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Isolating Factors that Influence Grazing Patterns in Dairy Cattle

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Abstract:

Factors influencing grazing patterns were identified utilizing remote sensors on lactating Holstein and Brown Swiss dairy cattle in order to recommend efficient management techniques to dairy farmers. Over the course of three separate two week periods- one in the spring, summer and fall- data was collected on the dairy herd at Eastern Kentucky University's Meadowbrook Farm. Approximately 18 cows were used each trial period; half being Brown Swiss and the other half being Holstein. Data was collected via CowManager ear tags, which tracked the five behavioral patterns of eating, ruminating, high, medium, and no activity. These activities served as dependent variables for this study. The independent variables included breed, temperature, humidity, month in lactation, pounds of milk produced, percent fat, percent protein and somatic cell count. This raw data was statistically evaluated using multivariate multiple linear regression analyses. Statistical analysis revealed that breed, season, temperature, stage of lactation and pounds of milk produced impact grazing patterns. Therefore, it is recommended that Brown Swiss cows be allowed to graze longer than Holsteins because of their superior utilization of forage as a low cost feed source. It is also recommended that dairy herds be allowed to graze longer in the summer and fall than in the spring. However, it is probably a more accurate recommendation to graze during hours of no direct sunlight, such as early morning and evening, rather than grazing midday. In addition, it is suggested that individual farm managers evaluate their net income per cow relative to feed costs.

Keywords and Phrases: honors thesis, undergraduate research, dairy management, grazing patterns, Brown Swiss, Holstein, pasture utilization

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Introduction

Dairy farming began thousands of years ago, shortly after the domestication of cattle. Since then, the practice of dairy farming has been refined and developed into what it is today. Currently, modern dairy farms favor fewer but larger operations, with greater production per cow. In the United States “86 percent of milk is produced on the 26 percent of farms that have more than 100 cows” and the “average dairy cow produces six to seven times as much milk as she did a century ago” (Modern Farmer, 2014). There are still several small operational dairy farms, but the modern farm contains hundreds, and sometimes even thousands of cows. Further, each cow is producing up to seven times more milk than her ancestors. This is made possible by the development of superior genetics and technology, such as breeding programs that incorporate artificial insemination and embryo transfer, computerized record keeping systems, and robotic milking machines, among other things. The research conducted at Eastern Kentucky University’s Meadowbrook Farm Stateland Dairy, from the time period of April 2015 to March 2016, fits into the development of the modern dairy farm because data was collected on factors affecting grazing patterns using remote sensors, which is one of the latest technologies available to the dairy industry. Conclusions, which will later be drawn from the data, will allow for grazing management suggestions to be made to dairy farmers, which will further encourage increased milk production.

Literature review

The factors under examination during this study, that potentially influence grazing patterns in dairy cattle, include breed, season, dairy production characteristics, and the environmental factors of temperature and humidity. Each one of these factors will further be explained in depth.

The two breeds of dairy cow used for production at Stateland Dairy include the Brown Swiss and the Holstein. The Brown Swiss breed originated in the Swiss Alps. This ancestry has contributed to the breed's dairy strength, along with its ability to adapt to harsh environments such as high altitude, extreme heat, and cold. Brown Swiss cows are also known for their ability to produce milk with a high fat to protein ratio, which is ideal for cheese-making. Therefore, producers can receive more money per hundred-weight of milk sold since the milk has higher components, or more percent fat and protein. According to the Brown Swiss Association, which is devoted to promoting and expanding the breed, the success of the Brown Swiss can be attributed to their "Correct feet and legs, well-attached udders and dairy strength [which] contribute to their exceptional productive life, allowing them to thrive in any modern dairy set-up" (Brown Swiss Association, 2015). This strength and adaptability places the Brown Swiss cow as one of the most popular dairy breeds in the United States, with the average cow producing 22,452 pounds of milk, 919 pounds of fat, and 749 pounds of protein in a year (Brown Swiss Association, 2015).

The Holstein, on the other hand, is the largest and most popular breed of dairy cow in the United States. The Holstein Association attributes the breed's popularity to their "unexcelled production, greater income over feed costs, unequaled genetic merit, and adaptability to a wide range of environmental conditions" (Holstein Association, 2015). The average Holstein can produce 23,385 pounds of milk, 858 pounds of butterfat and 719 pounds of protein in a year (Holstein Association, 2015). These statistics mean greater profits to farmers who milk Holsteins, because they can produce more milk per cow, given the same feed intake.

The milk production characteristics under consideration included month in lactation, pounds of milk produced, percent protein, percent fat and somatic cell count. The month in lactation is how many months the cow is from the last time they had a calf. On a dairy operation with a sound reproductive management program, this number is hopefully no more than 12 months. The pounds of milk produced is the average amount of milk produced by each cow per day, while percent fat and protein are the components of the milk. As mentioned earlier, Brown Swiss cows tend to have higher percent fat and protein, while Holsteins tend to produce more pounds of milk. Finally, somatic cell count (SCC) is a measure of bacteria load in the udder and is indicative of mammary gland health. At a high SCC, such as above the threshold of 200,000, it is likely that the cow is suffering from mastitis.

The final factors under consideration include season, temperature and humidity. Temperature and humidity, which change to a varying degree depending on what the season is, are thought to impact eating patterns in livestock. In Kentucky, spring tends to be warm and rainy, while summer and early fall tend to be hot with high percent humidity. When dairy cattle are exposed to high temperatures, their bodies rely on evaporative cooling to maintain homeostasis. However, when humidity is also high, evaporative cooling is less effective, leading to an increase in rectal temperatures in cattle. When air temperature, temperature-humidity index and rectal temperatures are above critical thresholds, this relates to a decrease in dry matter intake (DMI) and milk yield (West, 2003). This reduced efficiency of milk yield can lead to a loss of economic returns to the farmer.

