ASSESSMENT OF PRIOR GRAZING EXPERIENCES ON ADAPTATION TO PASTURE AND PERFORMANCE OF DAIRY HEIFERS AS LACTATING COWS

By

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CHAPTER 1

REVIEW OF THE LITERATURE

Introduction

Research with feeding behavior of dairy cattle has been extensively studied for years to determine the factors that influence the forage intake of grazing dairy cows. It is already known that pasture quality and yield (Gregoret, 2002, Kammes, 2007) the amount and type of supplement fed (Reis and Combs, 2000a; Reis et al., 2001), as well as sward structure and density (Kammes, 2007) can affect the intake from the pasture. Another factor that may influence intake, but has not been tested in dairy cattle grazing high quality pastures, is learned behavior. Many dairy grazing trials at university research stations utilize animals that are usually housed in confinement. Whether cows normally raised in confinement can graze as efficiently as cow that continuously are managed in a grazing system is unclear. This question have been raised by producers and scientists who observed that cattle and sheep learn to select specific forages, remember experiences from early pasture exposure, and specific forages and forbes (Flores et al., 1989, Distel and Provenza, 1991). Research shows that experience obtained as a young animal affects diet selection, grazing behavior and animal productivity months or years later (Hatfield et al., 1992, Ortega-Reyes and Provenza, 1993). However, most of the research has been conducted on rangeland grazing systems, where animals are exposed to toxic plants as well as forbes and grasses that vary greatly in nutritional value. Provenza (1995) reported that ruminants are exposed to pasture and acquire foraging skills at an early age graze more efficiently than animals that have not been exposed to pasture. There are only a few behavior studies with high producing cows under practical or production conditions (Bargo et al., 2003), probably because animal behavior is usually tracked by visual observation that requires significant labor and is susceptible to error. In the 1990s research with grazing behavior started to use GPS (Global Positioning System) to monitor grazing activities (Schlecht et al., 2004). GPS has been extensively used in research with beef cattle to track movement; distance travelled and speed. With GPS it is possible to define the animals' activity in the pasture and grazing preferences exhibited by individual animals in the pasture (Schlecht et al., 2004). In dairy grazing studies GPS collar devices have been used to measure jaw movements and animal activity; although, this type of equipment is very expensive, and has limited the number of grazing trials with large numbers of animals.

Our objective in this study, was to answer the questions that would impact facility design and the focus of dairy grazing research at the University of Wisconsin, thereby making it more applicable to grazing-based dairy producers. Specifically, we wanted to assess how dairy cattle adapt to grazing, and whether grazing experiences at a young age influence subsequent grazing behavior as a lactating cow. The following review of literature is offered to provide an overview of present knowledge about grazing behavior correlated with factors that affect animal production and the use of GPS to monitor animal activities.

Grazing behavior correlated with factors that affect animal production

Interest in studying the grazing behavior of dairy cattle increased in the mid 1950s, when Hancock (1950, 1954) conducted animal behavior research with cattle twins in pasture. According to Hancock (1950, 1954) it was necessary to develop research to investigate the effect of varying environmental conditions (unexpected weather, seasonal changes in pasture quality and quantity, and differences in management of pasture and stock) on the behavior of grazing animals. During the ‘60s and ‘70s more attention was given to understanding the interaction between the behavior of grazing animals and the environment in which they live. This interaction can have profound effects on both the environment and animal production (Arnold and Dudzinski, 1978).

Cattle have a distinct diurnal grazing pattern, which includes a major meal beginning approximately at sunrise. According to Albright (1993) cattle are crepuscular, meaning that they are most active at sunrise and again at sunset. Thus, nighttime grazing represent a small percentage of the total daily grazing time and contributes minimally to the daily forage intake (Stockdale and King, 1983). However, air temperature and relative humidity can affect the daily routine and production of grazing animals. Usually, in high temperatures time spent grazing is reduced (Arnold and Dudzinski, 1978). Factors connected to environment are expensive and difficult to control when working with grazing animal. Thus, the focus in dairy grazing research has been to improve the feed quality to increase the DMI and achieve high milk production.

Dairy cattle grazing high quality pastures frequently fail to achieve their production potential because voluntary intake is usually lower than what may be achieved when offering conserved and processed feed (Kammes, 2007). In this case there are some factors that can be controlled by diet and pasture management. Three major factors have been extensively investigated to explain the low DMI from the pasture and how they may affect animal behavior in grazing systems.

1. Sward structure and density

2. Amount and type of supplement fed

3. Pasture quality and yield

Another factor that has been discussed, but little information is available, is early grazing experience and the affect that experience can have on animal production later on life. It will be the fourth factor discussed in this review.

4. Early dietary experience and animal behavior

Sward structure and density

Cattle respond to grazing management and variations in herbage mass and structure by varying the time spent grazing, bite rate, bite size or mass, time spent at feeding station, and time spent selecting bites or feeding stations (Walker and Heitschmidt, 1989). According to Gibb et al (1996) each successive reduction of 1 cm in sward surface height results in a reduction in bite mass (product of intake per bite), as shown by data measured using lactating dairy cows grazing under steady sward state conditions (Figure 1). When pasture is short or low biomass (cm), more time will be spent grazing and the number of bites per minute (bite rate) will increase; but, the intake (bite mass) per hour will decrease (Arnold and Dudzinski, 1978; Rook et al., 1994; Gibb et al., 1997). The effect of bite mass on bite rate for lactating dairy cows is shown on Figure 2. Stobbs (1973) suggested that bite size and rate are more important and accurate evaluations of grazing behavior than grazing time and Arave and Albright (1981) reported that milk production is linearly related to bite size

Dairy grazing behavior and the effects of sward height on intake were studied by Gibb et al (1996). In this study the decrease in intake rate was caused by short sward heights (Figure 3). In response to the reduction in short-term intake, cows increased the time spent grazing over 24 hours (Figure 4). Nevertheless, the increase in time grazing usually is insufficient to fully compensate for the reduction in short term intake rate, because of the competing demands of ruminating and idling activity. However, providing tall sward it is not the solution of the problem. Penning et al (1994) reported that the mass of herbage within grazed horizon is likely to have a more profound effect on bite mass than the surface height per se. Hence, it is important to maximize the green leaf mass by providing dense, leafy swards to enable the grazing animal to achieve large bite mass. Mayne et al (2000) showed that at the same sward surface height, improving sward density can profoundly increase bite mass (Figure 5) particularly in the medium height range of 8 to 16 cm sward surface height. On taller swards the effect of sward density on bite mass will be less important, because it is difficult to maintain the number of the tillers per unit area and the bulk density of the material within the grazing horizon (Gibb et al. 1996).

These studies demonstrate that the major factor that influences pasture intake is the amount of herbage per bite. Therefore, it is important to understand the forage dynamics to manage it appropriate in order to optimize milk production.

Amount and type of supplement fed

Supplement feeding is normal practice adopted by grazing farms in the US. Usually the supplement provides a source of additional energy to maximize milk yield. Studies with dairy cows showed that increasing the amount of concentrate reduced grazing time but did not affect bite rate (Bargo et al., 2003). Arriaga- Jordan and Holmes (1986) found that grazing time was reduced 11min/kg of concentrate in a rotational grazing system, but the amount of supplementation did not affect the bite rate. The same results were reported by Kibon and Holmes (1987) who also found that the type of supplement or pasture height did affect the bite rate but the bite mass was lowered by lower pasture height.

The relationship between supplementation and grazing behavior of dairy cows were investigated in the review by Bargo et al (2003). These studies show that concentrate supplementation did not affect bite rate or bite mass, but did reduce grazing time (Table 1). They also reported that average grazing time for unsupplemented cows is 578 min/d and grazing time is reduced by 12min/d for every kilogram of concentrate (see review by Bargo et al, 2003). Bite rate and bite mass were not affected by supplementation, and these were the most important factors regulating DMI. It is beneficial to use concentrate supplementation in the grazing systems, because it has a tendency to increase milk production and it is source of energy for ruminal micro-flora growth.

Pasture quality and yield

Forages are a major component of dairy rations in both confinement and dairy grazing operations. Field and pastures used to produce forages for dairy cows should provide consistent forage production and persistence throughout the growing season; it will result in high milk production per cow and milk yield per hectare of land (Kammes, 2007)

In 1954, Hancock studied the grazing behavior in relation to grassland management. This study was a big step to understand that quantity and quality of the herbage offered are important in modifying the grazing behavior of dairy cattle. He observed the grazing behavior of cows over four separate fortnights. With this trial, it was possible to indicate the general pattern of the relationship between grazing behavior and quantity and quality of pasture, as show at Figure 6. Hancock (1954) noted that working time (grazing + ruminating) increased under adverse pasture conditions. The same results were found by (Phillips and Leaver, 1986; Bargo et al., 2003). Few studies, have examined the relationship of dairy cow behavior in relation to pasture quality and yield, almost the studies investigated the animal production.

Early dietary experience and animal behavior

Early experience and subsequent behavior have not been studied extensively in dairy cattle, especially on grazing rotational systems with high quality pastures. Most of the research about early experience in life has been conducted with sheep and goats grazing rangeland pastures. According to Provenza and Balph (1988) foraging behavior is determined in part genetically and in part through learning. In addition, learning involves changes in foraging behavior and on neurological, morphological and physiological systems.

In the neurological system, animals process the information about food through 2 interrelated systems: affective and cognitive (Garcia, 1989). According to Figure 7, taste plays a prominent role in both systems. The effective system integrates the taste of food with postingestive feedback (Provenza et al., 1992). This system causes changes in the intake of food items that depend on whether the postingestive feedback is aversive or positive. On the other hand, the cognitive system integrates the odor and sight of food with its taste. Animals use the senses of smell and sight to differentiate among foods, and to select or avoid foods whose postingestive feedback is either positive or aversive. Together, affective and cognitive process provides flexibility for animal to maintain homeostasis as their nutritional needs and environmental conditions change (Provenza et al., 1992).

The anatomical and physiological mechanisms underlying effective and cognitive system have been established by Garcia and Holder (1985). Taste afferents converge with visceral afferents in the solitary nucleus of the brain stem. For example the taste of food is adjusted according to that food's effect on the internal environment. Animals use thalamic and cortical mechanisms to select foods that are nutritional and to avoid those that are toxic. In addition, herbivores have physiological mechanisms to counter phytotoxins. The mechanisms include: (1) binding the compound before it can exert its action, (2) metabolizing the compound so it cannot exert its action, and (3) tolerating the compound.

But if the capacity of these detoxification systems is exceeded, mammals become ill and died (Garcia and Holder, 1985). Mammals usually adjust intake to avoid intoxication (Provenza, 1995).

Morphological system changes are directly correlated with physiological mechanism (Provenza et al., 1992). An example is how animals respond after ingesting certain toxins. Consumption of some potentially harmful phytochemicals results in a systemic change within the animal which causes the compound to be bound before the toxin can exert its action (Provenza et al., 1992). For example the size of parotid salivary glands, and their production of proline-rich proteins, increase in response to diets high in tannins in rats (Mehansho et al., 1983). Also, when animals are exposed to certain toxins, the animal may induce metabolic pathways that ability to metabolize the compound. In ruminants, the response involves organs such as the liver and rumen, as well as rumen microbes (Smith, 1992). The liver can decrease the toxicity of compounds absorbed from the gastrointestinal tract by increasing or decreasing enzyme production or by increasing growth of the entire organ (Schulte-Hermanm, 1979). In addition, rumen tissue mass and volume are significantly greater when goats are reared on a poorly nutritious shrub (blackbrush) than when they are reared on a nutritious diet (alfalfa and calf-manna) (Distel and Provenza, 1991).

According to Provenza and Balph (1998) changes in dietary habits are modulated by foraging environments; and experiences early in life may affect dietary habits as adults. Three mechanisms were reported by Provenza and Balph (1988) to explain how young herbivores learned to select appropriate foods efficiently in their environment. The first learning mechanism is **Food Imprinting** that occurs during a sensitive period, learning during this period tends to be persistent (reviewed by Hess, 1973). In ruminants this mechanism occurs during the transition from monogastric to ruminant (Provenza and Balph 1987), and when the young learn from their mothers (Hinch et al., 1987). According to Provenza et al. (1992) and Ramos and Tennessen, (1992), young herbivores learn more efficiently when they learn with their mother which food to eat and which to avoid. However, few studies suggest that weaning is the period during which the ruminants learn about food most efficiently (Squibb, 1988). In addition, after weaning and during the first year of life, desire to consume a novel food is decreased, and also in mature animals it is more difficult to introduce a new food than to young animals (Lobato et al, 1980). It is unclear the whether the effect of experience with food early in life can affect the animal as adult.

