Seasonal Variation of the Dairy Cattle Behavioral Indexes Using Different Scan Sampling Frequency in Free-Stall Housing

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Abstract— **Behavioral indexes are used as an indication of animal welfare. This study was performed to select the scan sampling frequency (SSF) that bests characterizes daily behavioral activity of dairy cows in free-stall housing (FHS) in Konya (Turkey) by season and to determine seasonal variation of this indexes at different SSF. The dairy cattle behaviors were observed in FHS at a commercial dairy farm from November 2007 to March 2009 using continuous video data (24 h/d). The cow behaviors in the barn were videotaped for a total of 24d (576 h) over 4 seasons using a different SSF. Temperature, humidity and temperature humidity index (THI) was calculated on an hourly basis. The values of the cow comfort index (CCI), cow stress index (CSI), and stall usage index (SUI) were calculated based on SSF of 10, 20, 30, 60, and 120-min. The results show that behavior indexes of dairy cows can be accurately evaluated by analyzing video recordings taken using 60-min SSF (highly correlated with 10, 20, and 30-min scan samples; r>0.89, P<0.01 for autumn, spring, and summer). Consequently, the determined method provides saving time, labor and an easy to accurately analyze dairy cattle behavior instead of continuous observations requiring long times.**

Index Terms— **Cow behavior, cow comfort index, cow stress index, dairy housing, free-stall use index**

I. Introduction

Behavior is considered an indicator of animal welfare [1], [2], and behavioral activity is used as a definition of animal comfort [3]. Good assessments of animal welfare consider animal functioning (good health, productivity), animal feeling (absence of pain, fear, stress), and animal behaviors that are as close as possible to natural behaviors [4]. The way in which a barn is constructed can allow or hinder animals' natural behaviors [5]. A free-stall barn system is a barn plan that contributes to the welfare of animals by allowing cows to perform their natural behaviors and offering them freedom of movement [6].

Indexes based on the time spent by cows in different activities (e.g., lying, standing, eating, drinking) have been used to assess animal welfare and animal comfort by several authors [3], [7]. Ref. [8], [9] reported that the longest resting behavior was observed in the spring and summer (12.12 h/24 h for the spring and 11.55 h/24 h for the summer in free-stall housing FHS). Ref. [3] and Ref. [10] reported that cows have average lying times ranging from 11.37 to 13.70 h/24 h. The lying behavior of cows in FHS is affected by design and management factors, including the freestall configuration and size [11], [12], freestall surface and bedding quality [6], [10], [13], stocking density [6], [14], freestall location [15], and pen flooring [8], [9], [16].

To evaluate the performance of the housing and management system used for a herd, observations of the behavior of the cows over a few days could be informative. In fact, the differences among seasons and the effect of external environmental conditions (e.g., temperature and humidity) affect the daily behavior pattern of the herd [17]. Researchers have reported that the environmental conditions in animal barns have significant effects on animal welfare [18]. Temperature [19], [20] and humidity [20] can significantly affect the behavior of animals [21]. THI (temperature humidity index) and lameness were also found to influence lying and standing time [22].

Methods used for assessing behavioral activity, i.e., the time spent in different activities such as lying, eating, or standing [1], have changed in recent years, favoring techniques that automate the sampling effort [23]. Human-based behavioral activity recording methods, such as direct observation and the analysis of video recordings, have drawbacks: both human- and video-based recording methods are often time-consuming and labor-intensive [23], [24]. However, behavior studies aiming to improve new barn designs appropriating animal welfare require the observation of dairy cattle behavior in different environments in the barn using video recording. Thus, the behavior of dairy cattle was evaluated by analyzing video recordings in this study.

Each behavioral sampling technique has specific strengths and weaknesses, and the technique to be used in a given study must be carefully selected based on the objectives of the study. The scan sampling interval is often chosen by the investigators for practical reasons and thus depends on the structure of the animal's environment, the number of animals to be sampled, and the need to conduct multiple observations in parallel [23]. Future studies on improving barn designs to promote animal

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comfort require the determination of daily cow behavioral activity and the development of SSFs that are easy to use, require short time periods, and are less labor-intensive.