The other portion of this project was analyzing the grazing patterns that the above mentioned factors potentially affect. Recording these grazing patterns was made possible by radio frequency tracking devices, which relay data to a router located on site. The specific record keeping system utilized at Stateland Dairy is known as the CowManager System, and was developed by Agis Automatisering. It is comprised of a chip that can be connected to an electronic ear tag of a cow and is capable of monitoring cow welfare 24 hours a day, 7 days a week (CowManager, 2015). Overall, the system contains four modules which include fertility, health, nutrition and “find my cow”. The use of wireless sensors is a growing trend on modern farms for a variety of reasons. One reason is that they lower production costs by keeping accurate records of livestock, while decreasing the labor needed to do so. In a study done by Arazi et, al. in 2010, researchers came to the conclusion that computerized herd management systems have high potential to monitor cow welfare and comfort by improving heat detection capabilities and early diagnosis of sick cows (Arazi, 2010). This concept applies to Stateland Dairy because the CowManager system has the ability to detect estrus patterns in dairy cattle, which further allows the farmer to time precisely when to inseminate each cow. This precise detection technically eliminates the need for a farm worker to visually watch for signs of heat and shortens the amount of time it takes for the cow to conceive; therefore, shortening the amount of days until the next milking cycle. Another feature is that the sensors have the ability to rapidly detect disease outbreaks. Innately, the quicker a disease outbreak can be recognized and identified, the faster the animals can be treated and return to full health. In the long run, this saves money for the manager because sick cows recover faster and the disease outbreak can be stopped before spreading to the rest of the herd. The installment of a wireless record keeping system can save a dairy farmer hundreds, and even thousands of dollars because of these efficiencies in management (Wang et al., 2006).

For the purposes of this project, the nutrition module of the CowManager system was specifically utilized to provide a reliable measurement of how many minutes per day each cow spent participating in the activities of high activity, low activity, no activity, eating and ruminating. In previous studies, the nutrition detection functions of wireless transmitters has been used to study dietary factors that impact normal ruminal function of dairy cows (Wang et al., 2006). However, this study used the nutrition module to isolate factors that influence grazing patterns. By understanding how much time each cow spends doing the five above mentioned behavioral patterns, recommendations can be made to dairy farmers such as the optimal time to let the dairy herd out to graze, how long to allow the herd to graze, and how to formulate a diet that maximizes pasture as a feed source. For instance, if a farmer knows the optimal time to graze their herd, then less money will be spent on grain. The overall impact of improving management practices in these ways is to have an increase in production, and further, an increase in economic returns.

Previous studies conducted on the performance of dairy cattle on grazing systems versus conventional systems coincide on major points. The first major finding is that cattle managed in conventional or moderate grazing systems have greater production characteristics, and therefore a higher net income, than cattle managed on extensive grazing systems (Kolver et al., 1997; Parker et, al., 1992; Hanson et, al., 1998). Specifically, “The performance of grazing cows differed significantly from that of cows fed the TMR in dry matter (DM) intake (19.0 vs. 23.4 kg/d of DM), milk production (29.6 vs. 44.1 kg/d), milk protein content (2.61% vs. 2.80%), live weight (562 vs. 597 kg), and body condition score (2.0 vs. 2.5)" (Kolver et al., 1997). This means that cows fed a total mixed ration (TMR) produced more milk and maintained a higher body weight and body condition score than cows fed exclusively pasture. Although this statement is true, it does not take other factors into consideration.

This leads to the second major point that feed costs are higher when feeding a TMR rather than utilizing pasture. Feed costs range anywhere from 50-90% of total farm operation costs, so the key is balancing production, or income, and total costs. For example, in a study done by Fontaneli et, al. in 2005 cattle that grazed had a lower milk yield, but less money was spent on grain. The outcome was that the total revenue for cows managed on pasture versus a free stall feeding system was the same. Another study titled *Profitability of Moderate Intensive Grazing of Dairy Cows in the Northeast* reiterated this point. Specifically the study found that the net income per cow was greater for moderately grazed cows rather than extensively grazed cows. However, the moderately grazed cows had greater feed costs, making their net worth comparable to the extensively grazed dairy herd (Hanson et al., 1998). Another great point that this study made is that no matter which system was used, profits were not high. This makes sense from an economic standpoint because the dairy industry falls under a perfectly competitive market. This means that long term equilibrium profits are zero. If profits were not zero, additional dairies would enter the market, causing an increase in supply. An increase in supply would return the profits back to zero. Therefore the goal of a dairy is to have maximum utilization of available resources, so that income received can adequately cover total costs.

A third key point that the studies mentioned was the importance of taking the postpartum period into consideration. When dairy cows have a calf, milk production starts and peaks around two to four months into lactation. This puts the cow into a negative energy balance because she cannot eat enough food in one day to keep up with her body's demand for lactation. This means she is losing fat reserves, or losing weight. Not only is she at peak lactation, but her body must prepare to conceive approximately 60 to 90 after having the first calf. With this knowledge in mind, it would be unwise for a dairy manager to extensively graze a cow who is in her postpartum period. The cow's diet should be supplemented so she can be nutritionally sound for peak lactation and reproduction (Fontaneli, et al., 2005; Piccand et al., 2013). This is especially important for Holsteins. In a study done by Piccand et, al. in 2013 on the production and reproduction of different breeds of dairy cattle in a pasture based, seasonal calving system, Holsteins had the lowest conception rates. Meanwhile, Brown Swiss had intermediate conception rates. Therefore, Holsteins may not be as suitable on pasture during the postpartum period compared to Brown Swiss, and should be given a supplement or a total mixed ration.

Other aspects to keep in mind when deciding whether or not to utilize a grazing system include receiving premiums for being organic or pasture only (Gillespie et al., 2009). Consumers have become more interested in where their food comes from, and are willing to pay extra for certified organic or grass fed products. Another aspect to keep in mind is that large conventional dairies tend to use less pasture grazing and invest in more technology. Overall, this results in a higher milk yield per cow but also more debt. On the other hand, pasture-based dairy producers are more likely to be smaller-scale and can be thought of as "extensive" grazing operations, meaning they utilize more land resource per cow (Gillespie et al., 2009). Therefore, small diaries tend to use less technology and more pasture to keep feed costs low, allowing them to accumulate less debt. A final aspect to keep in mind is that pasture based operations are more environmentally sustainable. This is because less acreage is used for growing and harvesting hay and silage as feed sources. This means that less fertilizer and pesticides are sprayed, resulting in less chemical residues in the soil and nearby water sources (Hanson et al., 1998).