The second mechanism proposed is **Social Learning** that is defined as learning about foods from social models and through trial and error by young livestock (Provenza and Balph, 1988). Trial-and-error learning should be favored in environments where the nutritional value of plants is extremely variable temporally and spatially (Provenza and Balph, 1987). It is because grazing animals have the ability to identify plants of different species through development of grazing skills (Flores et al., 1989) and by memorizing the distribution of resources that are essential to adapt to the environment (Dumont and Petit, 1998). Social models usually apply where moderate variability in nutritional value of plants exists, because social models provides for a measure of flexibility in feeding behavior with less risk of error than does trial and error learning (Provenza and Balph, 1988). According to Bandura (1977) the best models to predict social learning are nurturants (e.g. mother) and respected peers (e.g. dominant group member), this learned information can be transferred from generation to generation. Ramos and Tenessen (1992) exposed two groups of lambs; one group before weaning, and the other group after weaning to graze with their dam during 7 days to compare with an inexperienced grazing group. During the fourth week after weaning they compared the grazing time among groups during 5 days (30 min/d). In this study, no difference was found between group exposure to grazing before or after weaning, but those groups had longer grazing bouts and grazed for almost twice as long than the inexperienced group. Similar results were found by Thorhallsdottir et al (1987a) when lambs of 4 to 8wk of age exposed to foods with their mother consumed about twice as much of those foods after weaning, than lambs exposed with another adult ewe. Also, lambs exposed with an adult ewe consumed about twice as much as lambs exposed alone. However, it is not clear how long the effect of social learning remains with those animals and how much this can affect the animal production.

The third and final learning mechanism is **Individual Learning**. Individual Learning is the process which a young animal develops preference for certain foods as a result of experience with sensory, nutritional and physiological consequences of sampling particular dietary items (Arnold and Maller, 1977; Provenza and Balph, 1988). According to Booth (1985), young herbivores learn which foods are nutritional by developing preferences for foods based on beneficial nutritional consequences or they develop aversions to nutrient-deficient and toxic plants. Some authors reported that young herbivores, such as a goats, can remember food with either aversive or positive (Distal and Provenza, 1991) postingestive consequences for at least 1 to 3 yrs. Hence, individual animals should be able to seek and ingest foods that correct specific nutritional deficiencies (Provenza and Balph, 1987). Therefore, in same grazing environment inexperienced sheep (Arnold, 1970; Arnold and Maller, 1977; Gluesing and Balph, 1980), cattle (Hodgson, 1971; Hodgson and Jamieson, 1981) and goats (Provenza and Malecheck, 1986) may graze 40% less than experienced animals (Provenza and Balph, 1987).

These studies demonstrate there are many variables that may affect the efficiency of learning and the persistence of dietary habits. More research is need to investigated the effect of early dietary experience in life may affect adult animal performance. Since the duration of exposure to a food early in life may not be related linearly to intake of that food later in life (Ortega-Reyes et al., 1987).

Global positioning system (GPS) to monitor animal activities

Manual observations tend to be momentary observations in a discrete time point which are then converted to either discrete variables (grazing = yes, not grazing = no) or transformed into continuous variables (hours or period of true grazing vs. not grazing). When using manual observation it is difficult to track certain behaviors such as total distance walked, number of times the animal moved, and patterns or sequences of movements.

Various devices which automate recording of grazing behavior have been developed; these devices measure general and specific aspects of behavior, such as head or body position, walking speed, and animal location (Gordon, 1995). GPS is commonly used for tracking the movements of wild animals but has just recently become a way of studying cattle and other domestic animals (Agouridis et al. 2004). In the 1990s the University of Kentucky began incorporating information from GPS collars into cattle management practices (Agouridis et al., 2004). GPS-collars allowed researchers to evaluate animal pasture utilization, animal performance, and behavior of grazing cattle by taking animal behavior measurements with greater precision (Turner et al. 2001). GPS devices used in research enable scientists to assess pastures or paddocks design, including: shapes and sizes, fence designs, grazing systems, soil type, location of shade, water, and supplements, and other variables involved in cattle operations (Turner et al. 2001). The combination of GPS and geographic information systems (GISs) can relate animal distribution and movement to different features in a landscape (Ungar et al. 2005); this has been done with sheep (Hulbert et al. 1998) and cattle (Agouridis et al., 2004).

Rutter et al (1997) conducted a trial to measure the grazing behavior of free-ranging cattle with an automatic microcomputer-based system for the digital recording of jaw movements. Animals were monitored for 18 h during daylight hours in the UK. Foraging behavior (eating, ruminating or other behaviors) was recorded by the automatic microcomputer and by 11 different observers at 5 min intervals. The automatic recordings of grazing behavior were compared with those recorded by manual observations. The overall index of concordance of the GPS data and manual observations was 91%. Manual observations and GPS data are presented on Table 2. Rutter et al (1997) were disappointed by a 91% index of concordance for the automatic recordings. However, automatic systems recorded far more details than manual observations (Penning, 1994), of the three categories of behavior, 'other' has the lowest index of concordance because the observer recorded 'other' behaviors but the automatic system recorded it as ruminating (Rutter et al., 1997).

GPS-collars that record dairy cow jaw movements are expensive precision instruments. Such devices are often very costly and impractical when the goal is to monitor large number of animals to increase the power of the experiment (Maruyama and Nihei, 2007). There are some low-cost handheld GPS units available that can be used to track animals, a disadvantage is that battery life is low and changing batteries is difficult compared to GPS-collars. On the other hand, low-cost GPS units are a compacting size and lightweight. GPS has the ability for near continuous recordings with data updated at one second intervals. According to Schlecht et al (2004) errors in GPS data are mainly from the slowing down of the satellite radio signal during its way through the ionosphere and troposphere and signal reflection by local obstacles.

Schlecht et al (2004) conducted a trial to validate low cost GPS units combined with equipment (external antenna) for monitoring animals. They used the GPS information to calculate the distance travelled and the speed of travel. Speed should be zero for a resting animal, and higher for an animal changing location through large directional movement, and intermediate when the animal is moving between feeding stations. Schlecht et al (2004) monitored 14 Zebu (*Bos indicus)* cows during each measuring period, the itineraries of each animal were recorded on three consecutive days every 10s during daylight. An observer also followed each animal every 5 min, and a muted signal from a clock synchronized with the GPS clock prompted the observer to instantaneously record the animal's activity at that moment. The GPS-derived hourly activity profile compared reasonably with the hourly activity profile calculated for 30 itineraries from the observation data (Figure 8). The difference between the GPS-based estimate and the observed hourly fraction of time spent on each of the three activities (walking, grazing and resting) ranged from to 0.4-8.1 min, resulting in a cumulative failure estimation of 3.2-16.2 min per hour. GPS and manual observation data are presented on Table 2.

Low cost GPS units have been used often in grazing studies with beef cattle to monitor pasture use, to track animal routes, and to improve cattle management. Studies with dairy cattle in rotation grazing systems have used GPS-collars to report dairy cow jaw movements. However, as was shown by Schlecht et al (2004) it is possible to explore low cost GPS combined with other devices to monitor dairy cattle grazing behavior. Table 2 shows animal grazing activities recorded with different devices.

Adaptation period in grazing study

Cows are creatures of habit and thrive on routine, they are quick to adapt and learn the condition imposed (Albright, 1987). According to Albright's (1987) observations, cows managed in confinement and pasture spend 2 to 3 days to adapt to a new system of management. On the other hand, when animals switch from one ration to another, the period of microbial adaptation may vary from between 3 days to 3 weeks (Grubb and Dehority, 1975). This period can be defined as that time interval required for rumen microbial populations to stabilize (Van Soest, 1963). Grubb and Dehority (1975) investigated the changes in bacterial and protozoan concentration that occur in the rumen of sheep during an abrupt change from a ration of all orchardgrass hay to one containing 60% cracked corn and 40% orchardgrass hay. They found that after 5 days ration digestibility was stabilized, but continuing changes were observed in viable bacterial concentrations; these continuing changes appear to not have major significance on overall digestion in the animal. Another study of changes in rumen microbial concentrations of a single sheep found that when the diet changes from roughage to a concentrate ration at a fixed level of intake, 10 days was required for microbial changes occurs and concentration stabilized (Waener, 1962).

At the University of Wisconsin grazing studies are conducted with a 14 day adaptation period before starting to sample. This period of adaptation appears appropriate and essential, considering the studies cited above regarding rumen and animal adaptation periods.

The objectives of this thesis are to evaluate the learned grazing behaviors between cows raised in confinement in relation to the cows' exposure to grazing systems since weaning; if prior grazing experience is an important factor that effects grazing efficiency, research facilities and experimental protocols will need to be designed to allow animals to learn to graze efficiently.

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Table 1. Effect of supplementation on grazing time (GT), biting rate (BR), and bite mass (BM) of dairy cows (Bargo et al., 2003)

	Cows			Supplement		GT	BR	Total	BM
References	DIM	Milk	Pasture	Type	DMI, kg/d	min/d	bites/min	bites/d	g DM/bite
Arriaga-Jordan and Holmes, 1986	72	37.8	RG (rotational)[4]	Barley	1	467[a]	64[a]	30,000	0.53 g OM/bite
					6	424[b]	62[a]	26,100	0.58
			RG (continuous)[4]	Barley	1	525[a]	75[b]	39,400	0.47
					6	471[b]	75[b]	35,100	0.48
Bargo et al., 2002a	101	45.8	OG	Corn	0.8	609[a]	56	34,419[a]	0.55
					8.6	534[b]	54	28,501[b]	0.55
					0.7	626[a]	56	35,235[a]	0.60
					8.7	522[b]	55	28,563[b]	0.59
Delagarde et al., 2002	156	25.0	RG (0 kg N/ha)[5]	Control	0.0	510	54	27,300	0.47[a] g OM/bite
				Soybean meal	2.0	519	56	29,100	0.48[a]
			RG (60 kg N/ha)[5]	Control	0.0	546	54	29,000	0.53[b]
				Soybean meal	2.0	517	54	27,900	0.54[b]
Gibb et al.,	52	30.1	RG	Barley	0.0	591	57	32,967	0.32 g OM/bite
					1.2	610	60	35,800	0.33
					2.4	605	60	35,067	0.31
					3.6	610	59	32,333	0.33
					4.8	588	61	34,933	0.24
					6.0	572	61	33,400	0.29
Kibon and Holmesm, 1987	75	32.4	RG (5 cm)[6]	Control	0	596[a]	78	47,000[a]	0.32[a]
				Cereal	3	571[b]	77	44,000[b]	0.36[a]
				Beet-pulp	3	559[a]	77	43,000[b]	0.35[a]
			RG (6.5 cm)[6]	Control	0	585	76	45,000[a]	0.39[b]
				Cereal	3	550	76	42,000[b]	0.39[b]
				Beet-pulp	3	560	76	43,000[b]	0.40[b]

Continued on next page

Table 1. (continued)

	Cows			Supplement					
References	DIM	Milk	Pasture	Type	DMI, kg/d	GT min/d	BR bites/min	Total bites/d	BM g DM/bite
Rook et al., 1999	48	NA[7]	RG/WC (4 cm)[6]	Control	0	765[a]	62	NA	0.28
				Gluten corn/beet pulp	4	553[b]	45	NA	0.51
			RG/WC (6 cm)[6]	Control	0	651	47	NA	0.52
				Gluten corn/beet pulp	4	660	61	NA	0.33
			RG/WC (8 cm)[6]	Control	0	639[b]	53	NA	0.54
				Gluten corn/beet pulp	4	606[b]	52	NA	0.58
Sayers, 1994	207	NA	RG	Control	0.0	512[a]	51	25,814	0.39
				Soybean meal (10)[5]	2.6	537[a]	46	24,724	0.44
				Soybean meal (18)	2.6	476[a]	47	21,862	0.42
				Soybean meal (26)	2.6	507[a]	50	25,092	0.43
				Soybean meal (34)	2.6	528[b]	48	24,998	0.42
				Soybean meal (10)	5.2	491[b]	47	22,997	0.40
				Soybean meal (18)	5.2	477[b]	45	22,231	0.43
				Soybean meal (26)	5.2	453[b]	45	20,826	0.44
				Soybean meal (34)	5.2	469[b]	47	22,082	0.48
Sayers, 1999	40	NA	RG	Barley/Wheat/corn	5	458[b]	NA	21,302[b]	0.61
				Barley/wheat/corn	10	358[d]	NA	16,041[d]	0.58
				Beet pulp/citrus pulp	5	480[a]	NA	22,744[a]	0.60
				Beet pulp/citrus pulp	10	398[c]	NA	17,825[c]	0.61

[a, b, c, d] Means within reference with difference superscript differ ($P< 0.05$). [1] Pre-experimental DIM and milk (kg/d). [2] RG = perennial ryegrass *(lolium perenne);* OG = orchardgrass *(Dactylis glomerata)*; WC = white clover *(Trifolium repens).* [3] Main source of energy or protein in the supplement. [4] Grazing system. [5] Fertilization amount. [6]Pasture height. NA = Not available. [S] % CP of the supplement.