The aims of this study were as follows: (1) to identify the SSF that best characterizes the daily behavioral activity of the dairy cows, (2) to investigate seasonal changes in cow comfort indexes (CCI, CSI, and SUI) at different scan sampling frequencies (10, 20, 30, 60 and 120 min); and (3) to investigate the seasonal variation of all of the phenotypes.

II. Materials and Methods

A. *Housing, Animals, and Management*

The study was conducted between November 2007 and March 2009 at a Holstein dairy cattle farm located in Konya (Turkey) with the aim of studying cow behavior indexes obtained using different scan sampling frequencies during different seasons. Of the 150 cattle on the farm, 70 were dairy cows and rest was heifers and calves. As a component of farm management, the animals were maintained in different pens based on milk yield. The paddock used in this study contained cows in the peak season of their lactation period. A total of 13-20 animals (autumn: 20, winter: 13, spring: 14, summer: 18) were maintained in this pen. Different cows were used each season. The animals were able to move freely in their pens.

The cows were kept in a FHS (with 4 lines of cubicles head-to-head). The dairy housing has open courtyard areas in the northwest and southeast areas of the lot (Fig. 1).

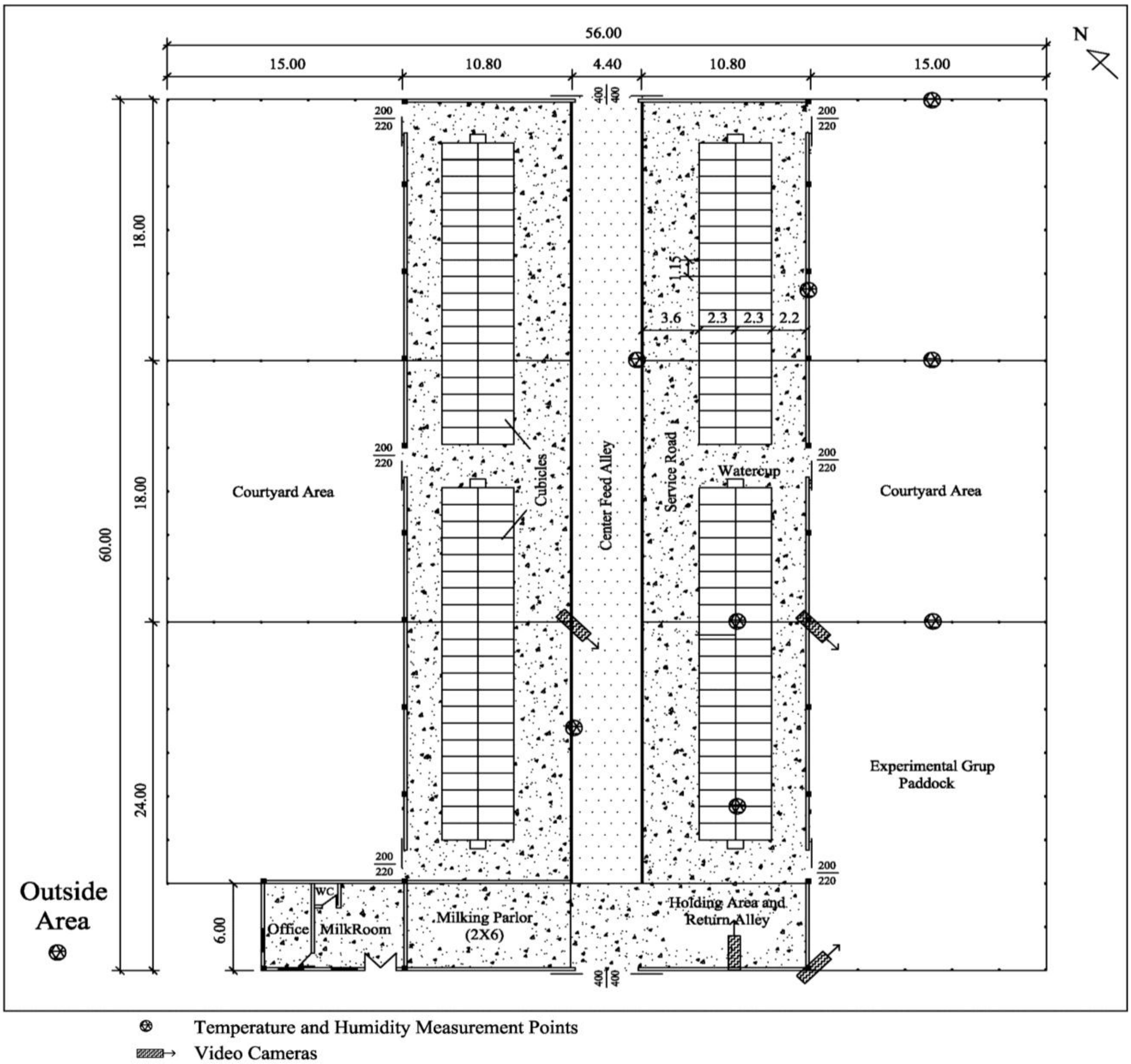

Figure 1. Plan of the free-stall dairy barn (distances in m) and measurement points for air temperature-humidity and video camera system

In the barn facilities, the freestall width, freestall length, neck rail height, neck rail distance from the curb, slope of cubicles (front-to-back), feeding length, courtyard area stocking density, and feed alley width were 1.15 m, 2.30 m, 1.10 m, 1.68 m, 2 %, 0.82 m per cow, 16.40 m2 per cow, and 4.40 m, respectively. The bedding surface of the freestalls was rubber. The stalls were cleaned once a week or twice a month.