Aside from the economic sustainability of utilizing pasture, grazing is beneficial from a herd health perspective, especially feet and leg disorders. The first illness that can improve with grazing is the incidence of claw disorders. Claw disorders can range anywhere from digital dermatitis to lameness, heel erosion and foot ulcers. According to recent estimates, the prevalence of lameness on dairy farms include “24% for organic herds (Huxley et al., 2004), 15% for grazing herds, and 39% for zero-grazing herds (Haskell et al., 2006)” (Barker et al., 2010). Grazing is thought to be beneficial for hoof health because pasture provides a comfortable and more natural surface upon wish cows can stand. This helps the cows to recover from hoof and leg injuries (Hernandez-Mendo et al. 2007). Several studies support this statement, one being a Swedish study conducted by Bergsten et, al. in 2015 on the influence of grazing management on claw disorders in free stall dairies with mandatory grazing. In general, what was found was a lower incidence of claw disorders in grazed herds versus herds with zero grazing. However, these disorders did not continually improve the longer the cows were allowed to graze. Not until the cows were free to graze 24 hours a day did you see another dramatic decrease in the prevalence of dermatitis in the herd. This study also found that a higher stocking density was correlated with an increase in claw disorders. This means that the more cows per acre, the higher the incidence of hoof disease. Therefore, in order to improve hoof health, cattle should be allowed to graze for a period of time each day, and the area provided to graze should not be overcrowded.

Another study conducted by O. Hernandez-Mendo et, al. in 2007 graded the gaits of dairy cattle allowed to graze pasture for different periods of time. The gaits were scored on a qualitative scale that included symptoms such as walking with a hunched back and reluctance to bear weight on all four hooves. The study concluded that cows allowed on pasture for a four week period had improved gaits. Hoof health is important because it impacts other aspects of management. For example, a cow with a claw disorder is more reluctant to display signs of heat, such as mounting and standing to be mounted. This makes it challenging for a farm manager to detect estrus, even if they are utilizing tracking devices to monitor for signs of heat. This ultimately affects the ability of the farmer to breed the cow. Another example is a cow in discomfort, due to a claw disorder, will not perform as well. More energy will be exerted trying to walk comfortably rather than eating and producing milk. Therefore, by taking the preventative measure of allowing the dairy herd to graze, the farmer will save money by having an increase in reproductive efficiency, having less cattle decrease feed intake due to being in pain, and having lower medical costs due to reduced incidence of claw disorders.

Another illness that can be improved with proper grazing management is udder health. The adoption of intensively managed rotational grazing (IMRG) may be practical and alternative method of enhancing milk quality and mastitis control (Goldberg et al., 1992). Grazing has been shown to enhance milk quality because cows who are allowed to graze have a lower SCC and standard plate count (SPC) than cows placed in confinement housing. As mentioned earlier, SCC is a measure of bacteria load in the udder, and is indicative of mastitis. SPC, on the other hand, is an estimate of the total number of viable aerobic bacteria present in raw milk. Once again, a high plate count is indicative of compromised udder health. Lower SCC and SPC in grazing herds is most likely lower because of the presence of a cleaner environment, not because of forage intake.

Cows housed in confinement are typically closer in proximity with one another, which increases the risk of spreading bacteria. Also, cows that lay down in an unsanitary confinement setting are more likely to pick up bacteria through their teat, especially directly after being milked.

Another element that should be kept in mind from a herd health perspective while grazing is the effect of heat stress on the cows. This is a concern because heat stressed cows are biologically similar to early lactation cows in that dietary intake may be energetically inadequate to support maximum milk and milk component synthesis (Moore et al., 2005). As mentioned before, when a cow is in extreme heat or humidity, she cannot properly cool down her body temperature. This causes more nutrients to be partitioned to maintaining homeostasis since her body is working in overdrive to try and cool down. Since more nutrients are being used to help cool off, less dietary intake goes to producing milk, thus resulting in a decrease in production. Therefore, precautions should be taken to monitor the herd's temperature if grazing for long periods of time, and adequate shade and cooling mechanisms should be provided for the herd to utilize. Common cooling apparatuses in confined operations include fans, water sprinklers, and evaporative cooling systems. In a study conducted by Donald Ray et, al. in 2004 titled *Thermoregulatory Responses of Holstein and Brown Swiss Heat-Stressed Dairy Cows to Two Different Cooling Systems*, the effects of fans and sprinklers versus evaporative cooling systems on Holstein and Brown Swiss cows were identified. The study concluded that there were no significant differences in the hormonal responses of the two breeds to the different cooling systems. These results demonstrate that either cooling system can be used to reduce the effects of heat stress in dairy cows during hot and humid days. Therefore, giving the herd access to at least one form of cooling system would be an appropriate method of reducing heat stress, in order to maintain high levels of milk production.

Another method of reducing heat stress is by letting the herd out to graze in the evening. Temperatures are generally cooler at night, allowing the cattle to graze without being exposed to direct sunlight or extreme heat. In comparison to midday, it has been shown that cows will graze for longer periods of time during the evening, with multiple grazing periods throughout the night (Seath et al., 1945). Specifically, milking cows that are let out to pasture between the A.M. and P.M. milking periods, or during the day, spend an average of 1.8 to 1.9 hours grazing. However, cows let out to pasture between the P.M. and A.M. milking periods, or during the evening, graze an average of 5.5 to 5.7 hours during the night. This means three times as much time is spent grazing overnight than spent grazing during the day. Simultaneously, the number of grazing periods is greater during the evening than during the daytime. The average number of grazing periods for the daytime is 1.4, while the average number of grazing periods for the nighttime is 2.7. Therefore, by letting the dairy herd graze at night, they will have better utilization of pasture, which will save in feed costs in the long run.

A final note to be made is on the nutrient content of pasture, and how it relates to grazing management. Forage typically contains higher fiber and lower protein in the summer months when environmental temperatures are warmer. However, in the cooler winter months, forage tends to have a lower fiber content and a higher protein content (Gibb et al., 1998). Although this is a general trend, forage samples should be taken per each pasture in order to assess the levels of fiber and protein. This knowledge, along with the help of a livestock nutritionist, will allow a manager to formulate a diet that meets the nutritional needs of the dairy herd.

The dairy manager and nutritionist should also keep in mind the transition period that takes place between the months of eating stored winter feed and eating fresh pasture in the spring. It takes time for the microbes in the rumen to adjust to a new diet. If the transition is made to quickly, the herd will have decreased performance and lose body condition (Gibb et al., 1998). Therefore, the cows should be allowed an adjustment period as they transition between the two types of feed. This is the case when implementing any type of diet transition in a ruminant species, such as being introduced to pasture forages. Once again, this will allow the microbes to properly adjust to the new diet, causing the cattle to not lose as much weight, which will help maintain milk production.