Table 2. Animal grazing activities recorded by different methods

	Record methods	Animal and grazing system	Total daily grazing time (min)	Time grazing (min)	Rumination (min)	Walking (min)	Resting (min)	Other behaviors (min)
Stobbs (1970)	Vibracords (Kienzly, W. Gemany)	Lactating Jersey Tropical grass legume pasture	594[a]					
Clastle et al (1975)	Vibracorders via a pendulum	Dairy cows Rotation system System of set stocking	 559[b] 638[c]					
Cowan (1975)	Manual observation	Lactating Friesian Tropical grass legume pasture	600[d]					
Hancock (1954)	Manual observation (24 h recorded)	Holstein cows Intensive grazing system Pastures temperate climates	413		383	293	351	
Rutter et al (1997)	Jaw movements recorder (mean time 18 h)	Dairy cattle Free-ranging cattle		350	100			218
Rutter et al (1997)	Manual observation (mean time 18 h)	Dairy cattle Free-ranging cattle		94	368			260
Schlecht et al (2004)	GSP-collars Recorded at daylight (9 h/d)	Zebu cattle Rangeland		304		113	123	
Schlecht et al (2004)	Manual observation Recorded at daylight (9 h/d)	Zebu cattle Rangeland		318		108	115	

[abcd]Total daily grazing time (min) represents the time spent grazing + pattern of grazing.

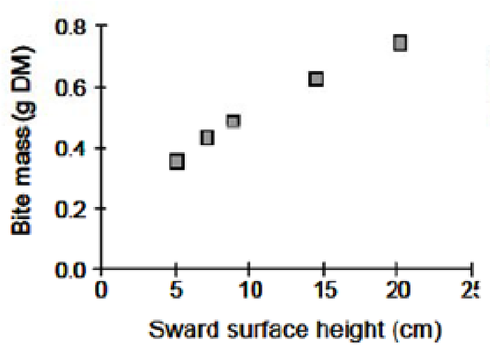

Figure 1. Effect of sward surface height on bite mass by lactating cows (Gibb et al., 1996).

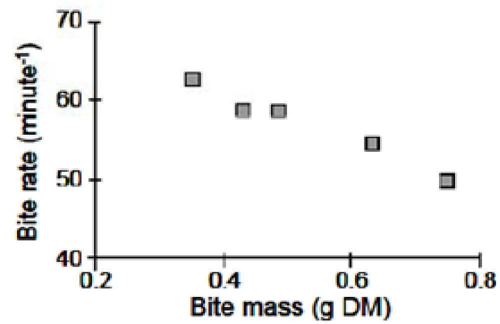

Figure 2. Effect of bite mass on bite rate by lactating dairy cows (Gibb et al., 1996).

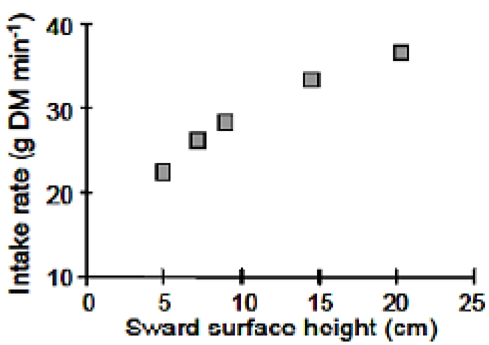

Figure 3. Effect of sward surface height on short-term intake rate by lactating dairy cows (Gibb et al., 1996).

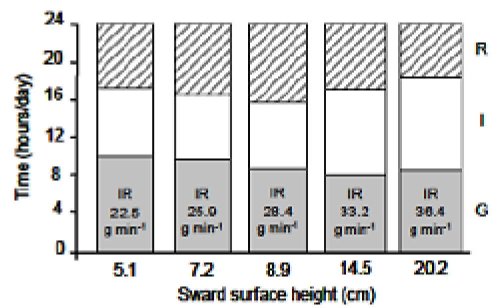

Figure 4. Effect of sward surface height and constraint on short-term intake rate on time spent grazing (G), idling (I) and ruminating (R) by lactating dairy cows (Gibb et al., 1996)

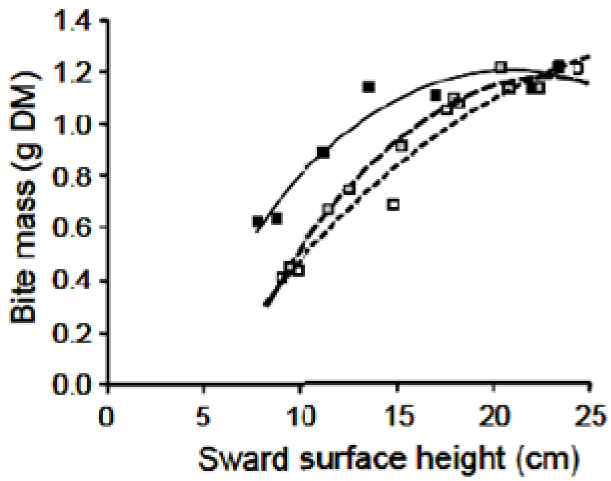

Figure 5. Effect of sward surface height on bite mass in sward of high ■ , medium ▢ and low □ density (Mayne et al., 2000)

1st fortnight → Quantity, abundant = Short grazing times
→ Quality, excellent = Short ruminating times

2st fortnight → Quantity, abundant = Long grazing times
→ Quality, mixed = Long ruminating times

3st fortnight → Quantity, scanty = Long grazing times
→ Quality, rather poor = Fairly long ruminating times

4st fortnight → Quantity, scantly = Long grazing times
→ Quality, good = Short ruminating times

Figure 6. Relationship between grazing behavior of dairy cows and quality and quantity of pasture occurred over the four fortnights (Hancock, 1954).

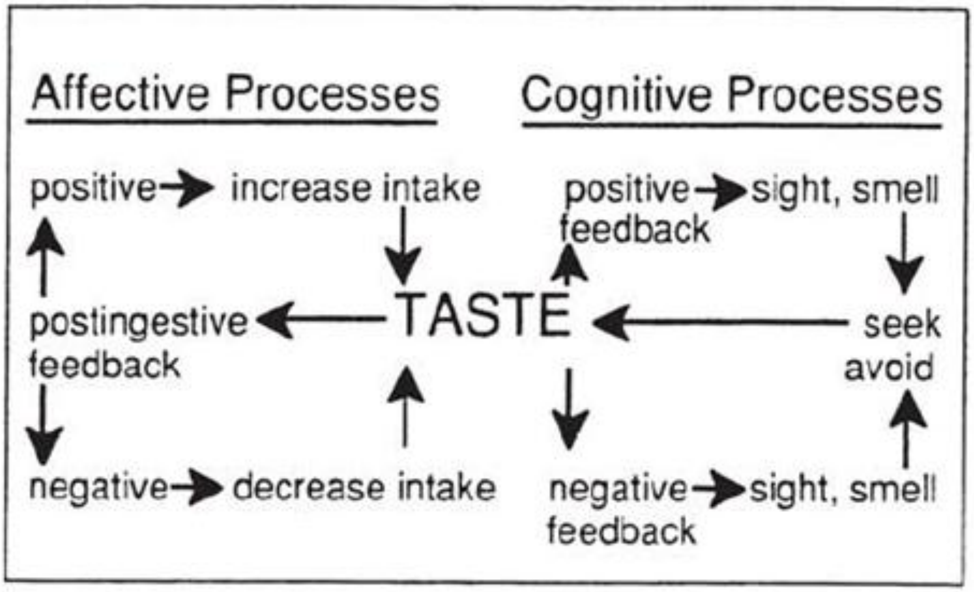

Figure 7. Schematic representation of effective and cognitive processes in diet selection. The effective system begins with and integrates the taste of food with postingestive feedback. This system causes changes in the intake of food items that depend on whether the postingestive feedback is aversive or positive. The net results incentive modification. The cognitive system integrates the odor and sight of food and its taste. Animals use the senses of smell and sight to detect subtle differences in food and to select or avoid specific food items. The result is behavior modification (Garcia, 1989).

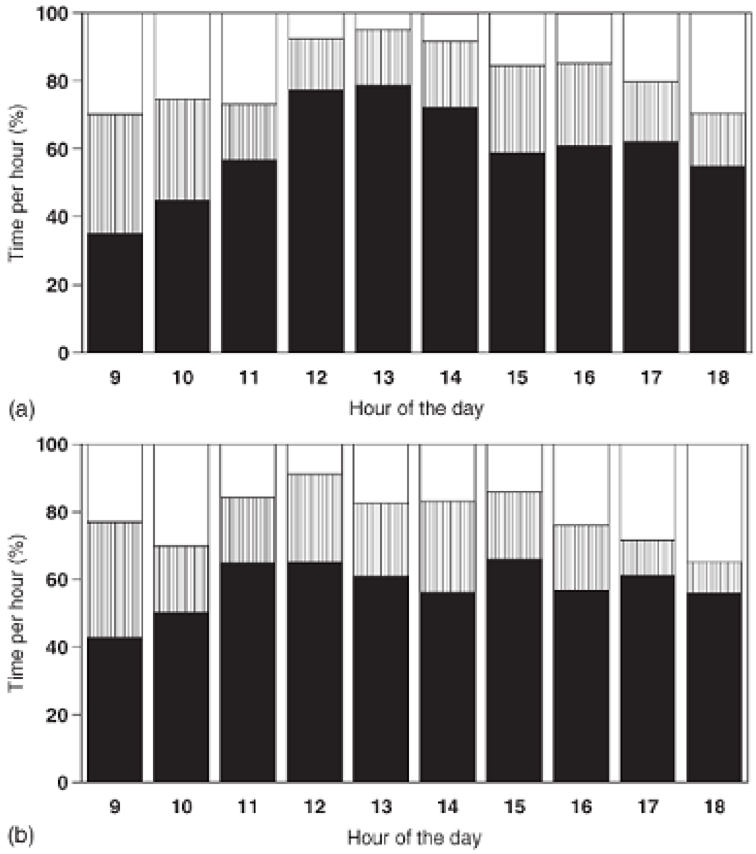

Figure 8. Hourly activity for grazing ■, resting ▥, and walking □, of cattle carrying a backpack GPS and grazing communal lands in Chikal, west Niger. Data are yearly average based on manual observation (a) or resulting from classification of GPS-derived parameters by discriminant analysis (b) of 30 cattle itineraries.

CHAPTER II

Assessment of prior grazing experiences on adaptation to pasture and performance of dairy heifers as lactating cows

ABSTRACT

Questions have been raised by farmers and scientist, if prior grazing experience is an important factor that affects grazing efficiency. To evaluate the impact of grazing experiences early in life on grazing behavior and performance of lactating dairy heifers, 3-years study was conducted. Forty one Holstein (H) and 23 Holstein-Jersey crossbred (HJ), weaned calves born between January and April 2008 were randomly assigned to one of 4 treatment (n = 16 per treatment) in a completely randomized design. Treatments were combinations of managing heifers in confinement or on pasture: **T1,** grazed 2008 and 2009; **T2**, grazed 2008 and confined in 2009; **T3**, confined in 2008 and grazed in 2009; **T4**, confined in 2008 and 2009. All animals grazed as lactating cows in 2010. In 2008, T1 and T2 heifers were exposed for 41 d to Italian ryegrass (*Lolium multiflorum*) pasture from August through October, and T3 and T4 were housed in bedded pack pens and fed TMR. During the exposure period BW and BCS were recorded. In 2009, T1 and T3 grazed Italian ryegrass (*Lolium multiflorum*) pasture during 65 d from June-September, 2009, while T2 and T4 remained in confinement. All 4 treatment groups calved between January and April, 2010, and grazed mixed pasture as primiparous cows during 61 d from May through July. In 2009 and 2010 grazing activities were assessed by visual observation. The same person recorded the activity of each heifer every 15 min during 9 h (0700 h to1600 h) in 2009 and 8 h (0700 h to 1500 h) in 2010, on selected days of the study. Heifer's activities were categorized as: walking, drinking water, grazing, lying down or standing but not grazing. To assess how previous grazing experience affects animal movement on pasture portable GPS units (Trackstick™) were attached to neck collars on each heifer on the same days and hours that was monitored heifer's activity by visual observation. The GPS units recorded the location and distance walked of each heifer at one second intervals. Besides the visual observation and GPS recorded, daily milk was also recorded in 2010. All data were analyzed using proc mixed (SAS) as a completely randomized design, with treatment and day as fixed effects. Paddock (experimental unit) was the random effect. In 2009 on d1, heifers that had grazed in 2008 spent more time grazing than heifers with no grazing experience (78 vs. 35 % of the time, $P < 0.05$). In 2010 on d1, time spent grazing was 62, 59, 76, and 13% for T1, T2, T3 and T4, respectively, with T4 ranking lowest ($P < 0.05$). In 2009 and 2010 on d 1-3, experienced heifers walked a greater distance in the pasture than inexperienced animals. Milk production was lowest ($P < 0.05$) initially for cows with no previous grazing experience (T4). Animals that had not grazed in 2009 (T2 and T4) produced less milk than those that had grazed in 2009 (T1 and T3) on d 1-3. However, average daily milk over the entire experiment was not significantly different ($P > 0.05$) (30.5, 30.1, 31.5 and 29.6 kg for T1, T2, T3 and T4, respectively). Results indicate that previous grazing experience can impact behavior and milk production during the first days on pasture. After this time, experienced and inexperienced cattle presented a similar grazing behaviors and performance. This study showed that experienced and inexperienced cattle adapt to a new grazing environment within a few days, and that adaptation to environment is essential for development of grazing skills for heifers on high quality pastures.

Key Words: Heifers, grazing behavior, milk production.