The mean ± SD of number of lactation, milk yield, and number of days in milk were 1.7±0.4, 31.6±3.1 kg per d and 88.6±45.6, respectively. All animals in this study were fed with a mixture of corn silage and grass silage, concentrated feed, and hay supplemented with a concentrated feed. Feed was delivered to the animals twice a day, and the forage was swept to clean the feeding area twice a day. The animals were milked twice a day, at approximately 06.00 and 18.00 h.

B. *Climatic Data Collection*

Digital temperature-humidity meters (climatic devices; temperature measurement range: -40 ℃, +100 ℃, resolution: 0.03 ℃, precision: ±0.3 ℃; RH measurement range: 0-100 % RH, resolution: 0.4 %, precision: ±3 %, HoboPro Data Logger, Onset Computer Corporation, USA) were used to obtain climatic data for the commercial dairy farm. The climatic devices were located at 9 different points in three different areas of the farm: the rest areas, courtyard, and outside areas (Fig. 1). The devices were at a level slightly above the cow's height, as suggested in Ref. [25] and Ref. [26]. A detailed plan of the experimental facility, including the dairy barn and the measurement devices, is shown in Fig. 1. Climatic data were recorded hourly with a data logger. The operational timetable for the study, including the periods of observation and the number of cows observed during each period, is specified in Table I. The temperature humidity index (THI), which is widely used in the literature, was used to express together the temperature and the humidity. The THI was calculated for each barn area by averaging the data obtained from each data logger. The equation $THI = Tdb + 0.36 \times Tdp + 41.2$ was used to calculate the THI, where Tdb is the dry bulb temperature in ℃ and Tdp is the dew point temperature in ℃ [27].

The environmental conditions were evaluated in terms of the mean of the temperature and temperature humidity index (THI) for the enclosed areas (cubicles, service road, feeding area and watering area) and the courtyard area, with each data point recorded in 1-h intervals in each observation period for each season (4 seasons). To analyze the correlation between the cow behaviors and climatic data, Pearson bivariate correlation with a two-tailed test of significance was used.