Materials and Methods

Data was collected in three separate trials, each for the duration of two weeks, for three hours per day. The first trial was in the spring, the second in the summer, and the third in the fall. The three hour intervals were based off when the herd was let out of the barn to graze. Each two week period included a sample set of Holstein and Brown Swiss cows. Since the dairy herd at Stateland Dairy has more Holsteins than Brown Swiss, every available Brown Swiss cow used in each trial was paired with a Holstein of a similar stage in lactation.

Data was collected using three devices. The first device was the CowManager ear tags, which were designated to individual cows. The ear tags monitored each cow's behavior 24 hours a day, 7 days a week. This information was relayed to the CowManager router, located at Stateland Dairy, and recorded onto the CowManager webpage for Eastern Kentucky University. However, only the behavior patterns for the two week intervals for three hours of grazing time per day were transferred onto an excel sheet. The data specifically needed for this study was the percentage of each time period that the individual cows were identified doing the behaviors of high activity, low activity, no activity, eating, and ruminating.

The second device used to collect data was the KyMesonet weather tracker, which is also located on Eastern Kentucky University's Meadowbrook Farm. The KyMesonet weather tracker would record weather patterns onto the KyMesonet webpage. The average temperature and humidity was calculated for the three hour period that the cows were out grazing, and transferred onto the excel sheet.

The third device used to collect data were the milkers, which were used to collect milk from the cows twice a day. As the cows were milked, the machine also recorded the pounds of milk produced. The percent fat, percent protein and SCC were obtained from monthly testing done by the Dairy Herd Improvement Association (DHIA). For the purpose of these trials, the average pounds of milk, percent fat, percent protein and SCC of each cow per two week period were transferred onto the excel sheet. Other data recorded, but did not need a specific piece of equipment to track, was breed and calving date- which was used to calculate the month in lactation. The date and times that the cows were let out and back into the barn were also recorded.

Spring Trial

Table 1 Sample of Data Recorded for Each Cow during Spring Trial

Cow	Breed	Date	Calving Date	Month in Lactation	Lbs of Milk	**Fat %**	**Pro %**	**SCS**	Time in	Time out
1090	BS	4/27/2015	1/28/2015	3	78	3.3	3.4	0.2	11:30	3:00 PM
1190	BS	4/27/2015	3/1/2014	14	60	3.3	3.6	1.2	11:30	3:00 PM
1191	BS	4/27/2015	7/27/2014	9	53	5.4	3.9	-	11:30	3:00 PM
1193	BS	4/27/2015	3/6/2015	2	86	3.4	3	0.5	11:30	3:00 PM
1227	BS	4/27/2015	6/4/2014	11	52	4.6	3.4	0.2	11:30	3:00 PM
1228	BS	4/27/2015	6/3/2014	11	50	4.1	3.7	1.6	11:30	3:00 PM
1229	BS	4/27/2015	9/27/2014	7	56	4.6	3.9	1	11:30	3:00 PM
1291	BS	4/27/2015	6/11/2014	11	40	4.4	3.6	1.1	11:30	3:00 PM
1290	BS	4/27/2015	4/25/2014	12	62	4.4	3.9	0.3	11:30	3:00 PM
1018	H	4/27/2015	12/19/2014	5	92	3	3	0.6	11:30	3:00 PM
1201	H	4/27/2015	9/9/2014	8	82	3.3	2.9	0.4	11:30	3:00 PM
1116	H	4/27/2015	7/31/2014	9	56	3.8	3.5	0.2	11:30	3:00 PM
1203	H	4/27/2015	1/18/2015	4	88	1.9	2.9	0.2	11:30	3:00 PM
1224	H	4/27/2015	8/20/2014	9	76	3.5	3.1	1.6	11:30	3:00 PM
1221	H	4/27/2015	9/15/2014	8	88	3.2	2.9	1.2	11:30	3:00 PM
1230	H	4/27/2015	11/27/2014	5	72	3.4	2.9	1.7	11:30	3:00 PM
1215	H	4/27/2015	3/28/2014	13	78	3.3	3	2.9	11:30	3:00 PM
1218	H	4/27/2015	7/9/2014	10	72	3	3	2.8	11:30	3:00 PM

Table 1 above contains a portion of the data recorded on the first day of the spring trial. The spring trial ran from April 27, 2015 through May 10, 2015. This trial included nine Brown Swiss cows and nine Holstein cows, whose respective ID numbers can be seen in Table 1. As mentioned before, the sample set was chosen based on calving date. For each Brown Swiss, there is a Holstein with a comparable month in lactation. As can be seen, the average pounds of milk, percent fat, percent protein and somatic cell count were recorded. Also, for this particular day, the cows were let out at 11:30 AM and were allowed to graze until 3:00 PM. Although the cows were allowed to graze for three and a half hours, only behavioral percentages from 11:30 AM until 2:30 PM were recorded onto the excel sheet. For the spring trial, the cows were generally let out to graze in the morning to early afternoon. This was left up to the discretion of the cow manager. The earliest the cows were let out in the spring was 7:50 AM, and the latest they were let out on a particular day was 11:30 AM.

Table 2 contains the rest of the data recorded for the first day of the spring trial. HA stands for high activity, LA stands for low activity, NoA stands for no activity, Rum stands for rumination and Eat stands for eating. Also, 1 stands for the first hour, 2 stands for the second hour, and 3 stands for the third hour. Therefore, when you put it all together, you get the percentage per hour that each cow spent doing one of the five behavioral activities. Every so often CowManager would fail to record data on a cow, as can be seen seven rows down on the table. In this case, the dairy manager would be notified and he would fix the sensor for the next day. The average temperature and humidity for each three hour interval were the final pieces of data recorded. From April 27th to May 10th the highest temperature was 75 degrees Fahrenheit while the lowest was 54 degrees Fahrenheit. The highest humidity was 73% while the lowest was 47%.