Introduction

Dairy cattle grazing behavior has been studied for years to identify factors that affect animal performance. Most of the attention has focused on ways to increase pasture DMI. Grazing activities are sensitive to environmental variables such as pasture management, type and quality of forage, and pasture supplementation, and those factors in turn affect forage intake and behavior (forage selection, time spent grazing, pasture rate and consumption) of grazing dairy cattle.

Most of the dairy grazing research conducted in the USA has been designed with animals that are usually housed in confinement, and many cows assigned to grazing studies may or may not have previous grazing experience. Little information is available that describes whether the behavior and productivity of dairy cattle grazing high quality pastures are affected by previous exposure to pasture. Distel and Provenza (1991) showed that cattle and sheep learn to select specific forages, remember experiences from early pasture exposure, and specific forages and forbes exposure in early in life. Studies show that experience obtained as a young animal affects diet selection, grazing behavior and animal productivity months or years later (Hatfield et al., 1992, Ortega-Reyes and Provenza, 1993). Provenza (1995) reported that ruminants that are exposed to pasture and acquire foraging skills at an early age graze more efficiently than animals that have not been exposed to pasture. However, most of the research has been conducted on rangeland grazing systems, where animals are exposed to toxic plants as well as forbes and grasses that vary greatly in nutritional value. It is not known if these early experiences affect milk yield and average daily gain of dairy cattle grazing high quality pasture, and how long it takes for animals with no previous exposure to grazing to adapt to pasture systems. According to Bandura (1977), grazing skills are refined through repeated performance, and the duration of exposure to a food early in life may not be related linearly to intake of that food later in life (Ortega-Reyes et al., 1987).

Our objective was to answer questions that would impact facility design and the focus of dairy grazing research at the University of Wisconsin, thereby making it more applicable to grazing-based dairy producers. Specifically, we wanted to assess (1) how do dairy cattle adapt to pasture, and does grazing at a young age influence how lactating cows graze, (2) how do previous experiences affect grazing behavior, and (3) how do lactating cows with no previous grazing experience (cows raised from birth in confinement) behave, relative to animals with grazing experience in the short term (first few days on pasture) and long term (after several weeks).

Materials and Methods

Experimental design, animals and treatments

Forty one Holstein (H) and 23 Holstein-Jersey crossbred (HJ), weaned calves born between January and April 2008 were randomly assigned to one of 4 treatment (n = 16 per treatment) in a completely randomized design. The treatments imposed were: (**T1**) heifers raised on pasture as weaned calves (year 1, 2008) and as yearlings (year 2, 2009); (**T2**) heifers raised on pasture as weaned calves (year 1, 2008) but then raised in confinement as yearlings (year 2, 2009); (**T3**) heifers raised in confinement as weaned calves (year 1, 2008) and then raised on pasture as yearlings (year 2, 2009); (**T4**) heifers housed in confinement during 2008 and 2009. In 2010, all treatments grazed as lactating cows. Treatments scheme is presented in Table 1.

The first two years (2008 and 2009) of the study were conducted at the University of Wisconsin's Integrated Dairy Research (IDR) facility located at Marshfield, WI. Heifers were housed in groups of 8 in 4.5 x 9.0 m pens in a two row bedded pack barn and allotted 30 m^2 resting area bedded with sawdust and had access to 0.75 m of bunk space/heifer in a neck rail bunk line, except for when the heifers were assigned to pasture. Heifers housed were fed TMR (1x/d) at 1100 h. Feed was pushed up at approximately 2 and 4.5 h post feeding. At approximately 6 wks prior to their expected calving date, heifers were transported from the Integrated Dairy Heifer Research Facility at Marshfield, WI to the Dairy Research Facility at Arlington, WI where the third year (2010) of experiment was conducted. Prior to calving, heifers were housed in a loose housing facility bedded with straw and fed a standard prepartum ration (87:13 forage: concentrate) until parturition. Heifers calved between January and April, 2010. After calving, heifers were housed in a free-stall barn until May 17, 2010 when the grazing trial started.

Temperature and relative humidity of environment were recorded daily (Figure 1). When temperature was more than 32.2^{O} C, animals were removed from the pasture and kept inside the barn.

Pastures

At the Marshfield facility, 7 ha of Italian Ryegrass (*Lolium multiflorum*) were established for the grazing trial during 2008 and 2009. In 2008, 4.1 ha were divided into 8 paddocks of 0.51 ha each for grazing. In 2009, the total area was divided into 12 paddocks of 0.58 ha each. At the Arlington facility, 14 ha were established with 41.5% of Tall Fescue (*Festuca Arundinacea* cv. Bariane), 41.5% Meadow fescue (*Festuca pretensis* cv. Pradel) and 17.0% kupu II white clover (*Trifolium repens*). The total area was divided in 24 paddocks (0.58 ha each) and used for grazing during spring-summer of 2010.

Heifers were managed on an intensive rotational grazing system based on forage availability (kg DM/head/d); the average was 3 days grazing in the same paddock. Forage DMI was calculated as a percent of body weight (1.9 % of BW for heifers and 2.3% of BW for lactating heifers). After the heifers left the paddock, it was clipped to a 10 cm stubble height with a mower and fertilized with 20 kg of N/ha at the Marshfield facility (2009). At the Arlington facility, the pastures were fertilized once with 120 kg of N/ha on June 25, 2010. At both facilities, water was offered ad libitum in confinement and in the access walkway to the pasture. No shade was provided in the pasture.

Pasture samples were collected by tossing a one square meter quadrant frame at four locations per paddock before and after grazing. Pasture within the quadrant was cut to a 5 cm stubble height, and samples were immediately weighed, placed in a 60^{o}C forced air oven for 72 h and ground through a 2-mm screen in a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Pre-grazing samples were composited daily on a paddock basis and sent to Dairyland Laboratories, Inc. (Arcadia, WI) where the samples were analyzed for chemical composition using AOAC (2006) methods for DM (method 930.15) and CP (method 954.01); and NDF determined using methods described by Van Soest et al (1991).

Year 1(2008): *Exposure to pasture*

In the first year of study, heifers from T1 and T2 were exposed to Italian Ryegrass pastures *(Lolium multiflorum)* for the first time from September 9 to October 14, 2008. At the same time, heifers from T3 and T4 were managed in the bedding-pack barn. At the beginning of the study, heifers averaged 179 ± 31 kg BW and 2.5 ± 0.2 BCS.

In 2008, 4 ha of pasture, divided in eight paddocks (Figure 2), were used to manage T1 and T2. Each treatment was divided in two groups of eight heifers. Each group was allocated to one paddock, resulting in four paddocks utilized at the same time. Daily availability of pasture was calculated from the 4 samples collected by tossing the quadrant in each paddock before grazing. The forage availability was approximately 15 kg (DM basis) per heifer per day. Grazing animals were supplemented at the pasture once a day with 0.5 kg/head/d of ground corn and mineral mix (Table 2). During the first three days of study at 1900 h heifers returned to barn and stay overnight, but not TMR was fed during this period. This procedure was followed to avoid broken fences during the first days, because the heifers were not already adapted to pasture. Treatments 3 and 4 were fed a TMR (5 kg/head/d) described on Table 2. Nutrient composition of pasture forage and TMR are presented on Table 2. During the exposure period, BW and BCS were recorded monthly for all 4 treatments. After finishing the grazing period (October 14, 2008), all heifer groups were housed in confinement and fed a TMR.

Year 2 (2009): *Influence of prior grazing experience*

The second year of the experiment was also conducted at the Marshfield IDR Facility. The goal in 2009 was to evaluate grazing behavior and growth of T1 (grazed in 2008) and T2 (confined in 2008 and grazed for the first time in 2009). Treatments 1 and 3 were assigned to grazing Italian Ryegrass pasture *(Lolium multiflorum)* from June 22 to September 17, 2009. In 2009, 7 ha of pasture divided into 12 paddocks were used Treatments 2 and 4 were kept in the bedding-pack barn during the grazing season. At the beginning of the grazing season, Jun 22, 2009, heifers averaged 400 ± 44 kg BW and 3.5 ± 0.1 BCS.

Daily availability of pasture was 25 kg (DM basis) per heifer per day initially. Grazing heifers were supplemented as in 2008. Also in 2009, during the first three days of study heifers (T1 and T3) returned to the bard at 1900 h to stay overnight, during this period not TMR was fed. Treatment 2 and 4 were housed and fed TMR (8kg/head/d). Nutrient composition of pasture forage and TMR are presented in Table 2. Body weight and BCS were recorded monthly for all 4 treatments. After the grazing period (September 17, 2009), all heifers were housed in confinement, and fed a TMR.

Year 3 (2010): *Influence of prior grazing experience on milk production*

The third year (2010) of the trial was conducted at the Integrated Dairy Research Facility at Arlington, WI. All animals were primiparous and grazed from May 17 to July 20, 2010. The aim of this year was to determine how grazing experiences as heifers affect the lactating cows. Each treatment was divided in two groups, group (n= 8), and randomly assigned in one of 24 paddocks. The total area grazed was 14 ha (Figure 3). Daily availability of pasture was 25 kg (DM basis) per cow per, initially. Each treatment group was separated from the other groups by one empty paddock to avoid external group influences. During the first week of the experiment the biomass was sufficient to maintain the animals for a week in the same paddock, which was important to measure the cows' behavior daily during this period. At the beginning of grazing season, May 17, 2010, cows average 74.4 ± 47.9 DIM, 33.72 ± 6.14 kg/d of milk, and 578 ± 48 kg BW.

During the first week, groups of lactating heifers were exposed to the pasture on different days. Groups from T2 and T4 grazed on days 1, 2 and 3 and then returned to confinement for 3 days. Groups from T1 and T3 grazed on days 4, 5 and 6. On day 7, all treatments grazed in the same time. This procedure was adopted to improve the quality of data recorded, since it would be difficult to evaluate all 56 cows at the same time in the period that we expected to find the largest differences.

Cows were allowed to graze approximately 19h/d and were milked daily at 0400 and 1530 h. After each milking, cows were offered half (4kg DM/head/d) of their daily allowance of supplementation in the barn. Pasture and supplement composition are presented in table 2.

Animal Behavior Measurements

In order to evaluate how previous grazing experience affects animal behavior on pasture, animal activity, movements and distance walked were recorded during an 8-hr time period on selected observation days during Year 2 and Year 3 of the study. Animal activity was assessed by visual observation, in 15 min intervals (Gary et al. 1970). The ID number of each heifer was painted on their back with a spray marker, which made it possible to identify each animal at a distance. To assure that the observation did not interfere on animal behavior, the measurements were taken from considerable distance, with a binoculars and a scaffold of 3.5 m high. Animal activity was classified as walking (K), grazing (G), laying (L), drinking water (W) and standing (S). All the animal activity was recorded by the same person during 2009 and 2010.

During the second year of experiment (2009), heifers' movements and distance walked were recorded by portable GPS units (Trackstick II ™, Telespial Systems, Marina Del Rey,CA), which were attached to neck collars on each heifer at 0600 hr for the first 5 consecutive mornings. GPS units recorded the location and movement of each heifer during eight hours, from 0700 to 1500 h. At 1500 h heifers returned to the barn, the GPS units were removed, and the heifers remained in the barn until the next morning. After the first week of experiment, heifers remained on the pasture all of the time. Data was downloaded every day after the GPS units were removed in the afternoon. Visual observation and GPS data were recorded every day during the first week of experiment.

After the first week, animal activity and movements were recorded every 2-wks from July through August of 2009 (7 periods, 2 consecutive days per period).

During the third year of experiment (2010), the measurements followed the same protocol as 2009, but the GPS units were attached to the cows' neck collars during the morning milking and removed during the afternoon milking. Data was recorded on days 1, 2, 3, 4, 5, 18, 19, 32, 33, 60, and 61 after the cows first started the grazing season.

Milk production

Milk production was recorded daily throughout the experiment; however, only days 1, 2, 3, 4, 5, 18, 19, 32, 33, 60 and 61 were used in analysis. Milk samples were collected at four consecutive milking from d 10 (pm) through 12 (am) of each month and analyzed for fat, protein, lactose, SNF, and MUN by AgSource Milk Analysis Laboratory (Menomonie, WI). Solids-corrected milk (**SCM**) and energy output in milk corrected (**ECM**) were calculated based on NRC (2001).

All animal handling procedures were approved by the Research Animal Resource Committee (RARC) of the University of Wisconsin.

Statistical analyses

Data were analyzed using the mixed model procedure of SAS 9.1 (Proc Mixed) for a completely randomized design (CRD). Kenward-Rogers adjustment for calculation of denominator degrees of freedom, and the averages were calculated by the LSMEANS adjusted for comparison by the Tukey test when necessary. Significance was declared at $P \leq 0.05$ and a trend was declared at $P \leq 0.10$.

The model used to analyze milk production, animal activity and movement, which had repeated measures taken on the same animal, included the fixed effects of treatment, day and interaction treatment by day; and random effect of paddock (experimental unit). Spatial power (SP (POW)) covariance structure was used on those variables because of an unequal sampling time. Milk composition, BW and BCS variables used the covariance structure type autoregressive (AR (1)) due to the equal sample time. The SLICE option was used to compare treatment differences at individual days when treatment by day interaction was significant.