C. *Observation Periods and Video Recording System*

The behaviors of the dairy cattle were recorded on seven predefined days each season. These observations included a total of 24 d, 576 h, and four seasons. A video camera system that allowed continuous recording was used for the observations. To analyze the behavioral activity of animals using different sampling frequencies, a 7-day video sequence pattern over a long-term (one-season) recording period was used according to [23]. The area preferences of dairy cattle were observed for 7 d per season (with four seasons in total; only 3 d of observations were possible in winter due to a power outage) using the methods described in previous research [23], [28], [29] (Table I).

TABLE I: THE PERIODS OF OBSERVATION OF DAIRY CATTLE BEHAVIOR AND THE NUMBER OF COWS OBSERVED

Season	Observation period	Number of cows in experimental paddocks	Number of hours analysed
Autumn	17-24 November 2007	20 cows	168
Winter	25-28 February 2009	13 cows	72
Spring	1-8 March 2009	14 cows	168
Summer	4-11 July 2008	18 cows	168

The data obtained from observation allowed for a detailed analysis of cow behavior. The video recordings ran for a full day. To eliminate the effects of variation among observers, all of the cattle behavior was evaluated by a single observer (S. Uzal). The barn area preferences of the cattle for daily activities (lying, standing, feeding, and watering) were noted individually on the barn plans and transferred to an Excel spreadsheet (Microsoft Corp., Redmond, WA) for each area.

A video recording system was placed in the barn to observe the animals' behavior (Aycan Alarm Security Joint Stock Company, Samsun, Turkey). The system included 4 digital color day/night vision cameras (1/3" Sony HQ1 color CCD, 752 (H) x 582 (V) pixels, minimum light sensitivity; Sony Corp., Taipei, Taiwan) and 1 portable 8-channel recording device (15" LCD display, 8 sensor inputs, 500 GB memory). Four cameras were placed in the outside and inside areas of the barn (2 cameras each). The cameras were linked to the recording device.

D. *Scan-Sampling Frequency*

The analysis of the video recording data comprised the evaluation of the number of cows engaged in different behavior activities (i.e., lying, feeding, standing). Standing was considered to be an upright posture (either motionless or walking), whereas lying only included cows that were observed in total lateral or sternal recumbency within the confines of a stall [1]. Additionally, lying behavior included only cows that were observed in total lateral or sternal recumbency within each area of the barn [6]. Feeding was defined as actively ingesting feed or water, or standing within 0.6 m of the feed bunk and oriented toward the feed ([1].

SSF defines the behavior that an animal displays during a stationary time interval. The behavior indexes of dairy cows were analyzed at scan intervals of 10, 20, 30, 60 and 120 min. The cow comfort index (CCI), cow stress index (CSI), and free-stall use index (SUI). The CCI is defined as the proportion of cows in stalls that are lying down [3]. The CSI was calculated as the number of cows observed standing (not lying and eating) divided by the total number of cows in the barn [23]. The SUI proportion of eligible lying cows was defined as total number of cows lying in free stalls divided by the total number of cows in the experimental paddock of the barn that were not eating or drinking during that time period [1].

E. Phenotypes

All phenotypes were analyzed using Minitab 14 [30] and a computerized spread sheet program (Microsoft Excel®). The mean values and standard errors (SE) of the mean for the three cow behavior indexes (CCI, CSI, and SUI) were obtained from observations taken at 10-min scan intervals during the observation period for each season. The daily mean of the behavior indexes was calculated for each observation day using all observations for each scan interval (10, 20, 30, 60, and 120 min). Pearson product correlations with a two-tailed test of significance for each season were used to correlate daily cow behavior indexes (CCI, CSI, and SUI) from scan samples (20, 30, 60, and 120 min) with 10-min scan sample observations using Minitab 14 [30].

III. Results and Discussion

A. Seasonal Variation of Scan Sampling Frequency

The Pearson correlation coefficients of the daily mean value of the behavior indexes (CCI, CSI and SUI) for each season (autumn, winter, spring, and summer; total 528 h) calculated using different SSFs (10, 20, 30, 60, and 120 min) are given in Table II.