Table 2 Sample Data of Grazing Patterns, Temperature and Humidity during Spring Trial

Cow	HA1	LA1	NoA1	Rum1	Eat1	HA2	LA2	NoA2	Rum2	Eat2	HA3	LA3	NoA3	Rum3	Eat3	Temp	Humidity
1090	0%	3%	0%	0%	97%	6%	5%	5%	8%	77%	6%	6%	18%	62%	8%	56 degrees F	47%
1190	11%	3%	27%	8%	79%	11%	3%	27%	47%	11%	16%	0%	0%	11%	72%	56 degrees F	47%
1191	5%	5%	0%	8%	86%	9%	6%	16%	2%	67%	6%	14%	13%	59%	8%	56 degrees F	47%
1193	0%	3%	0%	2%	95%	2%	2%	0%	13%	84%	13%	3%	17%	59%	8%	56 degrees F	47%
1227	3%	11%	0%	0%	85%	8%	2%	6%	0%	84%	8%	15%	8%	32%	37%	56 degrees F	47%
1228	2%	3%	0%	0%	95%	2%	0%	0%	0%	98%	7%	2%	41%	37%	14%	56 degrees F	47%
1229	no data															56 degrees F	47%
1291	0%	14%	0%	0%	86%	8%	2%	43%	9%	38%	5%	2%	33%	58%	3%	56 degrees F	47%
1290	0%	16%	0%	0%	84%	3%	13%	0%	0%	84%	3%	7%	44%	36%	10%	56 degrees F	47%
1018	0%	3%	2%	0%	95%	5%	5%	15%	27%	48%	3%	3%	65%	14%	14%	56 degrees F	47%
1201	2%	2%	6%	3%	87%	6%	8%	23%	47%	16%	5%	3%	74%	15%	3%	56 degrees F	47%
1116	2%	2%	2%	2%	94%	0%	2%	61%	21%	16%	8%	3%	44%	0%	45%	56 degrees F	47%
1203	0%	0%	2%	13%	86%	0%	2%	32%	16%	51%	3%	2%	46%	40%	10%	56 degrees F	47%
1224	0%	8%	0%	0%	92%	2%	2%	0%	33%	63%	5%	3%	0%	74%	18%	56 degrees F	47%
1221	2%	11%	0%	0%	87%	0%	0%	0%	16%	84%	5%	0%	11%	53%	31%	56 degrees F	47%
1230	0%	5%	2%	5%	69%	3%	0%	0%	44%	52%	3%	0%	0%	92%	0%	56 degrees F	47%
1215	5%	10%	2%	8%	76%	0%	2%	18%	31%	50%	6%	0%	73%	14%	6%	56 degrees F	47%
1218	16%	6%	5%	0%	73%	13%	0%	0%	23%	64%	6%	8%	2%	51%	33%	56 degrees F	47%

HA- High Activity
LA- Low Activity
NoA- No Activity
Rum- Ruminating
Eat- Eating

1- 1st Hour
2- 2nd Hour
3- 3rd Hour

Summer Trial

Table 3 Sample of Data Recorded for Each Cow during Summer Trial

Cow	Breed	Date	Calving Date	Month in Lactation	Lbs of Milk	**Fat %**	**Pro %**	**SCC**	Time in	Time out
1090	BS	7/20/2015	1/28/2015	6	68	4.4	3.4	0.2	8:00 PM	11:00 PM
1190	BS	7/20/2015	3/1/2014	17	74	4.6	3.9	0.9	8:00 PM	11:00 PM
1193	BS	7/20/2015	3/6/2015	5	76	3.4	3.1	0.2	8:00 PM	11:00 PM
1228	BS	7/20/2015	6/3/2014	14	47	3.7	3.3	4.2	8:00 PM	11:00 PM
1229	BS	7/20/2015	9/27/2014	10	49	4.3	3.8	0.2	8:00 PM	11:00 PM
1018	H	7/20/2015	12/19/2014	8	82	3.5	3.1	0.6	8:00 PM	11:00 PM
1201	H	7/20/2015	9/9/2014	11	74	3.5	3.1	0.2	8:00 PM	11:00 PM
1203	H	7/20/2015	1/18/2015	7	78	2	2.9	0.2	8:00 PM	11:00 PM
1221	H	7/20/2015	9/15/2014	11	56	4	3.1	2.5	8:00 PM	11:00 PM
1230	H	7/20/2015	11/27/2014	8	72	3.2	2.9	1.9	8:00 PM	11:00 PM
1218	H	7/20/2015	7/9/2014	13	72	3.2	3	3	8:00 PM	11:00 PM
1316	H	7/20/2015	6/18/2015	2	49	7.2	2.7	5.3	8:00 PM	11:00 PM

Table 3 above contains a portion of the data recorded on the first day of the summer trial. The summer trial ran from July 20, 2015 through July 31, 2015. This trial included five Brown Swiss cows and seven Holstein cows, whose respective ID numbers can be seen in the spreadsheet. As can be seen, this trial actually had a smaller sample set of Brown Swiss cows than Holstein cows. This was because a number of the CowManager trackers malfunctioned and failed to record data for several days. In fact, on Saturday July 25th the system failed to record data on any of the cows, so this day was omitted. For the summer trial, the dairy manager decided to let the cows out in the evening. On this particular day, the dairy herd was let out to graze from 8:00 PM to 11:00 PM. The earliest the cows were let out during the summer trial was 7:30 PM and the latest they were let out to graze was 8:00 PM. Once again, the average pounds of milk, fat percentage, protein percentage and somatic cell count were recorded.

Table 4 Sample of Grazing Patterns, Temperature and Humidity Recorded During Summer Trial

Cow	HA2	LA2	NoA2	Rum2	Eat2	HA3	LA3	NoA3	Rum3	Eat3	Temp	Humidity
1090	33%	15%	0%	32%	20%	40%	3%	0%	42%	15%	77 degrees F	92%
1190	25%	5%	0%	15%	56%	24%	5%	39%	15%	18%	77 degrees F	92%
1193	13%	3%	3%	48%	33%						77 degrees F	92%
1228	27%	11%	5%	21%	35%	19%	2%	0%	56%	23%	77 degrees F	92%
1229	41%	11%	3%	6%	37%	29%	10%	0%	8%	53%	77 degrees F	92%
1018	21%	22%	14%	29%	14%	11%	13%	43%	19%	14%	77 degrees F	92%
1201											77 degrees F	92%
1203	10%	6%	16%	35%	33%	2%	0%	86%	11%	2%	77 degrees F	92%
1221	13%	3%	6%	49%	29%	2%	2%	41%	54%	2%	77 degrees F	92%
1230	11%	2%	2%	77%	8%	0%	5%	56%	38%	2%	77 degrees F	92%
1218	36%	6%	0%	36%	22%	16%	3%	64%	16%	2%	77 degrees F	92%
1316	3%	2%	62%	27%	6%	0%	0%	33%	62%	5%	77 degrees F	92%

Another issue that occurred during the summer trial was the KyMesonet weather tracker was down for about a week. Therefore, instead of collecting temperatures directly from the farm where the cows were located, the average temperature and humidity for each three hour period was calculated based on the Weather Channel's data for Madison County. Also, on Tuesday, July 22nd it was raining, so the dairy manager decided to not let the cows out to graze at all in order to preserve the integrity of the pasture. Despite the various equipment malfunctions during the summer trial, as much data was recorded as possible, and later used in the statistical analysis. Table 4 above contains the second and third hours of data recorded, and the temperature and humidity for the first day of the summer trial. From July 20th to July 31st the highest temperature was 81 degrees Fahrenheit while the lowest was 69 degrees Fahrenheit. The highest humidity was 95% while the lowest was 72%. Inherently, the average temperature and humidity was higher overall in the summer trial than in the spring trial.