Results and Discussion

Forage and concentrate composition

The composition of pasture, TMR and concentrate are summarized in Table 2. Fiber and protein content of Italian ryegrass and mixture pasture were similar during the three years of experiment, most likely due to the same grazing management used in both areas. Those characteristics indicate high quality forage and were expected for temperate forages intensively managed. Italian ryegrass pasture diet in 2008 and 2009 contained approximately 17% CP and 42% NDF. TMR diet contained approximately 15% CP and 40% NDF. Mixed pasture diet in 2010 had approximately 18% CP and 33% NDF.

Year 1 (2008): Exposure to pasture

The first year of the experiment aimed to expose the animals to grazing environment. Treatments 1 and 2 remained in the pasture for 41 days, while the T3 and T4 were housed in confinement. At the beginning of the trial, heifers' body weights (BW) were 183 ± 59 and 177 ± 77 kg for grazed and confinement groups, respectively, with no difference ($P > 0.05$) between groups. At the conclusion of grazing period, average BW were 211 ± 59 and 213 ± 60 kg for grazed and confinement groups, respectively, with no statistic differences ($P > 0.05$). However the ADG was lower ($P < 0.05$) for the grazing treatment (T1 and T2), of 0.65 kg/d compared with 0.87 kg/d for treatments in confinement (T3 and T4). Similar results for ADG (0.61 vs. 0.87, $P < 0.05$) were reported by Rudstrom et al. (2005), when heifers of 6 to 8 months of age were grazing alfalfa pasture compare to heifers fed TMR.

The exposure period of 41 days was longer than other studies that have evaluated learning behavior of young ruminants. Flores et al. (1989) exposed lambs to pasture for 2 h/d in the morning during 15 d. Green et al. (1984) exposed lambs to wheat *(Triticum aestivum)* pasture 1 h/d for 5 days in order to test the impact of prior experience on feed intake 3 yr later. Also, calves were exposed to straw diet for 2 months to compare, 3-yr later, with calves that did not have previous experience of consuming straw early in life (Wiedmeier et al. 2002). According to Provenza (1995), 10 days of adaptation is sufficient for ruminants to develop strong preference for feeds that are richer in energy. The preferences are actived by neurological, physiological, and morphological mechanisms but are not rigidly fixed genetically (Provenza and Balph, 1988). Animals learn to associate different flavors with different postingestive feedback signal, and then the experiences early in life may cause lasting changes in preference for different forages, even poorly nutritious forbes like blackbrush (Provenza 1995).

Year 2 (2009): *Heifers' grazing behavior and growth performance*

In the second year of the study, we could begin to measure how previous grazing experience affects grazing behavior. Animal activity and pasture daily availability for groups that grazed in 2009 (T1 and T3) are presented in Table 3. The experienced heifers (T1) that grazed in 2008 spent more time grazing on d-1 of 2009 grazing period than T3 that grazed for the first time in 2009 (78.1 vs. 35.4%, $P < 0.05$). At d 2 and 3 heifers were removed from the pasture at 13:00 h due to the high temperature, which resulted in just 6 h of grazing. During those days, heifers spent the average of 63.0 and 50.2% of their time in the pasture grazing for T1 and T3, respectively, with a decrease of grazing time for T1 and increase for T3 compared to d 1. On d 4, both treatments showed a dramatic increase of grazing time in comparison to d 2 and d 3. This behavior is most likely due to the effect of hunger caused by the low forage intake on the previous days. However, after the first day of experiment no difference was found in time spent grazing between T1 and T3 (Table 3). The difference in time spent grazing between treatments reported on d 1 suggest that heifers with previous grazing experience (T1) remember how to forage for their food, since those heifers started grazing immediately when exposed to the pasture in year 2 (2009). On the other hand, heifers that had never grazed before showed reluctance to accept the pasture. Similar results were found by Ramos and Tennessen (1992), when lambs with previous experience started to graze immediately and grazed for most (> 90%) of the time in comparison with inexperienced groups during the first five days of pasture exposure. However, in this trial the observation was made for just 30 min/day during 5 days.

Data from several studies that compare grazing time for animals already adapted to the environment to animals that are new to the environment found that sheep (Arnold, 1970; Arnold and Maller, 1977; Gluesing and Balph, 1980), goats (Provenza and Malecheck, 1986) and cattle (Hodgson, 1971; Hodgson and Jamieson, 1981) placed in a new environment spend as much as 20% more time eating, but ingest as much as 40% less food than animals with experience. In this present study, the DMI was not measured, but experienced heifers spent more time foraging and grazing on the first day of the experiment than the inexperienced heifers (Table 3).

On the first day of the experiment, we observed that heifers from both treatments did not lay during the 9 h that animal activities were recorded (Table 2). On days 2, 3 and 4 amount of time spent laying increased in 2.2, 4.5 and 4.0%, respectively, for T1. Treatment 3 did not lay during the first four days of experiment during the hours of visual observation was recorded. However, time spent laying in the pasture was significantly lower for T3 ($P < 0.05$) than T1 only on d 15 and 50 (Table 3). The time spent for other activities, such as drinking, standing and walking, was significantly different ($P < 0.05$) between T1 and T3 on d 1, 2 and 3 (Table 3). Those significances were affected by the time spent without laying and less time spent grazing for T3. The lower time spent laying in the first days of experiment could be attributed to the high temperature encountered mainly on days 2 and 3 of the trial in 2009. During those days all heifers were observed spending more time standing.

The average kilometers walked for T1 and T3 during in 2009 are reported in Table 4, which recorded each movement of the heifers during 9 h/d on selected days. Data points reported reflect movements of cattle while on pasture; movements associated with walking to and from the barn and within the barn were not used in this analysis. Treatment 1 walked further (5.5 vs. 3.5 km, $P < 0.05$) than T3 at d1. The following days of experiment, T1 decreased time spent walking and spent more time laying. Treatment 3 also decreased the time spent walking on d 3, when the heifers started to spend more time grazing. After the first day, no statistical difference ($P > 0.05$) was found in amount of km traveled/day between treatments (Table 4).

The movement patterns of one heifer randomly chosen from each treatment on the first 5 days of trial in Y-2 are presented in Figure 5. Since all heifers moved as a group, the figures attempt to give the reader a general idea of how the pattern of movements differed between the treatments groups According to Figure 5, the experienced (T1) heifer was allocated at the left and the inexperienced (T3) heifer placed at the right side of each picture. The gates for entrances were located in the bottom left side and the water was placed at top right and left of each paddock. According to Figure 5, the experienced heifer walked throughout the whole area of the paddock that was provided and the inexperienced heifer spent most of the time close to the gate during the first four days. The red dots in the pictures indicate places where the heifer spent more than 1 min without moving. The red spots were concentrated around the gates and the water in the paddocks where the inexperienced groups were located in the first four days. On day 5 (Figure 5e), heifers from both treatments showed similar movement patterns in the pasture. The data suggest that experienced heifers (T1) walked further during the first days to recognize the area, and selected specific patches in the paddock to graze, considering that those animals remembered how to graze. On the other hand, inexperienced heifers (T3) spent almost all of their time walking to water or standing by the gates during the first days. The difference in behavior between experienced and inexperienced heifer may be explained by the spatial memory, which was defined by Larry et al. (1999), as the ability the animal has to remember where it has foraged and use that information to determine where it will travel and forage. For example, when cattle are exposed to the pasture, they explore the area to source for quantity or quality food, then cattle are able to associate the location with the quality or quantity of food found there (Larry et al., 1999).

The average daily pasture availability, measured as biomass above 5-cm stubble height, was 31.7 kg (DM basis) per heifer per day from the day 1 to 8 (June/2009). For July and August/ 2009 (days 15 to 65), the average daily pasture availability decreases to 17.7 kg (DM basis) per heifer per day (Table 3). The range in available forage DM in this trial were 13 to 30 kg DM/head/d. Daily forage availability did not seem to affect the heifers grazing behavior. Arave and Albright (1981) found that grazing and walking time increased in correspondence with a decrease in grass availability. In this present study, after heifers adapted to the pasture, the grazing time remained constant between treatments and the time spent walking decreased.

Initial BW was similar (*P* > 0.05) among treatments (403.2, 402.6, 406.6 and 392.0 kg for T1, T2, T3 and T4, respectively). Also, the ending BW was not different (*P* > 0.05) among treatments (465.3, 483.1, 457.0 and 456.43 kg for T1, T2, T3 and T4, respectively). The ADG was 0.72, 0.87, 0.58 and 0.72 for T1, T2, T3 and T4, respectively, with T3 being significantly lower (*P* < 0.05) than T2. The lower ADG for T3 may be explained by the lower time spent grazing during the first 3 days of experiment. However, heifers of T3 increased grazing time during the rest of the experiment, which allowed them to achieve an adequate body weight for their age. Distel and Provenza (1991) observed that inexperienced goats lost an average of 4 kg of BW when exposed to blackbrush diet, while no change in BW was reported for experienced goats.

Year 3 (2010): *Influence of prior grazing experience on milk production and animal activity*

Animal activity

At the third year of experiment (2010), eight heifers were removed due to reproductive problems, so only fifty-six heifers (treatment 1, 2, 3, & 4) completed the experiment. During year 3, the animal activities on the pasture were recorded during 8 h/d on selected days (Table 5). At day-1, cows spent 62, 59, 76 and 13 % of their time grazing for T1, T2, T3 and T4, respectively, with T4 being significantly lower (*P* <0.05) than T1, T2 and T3, and T2 grazing less time than T3 (P <0.05). At day 2 and 3, T4 increased the time spent grazing to 35 and 24%, respectively, but the inexperienced (T4) cows still grazed less (P < 0.05) than the cows that had prior grazing experience (T1, T2 and T3). As we reported earlier in the materials and methods, on the first week of experiment, T2 and T4 started to graze first, grazed for 3 days, and then returned to confinement for 3 days while T1 and T3 were grazing. This procedure was adopted to improve the quality of data recorded, since it would be difficult to evaluate activities of all 56 cows at the same time in the period that we expected to find the largest differences. However, this procedure affected the grazing activity for T4; that spent 12% less time grazing on d-4 than it did on d-3, before being housed. On d-4, inexperienced animals (T4) also grazed less time (P < 0.05) than T1, T2 and T3.

Temperatures on this day reached 33.3º C in the afternoon, which forced us to remove all heifers from the pasture at 1400 h. Therefore, the lower grazing time for all treatments T1 and T3 at d-4 was attributed to the high temperature. Time spent grazing increased for all treatments at d-5, being higher for T2 than T1, T3 and T4 (P < 0.05). After 5 days in the pasture, inexperienced cows showed the same grazing patterns as experienced cows. However, some differences among treatments were observed on days 32, 33 and 60. Days 32 and 33 had approximately the same temperature and humidity; however, the night of d-32 had a lot raining that may have increased the heat stress during d-33. Cows from all treatments appeared to be affected by heat stress. They decreased grazing time, increased time standing and drinking water. During the hottest day of the trial (d 33), T2 showed the lower ($P < 0.05$) grazing time in comparison with the other treatments. We could not find any specific reason why the animals from T2 were more affected by the high temperatures than the others. The biomass in the paddocks where T2 was allocated did not differ from biomass in the paddocks where T3 and T4 were allocated (Table 5).

Time spent laying on the first day was similar to Y-2, when the inexperienced heifers did not lay during the observation period. In 2010, the inexperienced cows (T4) spent 8 h in the pasture without laying (Table 5). Differences in laying time among treatments were found on days 5, 19, 32, 33 and 61 ($P < 0.05$). The time spent for other activities, such as drinking, standing and walking, was significantly different ($P < 0.05$) among treatments on days 1, 2, 3, 4, and 33 (Table 5). Those differences were affected by the lower time spent grazing by T4 on the first 4 days and by T2 on day 33. Table 5 shows that the number of other activities increased by the d-33 (June, 21), with the hottest days and decrease in forage biomass, cows spent more time drinking water and standing.

The average distance traveled for T1, T2, T3 and T4 during the yr-3 are reported in Table 6. Data were obtained with the GPS units, which recorded each movement of the cows during 8 h/d on selected days. No difference was found during the first 3 days of experiment among treatments ($P > 0.05$). However, on d-4 the distance walked was 5.1, 3.2, 2.6 and 1.6 km for T1, T2, T3 and T4, respectively, with T1 walking more than T3 and T4 ($P < 0.05$). Day 4 was when T2 and 4 returned from the confinement, and T1 and T3 were allocated to a new paddock. Treatment 1, which grazed for 3 years, seemed to explore more (travel longer distances) when introduced to the new environment. Also, the distance walked by T1 increased at the end of the experiment, most likely due to the lower biomass in the paddocks where that treatment was allocated.

The movement patterns in the pasture of one cow from each treatment for the days 1, 2, 4 and 30 in the Y-3 of study are presented in the Figures 7, 8, 9 and 10, respectively. Treatments that grazed in 2009 (T1 and T3) and treatments that grazed or did not graze in 2008, but grazed in 2010 (T2 and T4) show the same movement pattern in the pasture at d 1. Treatments 1 and T3 explored more the area in comparison to T2 and T4, which spent almost the whole time close to the entrance of the pastures (Figure 7). We observed the same situation in 2009, when the experienced group (T1) explored the whole area of the pasture and the inexperienced (T3) group spent large amounts of time in the same place. On day 2, T2 showed the same movement in the pasture as T1 and T3, but T4 remained grazing around the same place. After four days of exposure to pasture, all treatments presented similar movements during the 8 h of observation.