TABLE II: Pearson Correlation Coefficients of the Daily Mean Value Of Behavior Indexes (Cci, Csi, And Sui) for Four Seasons (Autumn, Winter, Spring, and Summer; Total 528 H) Calculated with Different Ssfs (10, 20, 30, 60, and 120 Min)

Scan samples minute intervals between scans	Season		Behavioral index											
			CCI				CSI				SUI			
			10	20	30	60	10	20	30	60	10	20	30	60
	Autumn	20	0,999**	-	-	-	0,997**				0,998**			
		30	0,997**	0,996**	-	-	0,987**	0,989**			0,994**	0,988**		
		60	0,984**	0,980**	0,985**	-	0,977**	0,981**	0,987**		0,986**	0,981**	0,989**	
		120	0,991**	0,992**	0,983**	0,981**	0,870*	0,880**	0,897**	0,901**	0,977**	0,981**	0,966**	0,976**
	Winter	20	0,995				0,902				0,864			
		30	0,995	0,980			0,989	0,956			0,991	0,788		
		60	-0,999*	-0,991	0,998*		0,315	0,694	0,453		-0,341	0,179	-0,466	
		120	-0,814	-0,754	-0,870	0,833	0,683	0,931	0,784	0,909	0,624	0,932	0,512	0,522
	Spring	20	1,000**				0,947**				0,999**			
		30	0,999**	1,000**			0,962**	0,920**			0,999**	0,998**		
		60	0,999**	0,999**	1,000**		0,911**	0,951**	0,943**		0,997**	0,998**	0,998**	
		120	0,994**	0,995**	0,997**	0,998**	0,752	0,725	0,814*	0,866*	0,989**	0,991**	0,994**	0,997**
	Summer	20	0,980**				0,908**				0,931**			
		30	0,968**	0,988**			0,982**	0,905**			0,952**	0,982**		
		60	0,948**	0,964**	0,992**		0,921**	0,914**	0,954**		0,899**	0,975**	0,986**	
		120	0,912**	0,871*	0,887**	0,905**	0,683	0,648	0,607	0,562	0,945**	0,893**	0,931**	0,908**

N= 120 observations (24 days ×5 scan samples per season; 7 days for autumn, spring, and summer and 3 days for winter).
* Significant effect at P < 0.05.
** Significant effect at P < 0.01.
Pearson product correlations with a two-tailed test of significance were used to correlate the daily behavioral activity indexes (CCI, CSI, and SUI) from all scan samplings with 10-, 20-,30-, 60-, and 120-min SSF observations based on the daily averaged value.

The results show the close relationship between the behavior indexes obtained from the different SSFs for the four seasons. In autumn, spring, and summer, the 10-, 20-, and 30-min scan samples were highly correlated to the 60-min scan samples for the lying, standing, and feeding behaviors. In contrast, in the winter, the 10-, 20-, and 30-min scan samples were moderately correlated to the 60-min scan samples for CCI only ($r = -0.999$, $P < 0.05$).

For CCI, the 10-, 20-, 30-, and 60-min scan samples were highly correlated to the 120-min scan samples during autumn, spring, and summer ($r > 0.91$, $P < 0.01$). For CSI, the 10-, 20-, and 30-min scan samples were highly correlated to the 60-min scan samples during autumn, spring, and summer ($r > 0.91$, $P < 0.01$). In contrast, the relationship among all SSFs was not significant for winter. For CSI, the 10, 20, 30 and 60-min scan samples were correlated moderately to the 120-min scan samples in autumn only ($r = 0.870$, $P < 0.05$). For SUI, the correlation values are the same as the CCI values during autumn, spring, and summer ($r > 0.94$, $P < 0.01$), whereas the correlation values are same as the CSI value for winter.