Fall Trial

Table 5 Sample of Data Recorded for Each Cow during Fall Trial

Cow	Breed	Date	Calving Date	Month in Lactation	Lbs of Milk	**Fat %**	**Pro %**	**SCC**	Time in	Time out
1090	BS	9/18/2015	1/28/2015	8	64	4.5	3.5	1.2	7:45 PM	10:45
1190	BS	9/18/2015	3/1/2014	19	58	4.5	3.8	1.6	7:45 PM	10:45
1191	BS	9/18/2015	9/7/2015	1	102	4.2	3.5	0.2	7:45 PM	10:45
1193	BS	9/18/2015	3/6/2015	7	66	2.6	3.7	2.2	7:45 PM	10:45
1227	BS	9/18/2015	8/5/2015	2	78	3.4	2.9	0.2	7:45 PM	10:45
1228	BS	9/18/2015	6/3/2014	16	44	4.6	4	2.3	7:45 PM	10:45
1229	BS	9/18/2015	9/27/2014	12	56	5.2	4.1	0.8	7:45 PM	10:45
1290	BS	9/18/2015	7/27/2015	2	108	2.2	3.2	2	7:45 PM	10:45
1319	BS	9/18/2015	6/19/2015	4	58	3.6	3.2	3.4	7:45 PM	10:45
923	H	9/18/2015	1/1/2015	9	76	3.9	3.5	0.2	7:45 PM	10:45
1201	H	9/18/2015	9/9/2014	13	82	3.5	3.2	1.3	7:45 PM	10:45
1116	H	9/18/2015	9/2/2015	1	92	3.4	2.9	0.3	7:45 PM	10:45
1203	H	9/18/2015	1/18/2015	9	54	2.2	3.4	0.6	7:45 PM	10:45
1224	H	9/18/2015	9/5/2015	1	96	2.9	2.7	2.3	7:45 PM	10:45
1221	H	9/18/2015	9/15/2014	13	56	3.9	3.4	2.7	7:45 PM	10:45
1230	H	9/18/2015	11/27/2014	10	48	3	3.7	2.9	7:45 PM	10:45
1215	H	9/18/2015	8/23/2015	1	98	2.8	2.7	0.9	7:45 PM	10:45
1316	H	9/18/2015	6/18/2015	4	60	3.6	3	1.5	7:45 PM	10:45

Table 5 above contains a portion of the data recorded on the first day of the fall trial. The fall trial ran from September 18, 2015 through October 1, 2015. This trial included nine Brown Swiss cows and nine Holstein cows, whose respective ID numbers can be seen in the spreadsheet. As mentioned before, the sample set was chosen based on calving date. For each Brown Swiss, there is a Holstein with a comparable month in lactation. For the fall trial, the dairy manager decided to let the cows out in the evening. On this particular day, the dairy herd was let out to graze from 7:45 PM to 10:45 PM. The earliest the cows were let out during the fall trial was 7:30 PM and the latest they were let out to graze was 8:30 PM. Once again, the average pounds of milk, percent fat, percent protein and somatic cell count were recorded. Table 6 below contains the second and third hour of data recorded, and the temperature and humidity for the first day of the fall trial. From September 18th to October 1st the highest temperature was 70.2 degrees Fahrenheit while the lowest was 54.8 degrees Fahrenheit. The highest humidity was 98% while the lowest was 76%. Therefore, the temperatures were cooler than those in the summer, but the humidity was relatively high.

Table 6 Sample of Grazing Patterns, Temperature and Humidity Recorded during Fall Trial

Cow	HA2	LA2	NoA2	Rum2	Eat2	HA3	LA3	NoA3	Rum3	Eat3	Temp	Humidity
1090	3%	2%	17%	68%	11%	2%	3%	18%	53%	24%	67 degrees F	92%
1190	0%	2%	31%	66%	2%	0%	2%	40%	34%	24%	67 degrees F	92%
1191	0%	2%	31%	66%	2%	0%	2%	40%	34%	24%	67 degrees F	92%
1193	3%	3%	37%	52%	5%	2%	3%	19%	76%	0%	67 degrees F	92%
1227	0%	0%	0%	100%	0%	3%	2%	6%	24%	65%	67 degrees F	92%
1228	3%	5%	23%	60%	10%	0%	2%	34%	58%	6%	67 degrees F	92%
1229	5%	0%	21%	48%	26%	5%	6%	19%	43%	27%	67 degrees F	92%
1290											67 degrees F	92%
1319	0%	2%	61%	34%	3%	2%	2%	24%	63%	10%	67 degrees F	92%
923	2%	2%	17%	80%	0%	0%	0%	97%	3%	0%	67 degrees F	92%
1201	7%	7%	44%	25%	18%	5%	5%	7%	80%	3%	67 degrees F	92%
1116	6%	0%	11%	71%	11%	3%	3%	18%	68%	8%	67 degrees F	92%
1203	2%	5%	28%	66%	0%	0%	2%	67%	27%	5%	67 degrees F	92%
1224	0%	0%	16%	55%	29%	0%	3%	46%	51%	0%	67 degrees F	92%
1221	2%	0%	19%	40%	39%	6%	3%	52%	6%	32%	67 degrees F	92%
1230	5%	8%	13%	58%	16%	0%	0%	92%	6%	2%	67 degrees F	92%
1215	0%	0%	5%	74%	21%	0%	5%	79%	16%	0%	67 degrees F	92%
1316	2%	5%	92%	2%	0%	0%	2%	90%	8%	0%	67 degrees F	92%

Statistical Analysis

Data was analyzed using Statistical Analysis System (SAS) software, version 9.4 (2016). Multivariate multiple linear regression analyses were performed with the general linear model procedure (Proc GLM) using the type III sums of squares. The dependent variables were cow activity (High Activity, HA; Low Activity LA; No Activity NoA; Eating and Ruminating, Rum) for each of the 3 hours during grazing (i.e HA1 = High activity for the first hour of grazing). The independent variables in each model were: Breed of Cow (Holstein & Brown Swiss), season (spring, summer & fall), month of lactation, pounds of milk, percent fat, percent protein, somatic cell count, environmental temperature and humidity. Overall 15 statistical models were analyzed with a total of 16,965 data points. A sample statistical analysis for HA1 is in Table 7.