Milk production and composition

During the first day, animals that had not grazed in 2009, (T2 and T4) produced less milk than those that had grazed in 2009 (T1 and T3). The milk yield for the d 1 was 32.6, 28.2, 32.9 and 28.8 kg for T1, T2, T3 and T4, respectively, with T2 and T4 being significantly lower (P < 0.05) than T1and T3 (Table 7). The following days (d 2 and 3), yields of milk were lowest (P < 0.05) for cows with no previous grazing experience (T4), most likely due to the lower percent of the time spent grazing by T4 during the first days of experiment (Table 5). However, average daily milk during the whole study (Table 8) was 30.5, 30.1, 31.5 and 29.6 kg for T1, T2, T3 and T4, respectively, with no difference among treatments ($P > 0.05$). Also no difference ($P < 0.05$) in milk composition was found among treatments (Table 8). Daily milk yield, SCM yield, fat and protein percentages averaged across the treatments were 30.4 kg, 23.0 kg, 3.5%, and 2.9%, respectively. Grazing studies conducted in the same herd with high producing dairy cows (Reis and Combs, 2000) grazing alfalfa and ryegrass pasture and supplemented with 10 kg/d of a corn-based concentrate had the average of daily milk yield, and milk fat and protein percentages of 30.4 kg, 3.08 %, and 3.05%, respectively. In the present study the milk yield is within the range reported by Muller et al. (1997) when cows consuming 11.4 to 15 kg/d of DM of pasture and receiving 7.3 to 8.6 kg/d of concentrate DM produced 30.5 to 39.2 kg/d of milk.

In general, cows lost weight during the experiment (Table 8). The changed in BW was -48.0, -36.4, -65.4, and -55.1 kg of BW for T1, T2, T3 and T4 respectively, with T3 losing significantly more ($P < 0.05$) BW than T2. At the beginning of the third year of the experiment, the BW was 576, 575, 607 and 575 kg of BW for T1, T2, T3 and T4, respectively. At the end of the trial, cows weighted 528, 538, 541 and 520 kg for T1, T2, T3 and T4, respectively. However, changes in milk production during the trial did not explain these changes in BW.

General discussion and conclusion

Results from our study show that experience early in life with dairy heifers grazing high quality pasture did affect grazing behavior and milk production in the short term. It appears however that inexperienced animals adapt relatively quickly to the pasture, and as a result growth and milk production recover within a few days.

The data from 2009 showed that a short exposure period when heifers (T1 and T2) were 6 mo. old affected the grazing behavior compared with the inexperienced heifers (T3) that were exposed to the pasture with 1 yr old. Heifers with experience remember how to graze immediately when allocated in the pasture. However, inexperienced heifers (T3) exhibited similar grazing times as experienced heifers after one day. According to Lobato et al (1988) young animals accept a new environment and a novel food easily during the first year of life, after that the desire to consume a novel food is decreased; in mature animals it is more difficult to introduce a new food. Maybe this difficulty is the reason why the heifers that started to graze when 2 yrs old (T4), took 3 days to show similar behavior and milk production when compared with heifers that had previous grazing experiences (T1, T2 and T3).

The interval that animals remained housed could affect the grazing memory. According to Larry et al. (1999) cattle were able to remember where they had foraged after delays of up to 8 hours but performed poorly, after delays of 12 hours, they reported the early experiences may affect this memory, but it is not understood. In the present trial, heifers (T2) that were initially exposed to a grazing environment when 6 mo. old, and after being in confinement for 18 months showed similar grazing behavior to the groups that grazed for both years.

This study showed that initial adaptation to the new environment occurs over the first few days, and productivity of the inexperienced animals recovers in those first days. It can be explained by the improvement of grazing skills that are made on the basis of information gained from repeated performance (Bandura, 1977). Also, all groups appeared to adjust to pasture as the summer progressed. In 2009, experienced and inexperienced heifers showed a similar behavior (time spent grazing and distance walked) after day 8 when the daily forage availability changed from 30 to 15 kg/DM/head/d as the summer progressed (Table 3 and 4). Also in 2010, experienced and inexperienced lactating heifers walked a similar distance and had similar milk production when forage availability decreased from 30 to 20 kg/DM/head/d after day 18 (Table 5, 6 and 7). According to Arave and Albright (1981) when forage availability is not sufficient to cover the animal demands, animals tend to spend more time grazing and walk longer distances looking for food. In our study, forage availability was higher than animal demand; this was part of the experiment design because we wanted to look specifically at how the degree of animal experience affects grazing behavior, and we wanted to minimize the effects of low pasture supply on animal behavior. Also the GPS data (Figure 4 and 6) showed that both inexperienced and experienced cattle adjust to a new environment in a few days. Experienced and inexperienced cattle showed the similar variation in distance walked as the summer progress.

GPS was used in this study as an important tool to report heifer movement patterns in the pasture. We could see differences in movement between experienced and inexperienced heifers during the first week in the pasture. The way that heifers with grazing experience move in the pasture could be explained by spatial memory, these animals remember how to graze and use this information to explore the pasture (Larry et al., 1999). According to Larry et al (1999) animals moved from one pasture to a new environment have the tendency to graze in the same direction they usually grazed in the previous environment. In this present study, heifers in 2009 grazed in a south to north direction, but in 2010 the same heifers grazed in an east to west direction. Figures 5 and 7 show that direction did not influence grazing activity of experienced heifers. Heifers tend to graze in the direction to the fences is designed and the direction that shows more area to explore. In addition, the average kilometers walked for heifers (2009) and lactating heifers (2010) were not different (2.7 vs. 2.9, $P > 0.05$) respectively; but, the movement patterns did change from 2009 to 2010. Yearling heifers explore the entire paddock more frequently (Figure 5) than lactating heifers (Figure 7, 8, 9 and 10). Lactating heifers explored the pasture more in the first day than the following days.

Also inexperienced yearling heifers behave differently from inexperienced lactating heifers. After they adjusted to the pasture, inexperienced yearling heifers explored the entire paddock (Figure 5) in the same day. Inexperienced lactating heifers, after they learned to graze, did not explore the entire paddock in the same day, they moved according to the forage available in each spot. The differences in movement patterns in the pasture between heifers and lactating heifers may be influenced by the difference in energy demand. It is important to consider that heifers and lactating heifers were located in paddocks of approximately the same size (~ 0.50 ha).

Implication

Grazing studies that utilize cattle normally managed in confinement should offer at least one week to allow both experienced and inexperienced cattle to adapt to the grazing environment. This should provide adequate time for inexperienced animals to adjust to the new environment and recover milk production. This present study confirmed that the short period of adaptation (10 to 14 days) normally used in grazing studies with cows raised in confinement can provide valuable data to grazing dairy farms. In addition, pasture forage production and quality varies rapidly during the grazing season, a short adaptation period is important for grazing studies, mainly in the Midwest of US where the grazing season usually is only 6 to7 months.

Low cost GPS units are an important tool and can provide valuable data in dairy grazing studies. This equipment can offer quantitative ways to measure how animals move in the pasture. GPS data could offer insight into forage preferences by evaluating the time spent grazing the same type of forage. It also can monitor changes in animal behavior due to heat stress or others weather factors.

In addition, monitoring of animal body weight and movements recorded by GPS provide quantitative data that can be important for studies that evaluate energy requirements of grazing animals; likely the special relationship between animal movements and forage availability can be better understood.

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Table 1. Treatment scheme

	Treatment			
	T1	T2	T3	T4
Year 1[a]	Grazed (16)	Grazed (16)	Not grazed (16)	Not grazed (16)
Year 2[b]	Grazed (16)	Not grazed (16)	Grazed (16)	Not grazed (16)
Year 3[c]	Grazed (15)	Grazed (14)	Grazed (14)	Grazed (15)

[a] 2008, calves at approximately 6 months old.
[b] 2009, heifers at approximately 1 year old.
[c] 2010, primiparous cows.
Numbers in parentheses represent the number of animals per treatment, per year.

Table 2. Pasture and supplementation composition.

	Year					
	2008	SD (±)	2009	SD (±)	2010	SD (±)
Italian Ryegrass Pasture [1]						
DM %	22.3	2.0	21.9	3.1	--	--
CP, % DM	18.7	1.4	19.3	4.5	--	--
NDF, % DM	48.7	5.4	47.0	4.8	--	--
Mixed Pasture [2]						
DM %	--	--	--	--	22.0	3.0
CP, % DM	--	--	--	--	19.2	4.3
NDF, % DM	--	--	--	--	49.7	4.9
TMR[3]						
DM %	34.0	2.0	35.5	5.5	--	--
CP, % DM	15.7	1.1	14.9	1.8	--	--
NDF, % DM	40.1	4.2	52.7	4.1	--	--
Concentrate [4]						
DM %	87.6	0.2	88.0	0.4	90.6	0.3
CP, % DM	8.8	0.7	9.0	0.8	17.3	0.5
NDF, % DM	10.7	0.5	10.9	0.3	6.7	0.8

[1] Composition of pastures at the Marshfield IDR facility.
[2] Composition of mixed pasture (composed of Tall fescue, Meadow fescue and white clover) at The Arlington IDR facility.
[3] TMR composition (fed to animals in confinement): 45.2 % grass silage (haylage, oatlage and sorghum sudan), 53.60% corn silage, 0.84% shelled corn and 0.34% low phosphorous mineral.
[4] Concentrates composition: 2008 and 2009: 90% ground dry corn and 10% salt with trace minerals and vitamin AD&E. 2010: 78.9% ground dry corn, 11.3 % soybean meal, 5.6% corn gluten meal, 1.4% calcium carbonate, 0.8% magnesium oxide, 1.4% salt with trace minerals and 0.6% vitamin AD&E.

Table 3. Effect of prior grazing experience on grazing activity and forage DM available per heifer per day on selected days, yr-2 (2009).

	Experiment day										
	1	2	3	4	5	8	15	32	50	65	SEM[5]
Treatment[1]	Grazing, %										
T1	78.1[a]	59.6	66.5	91.5	61.5	54.5	46.1	57.6	60.8	59.8	7.1
T3	35.4[b]	47.4	53.0	84.7	71.3	64.3	55.9	57.9	70.9	68.3	7.1
	Laying, %										
T1	0.0	2.2	4.5	4.0	14.1	38.1	46.0[a]	35.4	30.5[a]	36.3	4.6
T3	0.0	0.0	0.0	0.0	7.2	29.1	33.4[b]	31.3	17.0[b]	27.4	4.6
	Other[2], %										
T1	21.9[b]	38.2[b]	30.0[b]	4.5	24.4	7.4	7.9	7.0	8.7	3.9	4.4
T3	64.6[a]	52.6[a]	47.0[a]	15.3	21.5	6.6	10.7	10.8	12.1	4.3	4.4
	kg/DM/head/d[3]										
T1	28.6	28.6	28.6	28.6	28.6	34.8	16.4	13.9	15.9	24.9	-
T3	32.1	32.1	32.1	32.1	32.1	36.5	15.9	11.7	13.9	25.7	-

[ab]Means within columns with different superscripts differ in at $P<0.05$ for treatments 1 and 3.
[1] T1 represents the heifers that grazed in 2008, 2009 and 2010. T3 represents the heifers that were in confinement in 2008 and grazed in 2009 and 2010.
[2]Other represents the average time spent standing, drinking water and walking for each treatment.
Animal activities (grazing, lying and other) from T1 and T3 were observed for 9 h/d (0700 to 1600 h).
[3] Forage DM available for heifer per day, calculated by samples collected before grazing.

Table 4. Distance (km) walked for each treatment on selected days of experiment, yr-2 (2009).

	Experiment Day									
	1	2	3	4	5	8	15	32	50	65
Treatment[1]	km[2]									
T1	5.5[a]	4.6	2.9	3.9	3.1	1.9	2.6	1.9	1.9	1.3
T3	3.5[b]	3.9	2.8	3.0	2.5	1.7	2.3	1.8	2.1	1.6
SEM	0.3	0.9	0.6	0.7	0.8	0.5	0.2	0.7	0.8	0.1

[ab]Means within columns with different superscripts differ in at $P<0.05$ for treatments 1 and 3.
[1] T1 represents the heifers that grazed in 2008 and 2009. T3 represents the heifers that were in confinement in 2008 and grazed in 2009 and 2010.
[2]Distance (km) walked for 9h/d (0700 to 1600 h) for treatment 1 and 3.

Table 5. Effect of prior grazing experience on grazing activity and forage DM available per heifer per day on selected days, yr-3 (2010).

