and SCM with 216.28 min/day. The least preferred bedding material is C with 73.75 min/day. C was determined the least preferred bedding material either at different application times or at different time periods in each application. Barn surface are usually made with concrete bedding material because of service life, easy cleaning, excessive strength and durability. However, with this study, it was determined that the least preferred bedding material is concrete in terms of cow comfort according to other bedding materials. It was determined that Hard Rubber Mat, Soft Curly Mat and Tartan Rubber Mat from 4 different bedding materials used were materials that can be used in freestall surfaces in terms of ease of use and durability. However, it was observed that soft foam mat is not suitable for freestall surface as bedding material because of its lightness and softness. It was also observed that this bedding material is not also suitable for long term usage although cows prefer these soft bedding materials. Because cows threw away it from freestalls due to its lightness and it was easily deformed. Thus, the advantages in terms of usage of HRM, SCM and TRM

bedding materials compared to SFM and C bedding materials are that these bedding materials can be used as bedding material in freestall surfaces of dairy cattle farms due to some advantages such as they are lying easily on the freestall surface, they can be re-used after washing, they provide isolation between concrete surface and cows against hot and cold conditions, they have too much strength and durability, they are more hygienic and comfort than concrete surfaces.

ACKNOWLEDGE

This research was supported by the Scientific Research Projects Unit of the Akdeniz University as a Master thesis with project number FYL-2016-1266. The authors wish to thank to Akdeniz University for its support.

REFERENCES

- Boone, R.E., 2009. Comparison of Freestall Bedding Materials and Their Effect on Cow Behavior and Cow Health. University of Florida. 100 p.
- Chaplin, S.J., Tierney, G., Stockwell, C., Logue, D.N., Kelly, M., 2000. An evaluation of mattresses and mats in two dairy units. *Applied Animal Behaviour Science*. 66: 263–272.
- Dumelow, J., 1995. Testing cubicle mats for dairy cows. *Agricultural Engineering*. 50: 17–21.
- Fulwider, W.K., Palmer, R.W., 2004. Stall Usage Differences of Thirteen Different Freestall Base Types. *Animal Science*. 20: 470–482.
- Gaworski, M.A., Tucker, C.B., Weary, D.M., Swift, M.L., 2003. Effects of Stall Design on Dairy Cattle Behaviour, in: 5th Intl. Dairy Housing Conf. K. A. Janni, St. Joseph, Mich.: ASAE, 139–146.
- Gebremedhin, K.G., Cramer, C.O., Larsen, H.J., 1985. Preference of Dairy Cattle for Stall Options in Free Stall Housing. *Trans. ASAE* 28: 1637–1640.
- Greenough, P.R., 2007. Bovine laminitis and lameness : a hands-on approach. Saunders Elsevier. 311 p.
- Haley, D.B., De Passillé, A.M., Rushen, J., 2001. Assessing cow comfort: Effects of two floor types and two tie stall designs on the behaviour of lactating dairy cows. *Applied Animal Behavior Science*. 71: 105–117.
- Haley, D.B., Rushen, J., Passillé, A.M. de, 2000. Behavioural indicators of cow comfort: activity and resting behaviour of dairy cows in two types of housing. *Canadian Journal of Animal Science*. 80: 257–263.
- Herlin, A.H., 1997. Comparison of lying area surfaces for dairy cows by preference , hygiene and lying down behaviour. *Swedish Journal of Agricultural Research*. 27: 189–196.
- Kara, N.K., Galic, A., Koyuncu, M., 2015. Comparison of milk yield and animal health in Turkish farms with differing stall types and resting surfaces. *Asian-Australasian Journal of Animal Science*. 28: 268–272.
- Mitev, J., Varlyakov, I., Miteva, T., Vasilev, N., Gergovska, J., Uzunova, K., Dimova, V., 2012. Preferences of freestall housed dairy cows to different bedding materials. *Istanbul Universitesi Veterinerlik Fakültesi Dergisi*. 38: 135–140.
- O’Connell, J.M., Meaney, J.W., 1997. Comparison of shredded newspaper and sawdust bedding for dairy cows: Behavioural, clinical and economic parameters. *Irish Veterinary Journal*. 50: 167–170.
- Rodenburg, J., House, H.K., Anderson, N.G., 1994. Free Stall Base and Bedding Materials: Effect

- on Cow Comfort, in: 3rd International Dairy Housing Conference. 2–5 Feb. Orlando, FL. Dairy Systems for the 21st Century, pp. 159–164.
- Rushen, J., de Passillé, A.M., Haley, D.B., 1998. The effects on productivity, health, and behaviour of housing lactating dairy cows in NRI “Cloud 9” rubber mats. Report to NRI, Inc.
- Tucker, C.B., Weary, D.M., 2001. Cow comfort and stall design. *Advance Dairy Science Technology*. 13: 155–168.
- Tucker, C.B., Weary, D.M., Fraser, D., 2003. Effects of Three Types of Free-Stall Surfaces on Preferences and Stall Usage by Dairy Cows. *Journal of Dairy Science*. 86: 521–529.
- Visser, R.Q., 1994. A Comparison of Bedding Materials for Dairy Cows., in: 3rd International Dairy Housing Conference. 2–5 Feb. Orlando, FL. Dairy Systems for the 21st Century, pp. 186–191.
- Zhao, D., Büyüktaş, K., Boone, R.E., Bucklin, R.A., Bray, D.R., 2012. Impact testing to assess the softness of freestall resting surfaces. *Applied Engineering Agriculture*. 28: 417–421.