Table 7 Sample Regression Analysis for the dependent variable High Activity during the first hour of grazing

Source	DF	SS	Mean Square	F	Pr>F
Model	10	0.9582589	0.09582589	13.76	<.0001
Error	578	4.02553635	0.006964596		
Corrected Total	588	4.98379525			

Source	DF	Type III SS	Mean Square	F	Pr>F
Breed	1	0.02692334	0.02692334	3.87	0.0498
Season	2	0.06197513	0.03098757	4.45	0.0121
Month_Lactation	1	0.11069703	0.11069703	15.89	<.0001
Lbs_milk	1	0.07190319	0.07190319	10.32	0.0014
% Fat	1	0.04050576	0.04050576	5.82	0.0162
% Protein	1	0.00098174	0.00098174	0.14	0.7075
SCC	1	0.00073607	0.00073607	0.11	0.745
Temperature	1	0.27838143	0.27838143	39.39	<.0001
Humidity	1	0.01871695	0.01871695	2.69	0.1017

Results

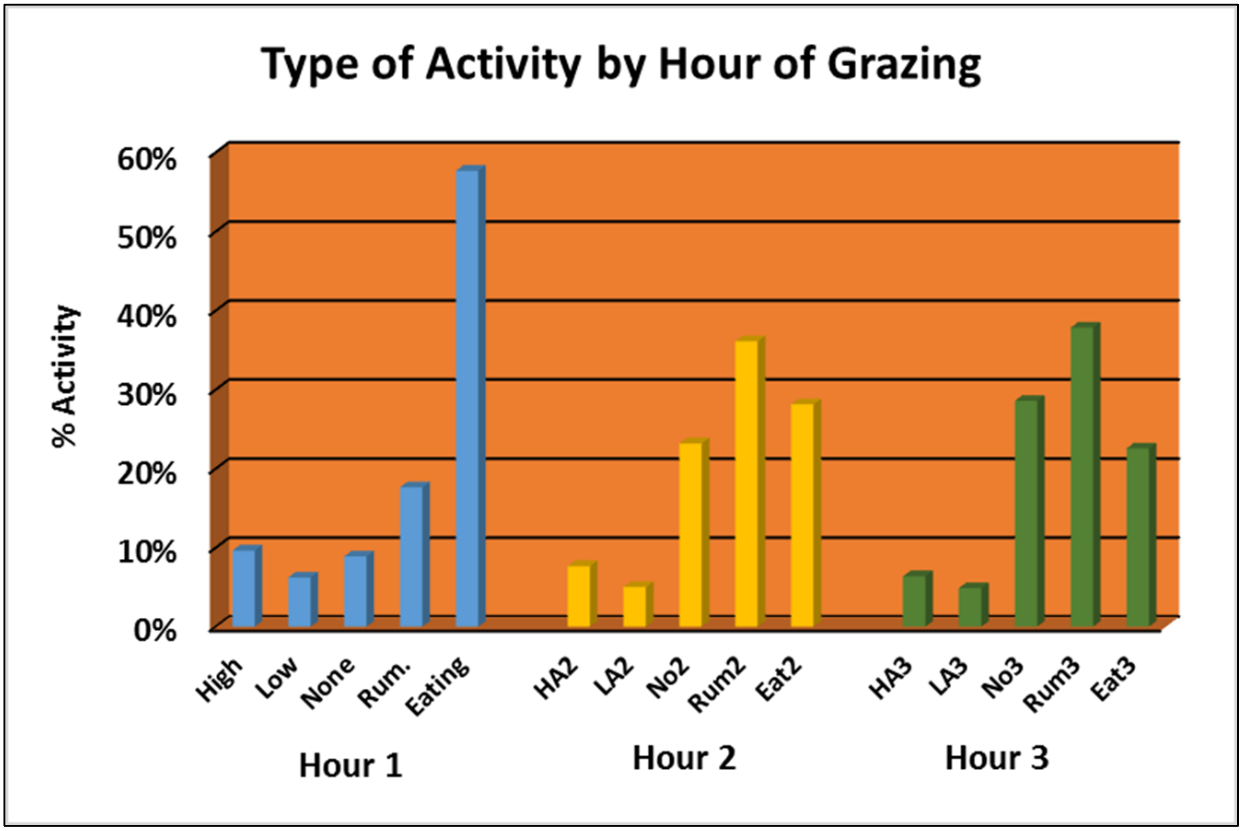

Figure 4 Type of activity by hour of grazing

Figure 1 summarizes the type of activity by hour of grazing. It is a combination of all three seasons and both breeds of dairy cattle. As can be seen in the graph, for the first hour, the activity of eating dominated the cow's time, followed by ruminating. For the second hour, the cows spent most of their time ruminating, followed closely by eating and then no activity. In the third hour, the cows slightly increased their time ruminating, which was then followed by no activity and eating. The activities of high and low activity took up less than 10 percent of the cow's time during each hour of grazing.