The results showed that for cow behavior indexes (CCI, CSI, and SUI), SSFs lower than 120 min (10, 20, 30, or 60 min) were good predictors and were precise and accurate for measuring daily behavioral activities. For CCI, the 60-min SSF can also be a good predictor of daily activities during winter. However, for CCI and SUI, the 120-min SSF can be a good predictor of daily activities during autumn, spring, and summer. In the future research, the use of 60-min SSFs to determine cow behavioral activity will yield more accurate results because all of the behavior indexes were calculated using the same activity values of cow behavior. The finding that some activities, such as lying, feeding, and standing, can be properly interpreted using 60-min SSFs confirms the results of previous studies [7], [23], [26].

TABLE III: THE SEASONAL VARIATION OF VALUES FOR THE PEARSON CORRELATION COEFFICIENTS BETWEEN THE BEHAVIOR INDEXES (CCI, CSI AND SUI) OF COWS AND THE ENVIRONMENTAL PARAMETERS (THI; T, ℃) OBTAINED FOR THE EXPERIMENTAL DAYS

	Behavior indexes		Seasons			
			Autumn	Winter	Spring	Summer
Environmental parameters	CCI	$THI_{resting}$	-0,967**	-0,164	0,013	0,492
		$T_{resting}$	-0,958**	0,379	-0,818*	0,651
		$THI_{courtyard}$	-0,857*	-0,989	-0,869*	0,442
		$T_{courtyard}$	-0,880 **	-0,978	-0,893**	0,625
	CSI	$THI_{resting}$	-0,494	-0,849	0,005	-0,527
		$T_{resting}$	-0,611	0,711	0,074	-0,572
		$THI_{courtyard}$	-0,347	0,242	0,121	-0,654
		$T_{courtyard}$	-0,443	0,564	0,118	-0,734
	SUI	$THI_{resting}$	-0,931**	0,522	0,041	0,527
		$T_{resting}$	-0,929**	-0,319	-0,825*	0,684
		$THI_{courtyard}$	-0,792*	-0,652	-0,871*	0,438
		$T_{courtyard}$	-0,819*	-0,875	-0,901**	0,631

* Significant effect at $P < 0.05$
** Significant effect at $P < 0.01$

The values of the Pearson correlation coefficients between the behavior indexes (CCI, CSI and SUI) and the environmental parameters (THI and T ℃) calculated using data for all hours of the day (24 h) are given in Table III. The behavior indexes (CCI and SUI) were strongly correlated with the THI and T of the resting and courtyard areas during autumn and spring. However, CSI is not correlated with these behaviors and has a lower correlation coefficient than the other two indexes in this respect. The daily patterns of the cows' behavioral activity are not only influenced by THI and T but also by farm management.

B. Seasonal Variation of Cow Behavior Indexes Obtained from 10-min Scan Sampling Frequency

The seasonal variation of the mean values of the behavior indexes (CCI, CSI, and SUI) obtained from the observations at 10-min scan intervals is given in Fig. 2. The highest values for the CCI and SUI were observed during the winter, whereas the lowest values for these indexes were observed during the summer. The highest values for the CSI were observed during the summer, while the lowest values for same index were observed during the winter.

The highest value for the CCI was observed at night and midday, whereas the lowest values of this index was observed morning and before the afternoon milking in every season. The highest values for the CCI were observed during the night (between 02.20 and 04.40 a.m., range 0.86-0.97) at 04.30 a.m. (range 0.97) and had low variability in winter. The lowest value of this index (0.27) was observed before the afternoon milking (between 16.50 h and 17.10 h), and second lowest value was observed after the morning milking (during feeding time). This finding is explained by the fact that the barn doors were closed from the afternoon milking to the end of the morning feeding. Therefore, the cattle were forced to use the freestall instead of the courtyard for lying during this time. In addition to feeding times, the CCI values were low during the morning hours (between 09.00 and 10.00 a.m., range 0.22-0.27) and afternoon (near 03.00 p.m., range 0.30-0.35). This result reflects the dairy cattle's preference for walking and lying in the courtyard instead of lying in the freestall during this time period.