	Experiment day											
	1	2	3	4	5	18	19	32	33	60	61	SEM[5]
Treatment[1]	Grazing, %											
T1	62[ab]	48[ab]	50[a]	45[a]	55[b]	60	65	78[a]	60[a]	47[ab]	46	5.0
T2	59[b]	42[ab]	41[a]	41[a]	72[a]	66	65	59[b]	25[c]	43[b]	40	5.0
T3	76[a]	53[a]	56[a]	44[a]	54[b]	65	75	68[ab]	57[ab]	58[a]	44	5.0
T4	13[c]	35[b]	24[b]	12[b]	50[b]	53	69	62[b]	43[b]	53[ab]	33	5.0
	Laying, %											
T1	16[a]	38	38	14	23[a]	34	15[b]	21[b]	13[b]	11	20[b]	3.9
T2	13[a]	47	43	5	11[b]	30	17[b]	38[a]	27[a]	9	30[ab]	3.9
T3	12[a]	40	36	13	25[a]	28	8[b]	31[ab]	33[a]	14	24[b]	3.9
T4	0[b]	36	40	9	22[a]	40	21[a]	37[a]	28[a]	17	41[a]	3.9
	Other[2], %											
T1	22[b]	14[ab]	12[b]	41[b]	22	6	20	1	27[b]	42	34	6.7
T2	28[b]	11[b]	16[b]	54[b]	17	4	18	3	48[a]	48	30	6.7
T3	12[b]	7[b]	8[b]	43[b]	21	7	17	1	10[b]	28	32	6.7
T4	87[a]	29[a]	36[a]	79[a]	28	7	10	1	29[b]	30	26	6.7
	kg/DM/head/d[3]											
T1	31.7	31.7	31.7	35.4	35.4	28.1	28.1	18.1	18.1	20.1	20.1	--
T2	38.2	38.2	38.2	38.4	38.4	27.6	27.6	19.6	19.6	22.6	22.6	--
T3	33.4	33.4	33.4	35.1	35.1	29.5	29.5	20.5	20.5	23.5	23.5	--
T4	39.1	39.1	39.1	38.5	38.5	30.5	30.5	20.3	20.3	24.5	24.5	--

[abc]Means within columns with different superscripts differ in at $P < 0.05$ for treatments 1, 2, 3 and 4.

[1] T1 represents the heifers that grazed in 2008, 2009 and 2010. T2 represents the heifers that grazed in 2008 and 2010. T3 represents the heifers that grazed in 2009 and 2010. T4 represents the heifers that grazed in 2010.

[2]Other represent the mean time spent standing, drinking water and walking for each treatment.

Animal activity means (grazing, lying and others) from T1 and T3 were observed for 8 h/d (0700 to 1500).

[3] Forage DM available for heifer per day, calculated by samples collected before grazing.

Table 6. Distance (km) walked by each treatment for select days of experiment on yr-3 (2010).

	Experiment day[1]									
	1	2	3	4	5	18	32	33	60	61
Treatment[1]	Km[2]									
1	4.9(1.0)	3.7(0.9)	1.6(1.4)	5.1(1.1)[a]	4.4(1.3)	3.0(1.1)	2.0(1.4)	3.5(2.4)	3.9(1.4)[a]	4.5(1.8)
2	4.6(0.9)	3.6(1.7)	3.2(0.9)	3.2(1.0)[ab]	2.6(1.7)	2.6(1.2)	2.7(1.3)	1.7(1.3)	1.9(1.4)[ab]	4.0(2.4)
3	5.2(1.0)	2.6(1.2)	3.7(2.2)	2.6(1.1)[b]	2.6(1.5)	1.8(1.4)	2.1(1.2)	1.5(1.5)	1.5(1.9)[ab]	2.7(1.6)
4	3.2(1.0)	3.8(1.0)	2.6(0.9)	1.6(1.3)[b]	3.0(1.8)	2.0(1.4)	3.6(2.8)	1.5(1.9)	0.7(2.0)[b]	2.0(2.5)

[ab]Means within columns with different superscripts differ in at $P<0.05$ for treatments 1, 2, 3, and 4.

[1] T1 represents the heifers that grazed in 2008, 2009 and 2010. T2 represents the heifers that grazed in 2008 and 2010. T3 represents the heifers that grazed in 2009 and 2010. T4 represents the heifers that grazed in 2010.

[2] Average of kilometers walked during 8h/d (0700 to 1600) for treatment 1, 2 ,3, and 4.

Numbers in parentheses represent the SEM within treatments.

Table 7. Milk production by treatment on selected days of experiment, yr-3 (2010).

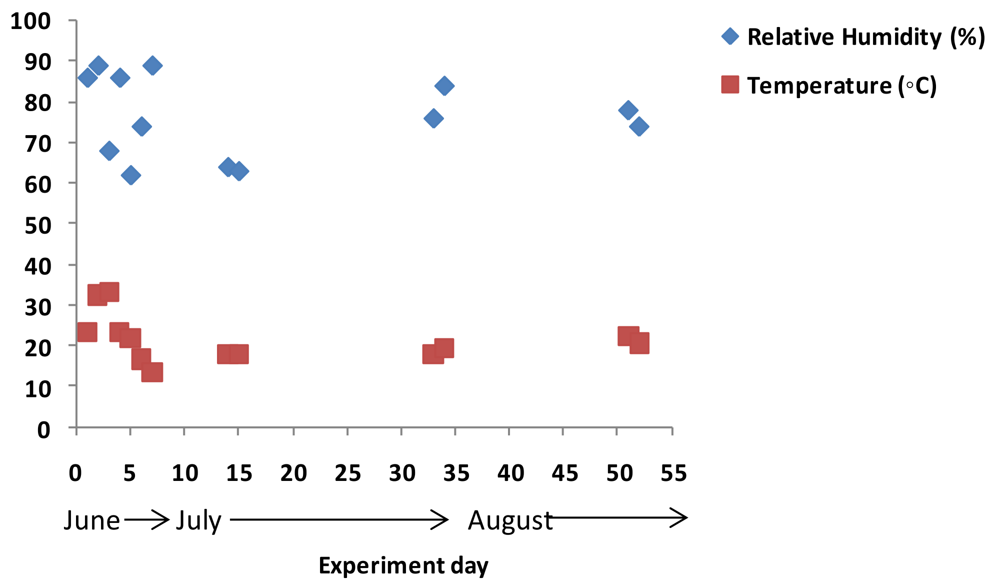
Treatment	Experiment Day[1]										
	1	2	3	4	5	18	19	32	33	60	61
T1	32.6[a]	29.0[a]	30.8[ab]	29.2	28.6	24.7	26.8	24.4[b]	24.0	27.1	27.5
T2	28.2[b]	28.8[a]	27.5[bc]	31.9	29.5	27.1	29.0	25.6[b]	27.0	28.2	27.6
T3	32.9[a]	31.6[a]	32.1[a]	31.0	30.3	26.7	27.8	29.1[a]	28.4	29.8	31.1
T4	28.8[b]	25.0[b]	26.6[c]	29.2	28.8	25.4	27.3	26.9[ab]	27.1	27.2	27.9

[abc]Means within reference with different superscripts differ (P<0.05)
[1]SEM (standard error of differenced of least square means) = 1.14

Table 8. Average of milk production and milk composition for each treatment in 61 d of experiment, yr-3 (2010).

	Treatment					
	T1	T2	T3	T4	SEM	Trt P <
Milk, kg/d	30.5	30.1	31.5	29.6	1.0	0.64
4% FCM, kg/d	28.1	27.7	28.5	27.4	1.0	0.88
SCM, kg/d	23.2	22.6	23.5	22.6	1.2	0.94
ECM	30.0	29.4	30.4	29.2	1.1	0.88
Fat, %	3.4	3.5	3.4	3.5	0.0	0.24
Fat, kg/d	1.1	1.0	1.1	1.0	1.0	0.64
Protein, %	3.0	3.0	2.9	3.0	0.1	0.80
Protein, kg/d	0.9	0.8	0.9	0.8	0.0	0.87
BW change, kg/61d	-48.0^{ab}	-36.4^{b}	-65.4^{a}	-55.1^{ab}	10.3	0.05

(a)



(b)

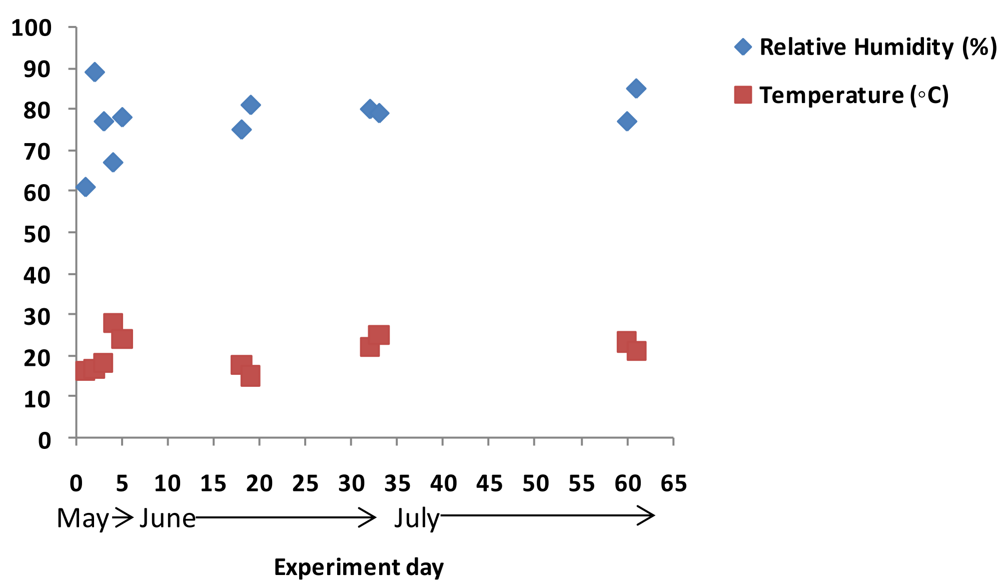


Figure 1. Temperature (^{o}C) and relative humidity (%) recorded on the same experiment days that was recorded the animal behavior in 2009 (a) and 2010 (b).

(a)

------------------------------- Pasture ------------------------------------			
A	B	C	D
T1	T2	T1	T2

(b)

------------------------------- Pasture ------------------------------------			
A	B	C	D
T3	T1	T3	T1

Figure 2. Marshfield -WI, pasture layout (North ↑) (a) 4 ha were divided in 8 paddocks for the grazing period in 2008. (b) 7 ha were divided in 12 paddocks for the grazing period in 2009.

Figure 3. Arlington-WI, pasture layout (➔East) 14 ha were divided in 32 paddocks for the grazing period in 2010.

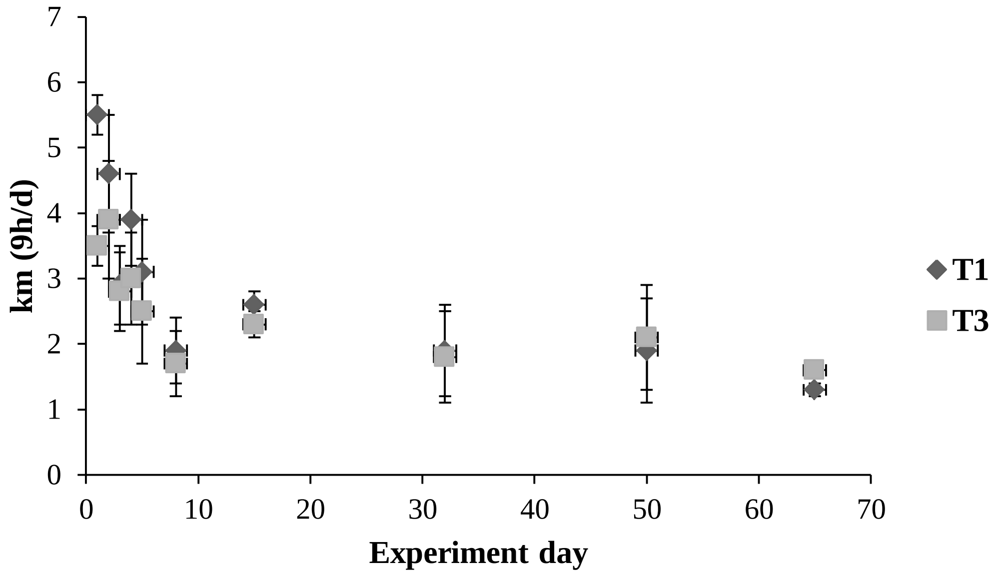


Figure 4. Distance (km) walked by each treatment on selected days (9h/day) of experiment on yr-2 (2009).