In summer, the highest value for the CCI was observed at 12.00 a.m. (range 0.15). The highest values for the same index were observed during midday, just as in autumn and spring. At noon, the courtyard area was directly exposed to the sun. Because there was no shade in this area, the cows preferred to lie in the stalls in the closed areas, which furnished shade. The values of this index were zero at night, in the evening, and before afternoon milking because dairy cattle prefer lying in the courtyard area, an open area with ground floor, during these parts of the day in summer. Ref. [31] analyzed cow behavior in shaded and unshaded barn conditions and reported that the cows kept in the shade had longer resting times. Ref. [21] reported CLI (equivalent to the CCI) values of 0.54 for August, 0.64 for October, 0.65 for December, and 0.80 for January.

The highest values for the CSI were found after the morning feeding and before the afternoon milking (i.e., approximately during the daytime period), whereas the lowest values of this index were observed during the evening and night periods for each season (Fig. 2). When each season was evaluated separately for the CSI, the highest values were found for winter (range 0.03-0.95), whereas the lowest was found for the summer (range 0.00-0.63). However, the CSI values obtained for the summer during the daytime period are higher (range 0.20-0.60) than those obtained for other seasons, while those obtained for the summer during the evening and night periods are lower than those obtained from other seasons. This situation indicates that dairy cattle prefer using (e.g., lying, standing) the courtyard area. During the day, especially at noon, the courtyard area was directly exposed to the sun. Because there was no shade in this area, the cows preferred to use in the stalls in the closed areas, which furnished shade. Ref. [32] reported that cattle preferred to use shaded areas in the summer, even during cool days, and that they spent more time in these areas. Ref. [21] reported CSI values of 0.31 for August and 0.10 for January.

The highest SUI values were found for the winter (range 0.05-0.97), and the lowest values were observed during the summer (range 0.00-0.23). Additionally, the highest values were observed during the night and at midday (range 0.86-0.97) at 0400 a.m. (range 0.97), with low variability in winter. The decrease in the SUI values observed during the night and morning hours resulted from the doors of the barn being closed and the dairy cattle being prevented from passing through the courtyard area in the winter. In summer, the highest value for the

SUI was observed at 08.00 a.m. (range 0.23). The highest values for this index were observed during morning and midday, just as for the CCI. In this time periods, the cows preferred to use closed areas, which furnished shade, instead of the courtyard area, which was directly exposed to the sun. Ref. [21] reported SUI values of 0.61 for August, 0.73 for October, 0.78 for December, and 0.89 for January.

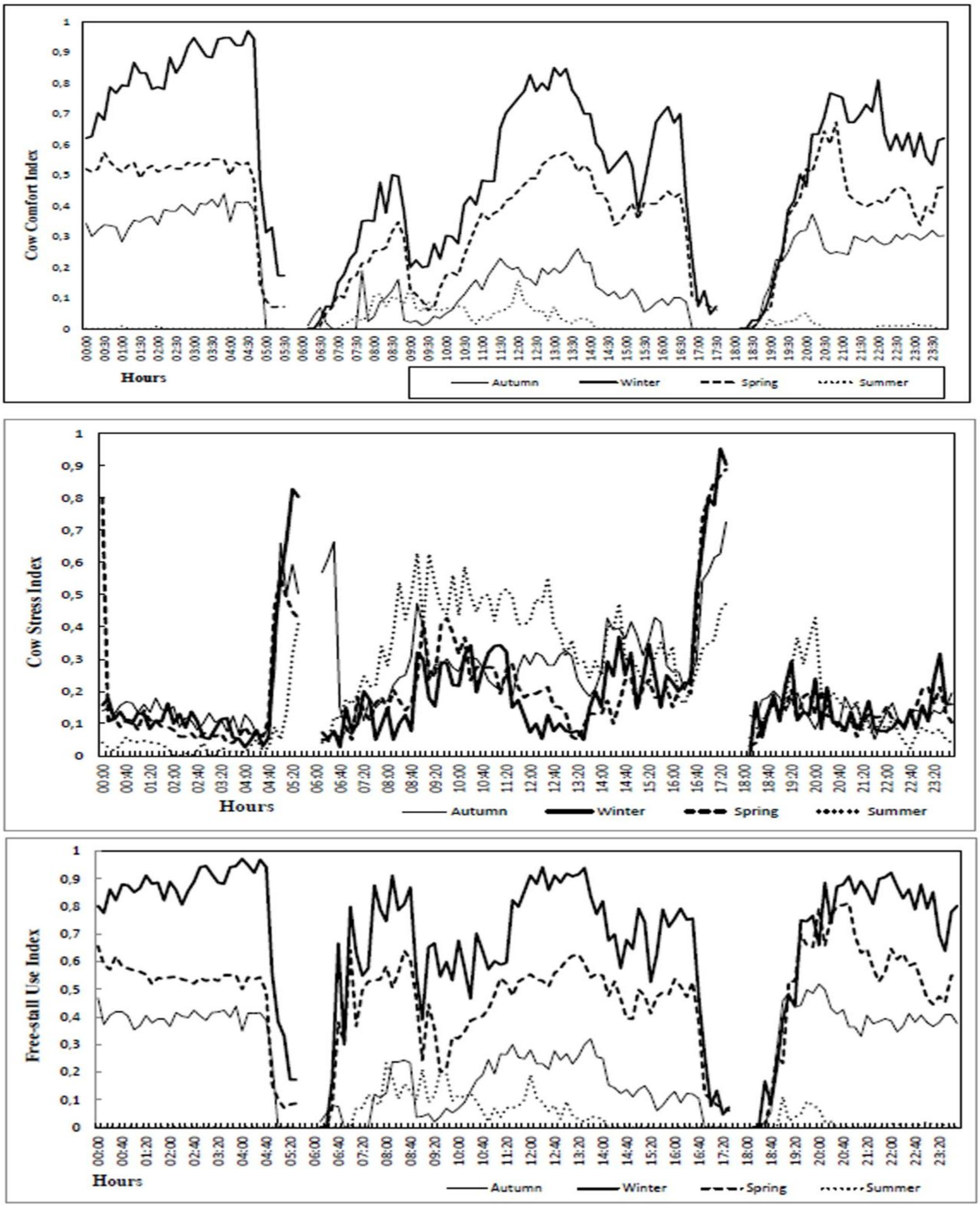

Figure 2. The seasonal variation of the mean values of the behavior indexes (CCI, CSI and SUI) obtained from the observations at 10-min scan intervals over experimental days

When the behavior indexes were evaluated for all seasons, the CCI values were inversely correlated with the CSI values, whereas the CCI and SUI values were linearly related (Fig. 2). The apparent discrepancy is a result of the tendency of the cattle to prefer the courtyard area to the stalls for resting during warm periods in this barn system. This result indicates that the CCI and SUI values obtained from this study are high in the winter and low in the summer

IV. CONCLUSIONS

Behavior studies require large amounts of time and are labour-intensive. Therefore, developing a scan sampling frequency (SSF) appropriate for the specific research subject improves the efficiency of such studies as well as improving economy of time and labor, consuming behavior study. A 60-min SSF can be used to accurately determine behavior indexes indicative of animal welfare. Moreover, 60-min SSF can also be used to observe the daily lying, standing, and feeding behavior of individual animals and determine the behavior of the herd. Contrary to previous studies, this study determined that 120-min SSF can be used to accurately calculate CCI and SUI values for all seasons except winter. These results provide economy of labor and time costs for future studies, especially new barn design studies seeking to provide appropriate dairy cattle welfare.

According to behavioral indexes obtained from 10-min scan sampling, when the dairy cattle were free to move to the courtyard, they preferred to use the courtyard for lying and standing during all seasons. Thus, the development of a new behavioral index for dairy cattle in barn systems with a courtyard or open area, as dairy cattle prefer to use courtyard areas, is very important to accurately and efficiently assess animal welfare. Therefore, all areas in the barns should allow the animals' comfortable movement. In addition, well-designed barn areas will be advantageous for animal comfort.

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