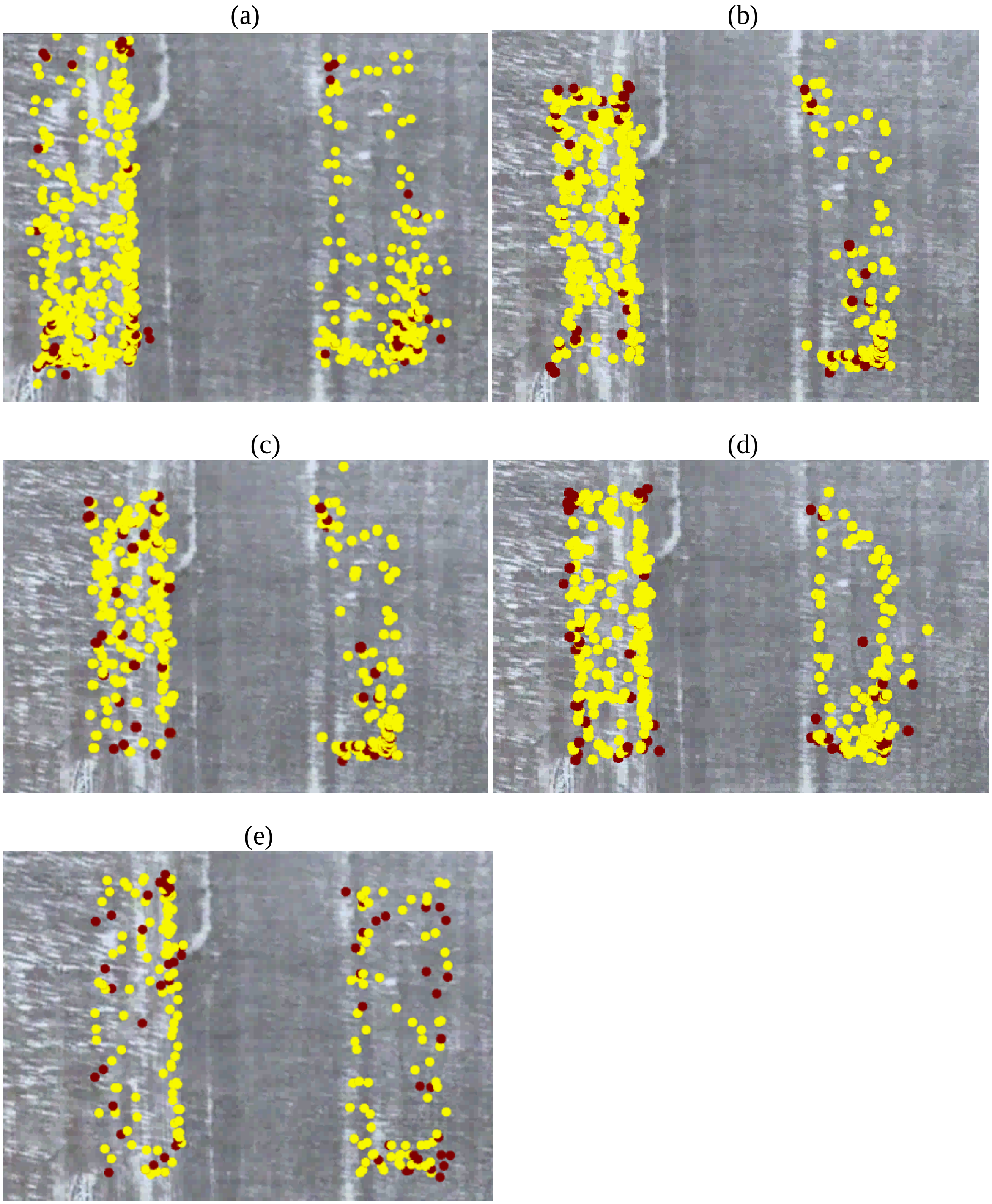


Figure 5. Heifer movements in the pastures recorded during 9 h/d (0700 to 1600) in the yr-2 (2009). Left side of the pictures are T1 and right side is T3. (a) day 1, (b) day 2, (c) day 3, (d) day 4 and (e) day 5.

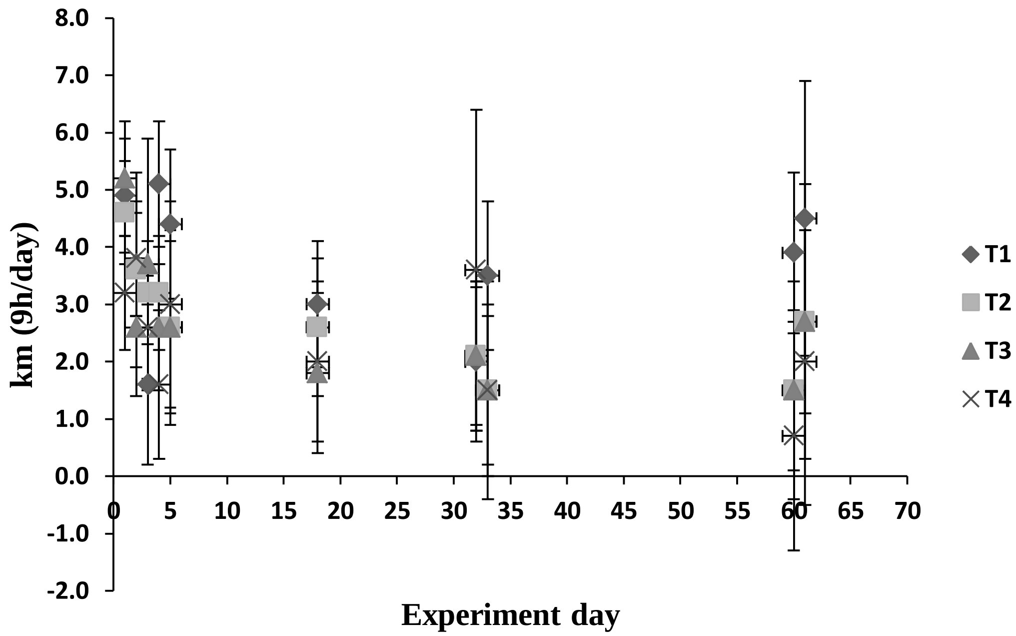


Figure 6. Distance (km) walked by each treatment on selected days (8 h/day) of experiment on yr-3 (2010).

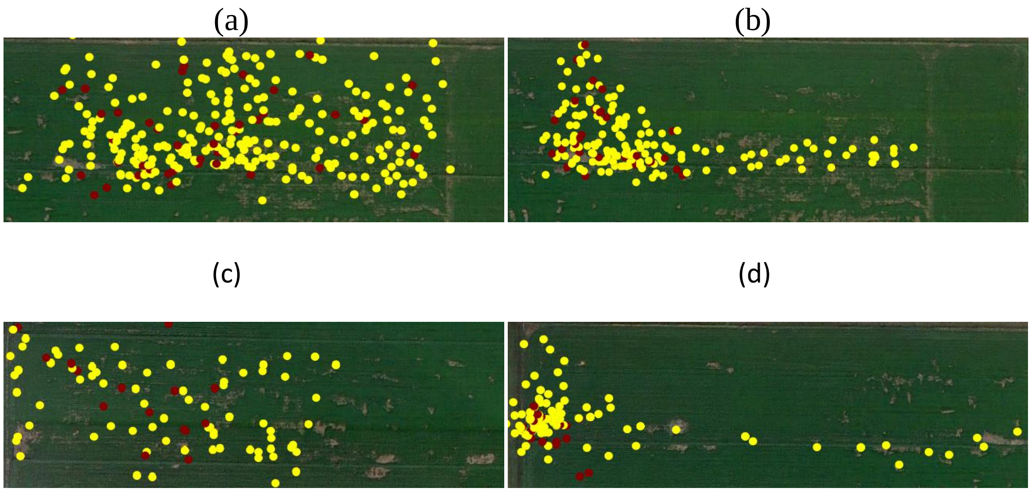


Figure 7. Cow movement in the pastures recorded during 8 h on day 1, yr-3 (2010).
(a) T1, (b) T2, (c) T3, (d) T4.

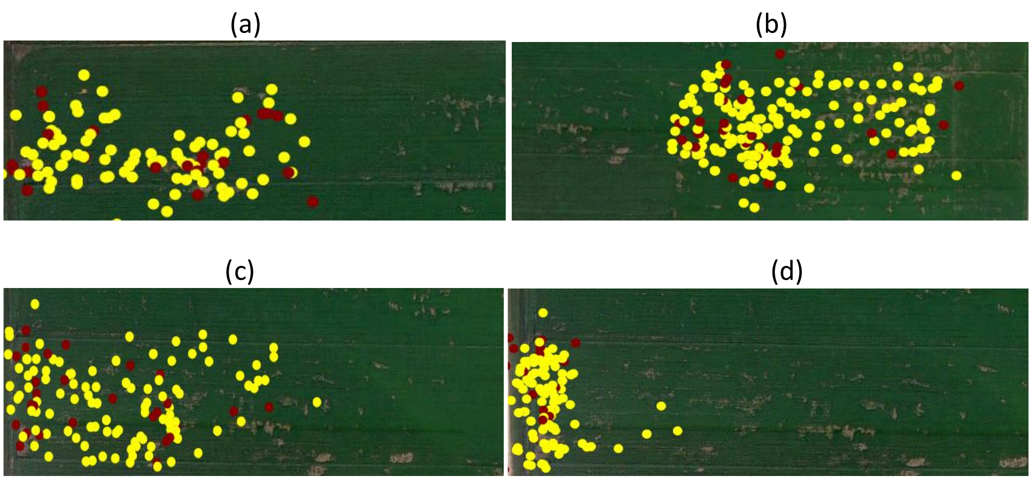


Figure 8. Cow movement in the pastures recorded during 8 h on day 2, yr-3 (2010).
(a) T1, (b) T2, (c) T3, (d) T4.

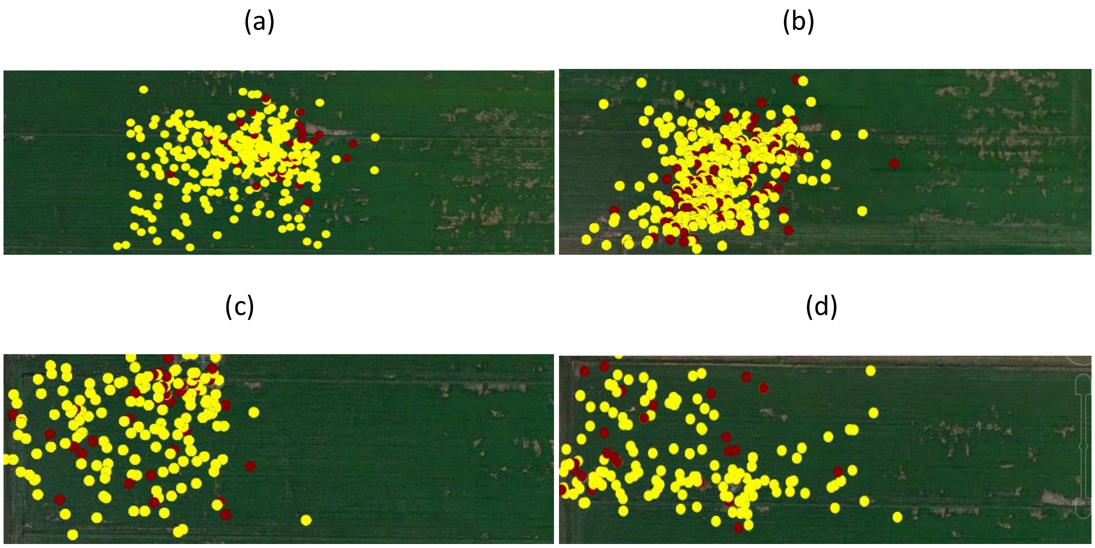


Figure 9. Cow movement in the pastures recorded during 8 h on day 4, yr-3 (2010).
(a) T1, (b) T2, (c) T3, (d) T4.

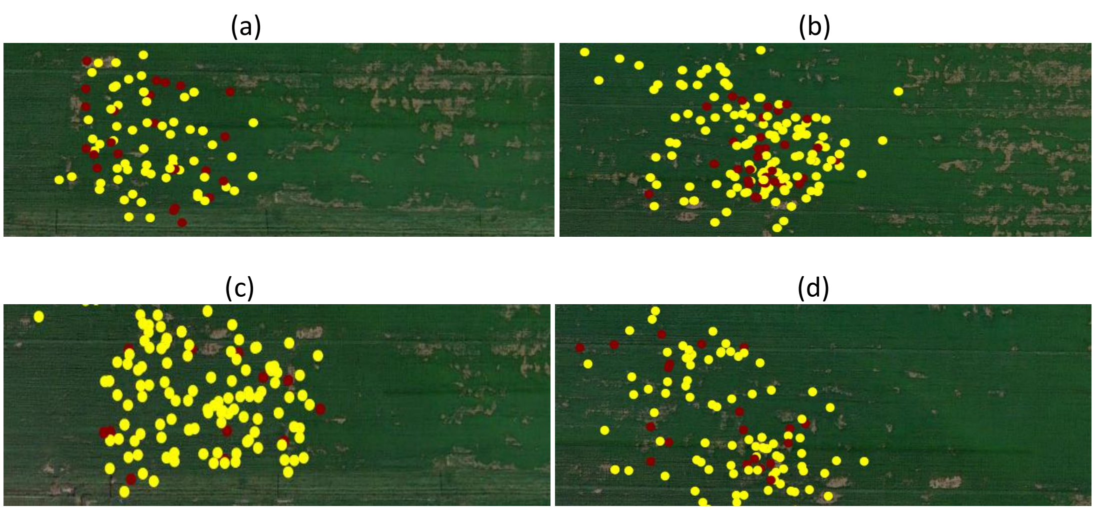


Figure 10. Cow movement in the pastures recorded during 8 h on day 30, yr-3 (2010).
(a) T1, (b) T2, (c) T3, (d) T4.