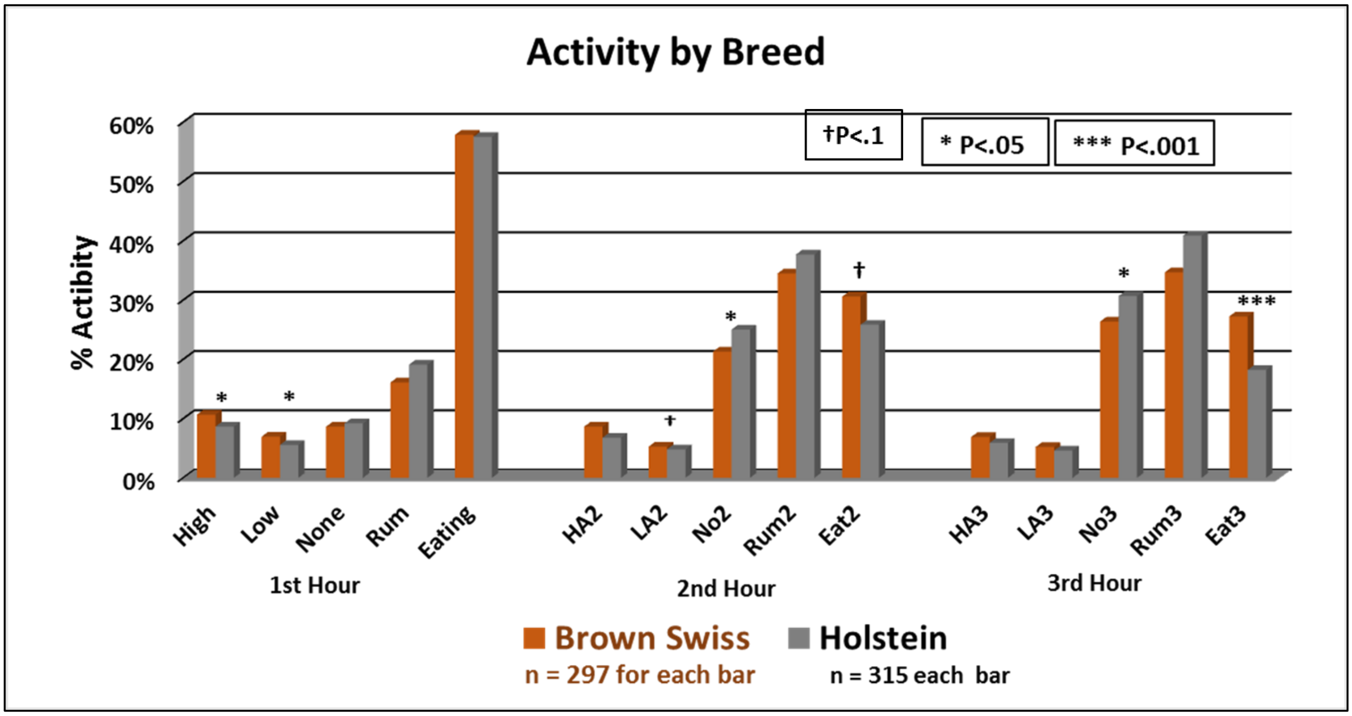

Figure 5. Breed comparison between Brown Swiss and Holstein on of type of grazing activity.

Figure 2 summarizes the activity by breed. Again, the seasons are combined, but now breed differences are accounted for. Important trends to note include that during the first hour, both the Holstein and the Brown Swiss were eating and ruminating to the same extent. Minor differences were not statistically significant. During the second hour the Brown Swiss cows were eating more in proportion to the Holstein, and the Holstein were ruminating more and were less active in proportion to the Brown Swiss. As signified by the cross symbol, the Brown Swiss showed a statistical tendency to be eating more than the Holstein. For the third hour, the activities of the second hour were exaggerated. The Brown Swiss were eating at a statistically significant higher amount that the Holstein. Also, the Holstein were still ruminating more and having less activity in proportion to the Holstein.

Table 8 Probability from Type III Sum of Squares

		Probability from Type III Sum of Squares														
Source	DF	HA1	LA1	NoA1	Rum1	Eat1	HA2	LA2	NoA2	Rum2	Eat2	HA3	LA3	NoA3	Rum3	Eat3
Breed	1	0.0498	0.0142	0.2569	0.2638	0.7188	0.0713	0.9304	0.0026	0.5584	0.0904	0.9982	0.775	0.0216	0.5098	0.0008
Season	2	0.01221	0.6304	0.0022	0.0034	0.0001	0.0011	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0066	0.0002	0.0019
Mo. Lact.	1	0.0001	0.3039	0.0261	0.6062	0.8079	0.0038	0.6781	0.0906	0.3229	0.6232	0.1133	0.7137	0.1954	0.4896	0.1049
lbs milk	1	0.0014	0.5904	0.2766	0.7825	0.6724	0.3543	0.331	0.1508	0.5411	0.502	0.2616	0.1676	0.3236	0.6567	0.4182
% Fat	1	0.0162	0.3604	0.0265	0.6328	0.5366	0.2299	0.723	0.2523	0.4072	0.1724	0.3659	0.1742	0.3214	0.4492	0.2203
% Protein	1	0.7075	0.371	0.1251	0.7003	0.7596	0.4208	0.9708	0.1767	0.111	0.563	0.6369	0.554	0.0366	0.2416	0.2006
SCC	1	0.745	0.9255	0.6433	0.1228	0.3022	0.4232	0.0511	0.612	0.2115	0.0195	0.7711	0.0152	0.3567	0.4037	0.185
Temp	1	0.0001	0.0001	0.1163	0.3295	0.0001	0.0001	0.0001	0.0013	0.1656	0.1141	0.0001	0.0001	0.9105	0.002	0.3749
Humid	1	0.1017	0.8178	0.0835	0.0688	0.0048	0.0065	0.0115	0.9993	0.0199	0.0004	0.161	0.1631	0.5739	0.5568	0.0874

Table 8 summarizes the probabilities from type III sums of squares. When taking a closer look at the hypothesis of no overall breed effect on grazing patterns, the probability of a difference was 0.0754. Since this value is less than 0.1, it means there was not a statistical difference in how the breeds grazed during the first hour, but they had a tendency to be different. In the second hour, the probability of a difference was 0.0454. Since this value is less than 0.05, this means that the difference in grazing patterns between Brown Swiss and Holstein became statistically significant. Finally, the probability of a difference during the third hour is 0.0111. This means that breed difference plays a significant role in grazing during the third hour.

The probabilities for the factors that were statistically significant for an average of all three hours included breed, season, temperature, month in lactation and pounds of milk produced. This means that these factors have an influence on grazing patterns in dairy cattle. Season and temperature contributed significantly to the grazing patterns as indicated by $p<0.0001$. Season and temperature were followed by breed, month in lactation and pounds of milk produced. Factors that were not statistically significant for an average of all three hours include percent fat, percent protein and somatic cell count. This means that these factors did not impact grazing patterns in dairy cattle. The one factor that was inconclusive was humidity. During the statistical analysis process, a few of the humidity data points were entered incorrectly into the SAS program. This gave inaccurate probabilities for humidity; therefore, conclusions cannot be drawn on humidity's impact on grazing patterns.

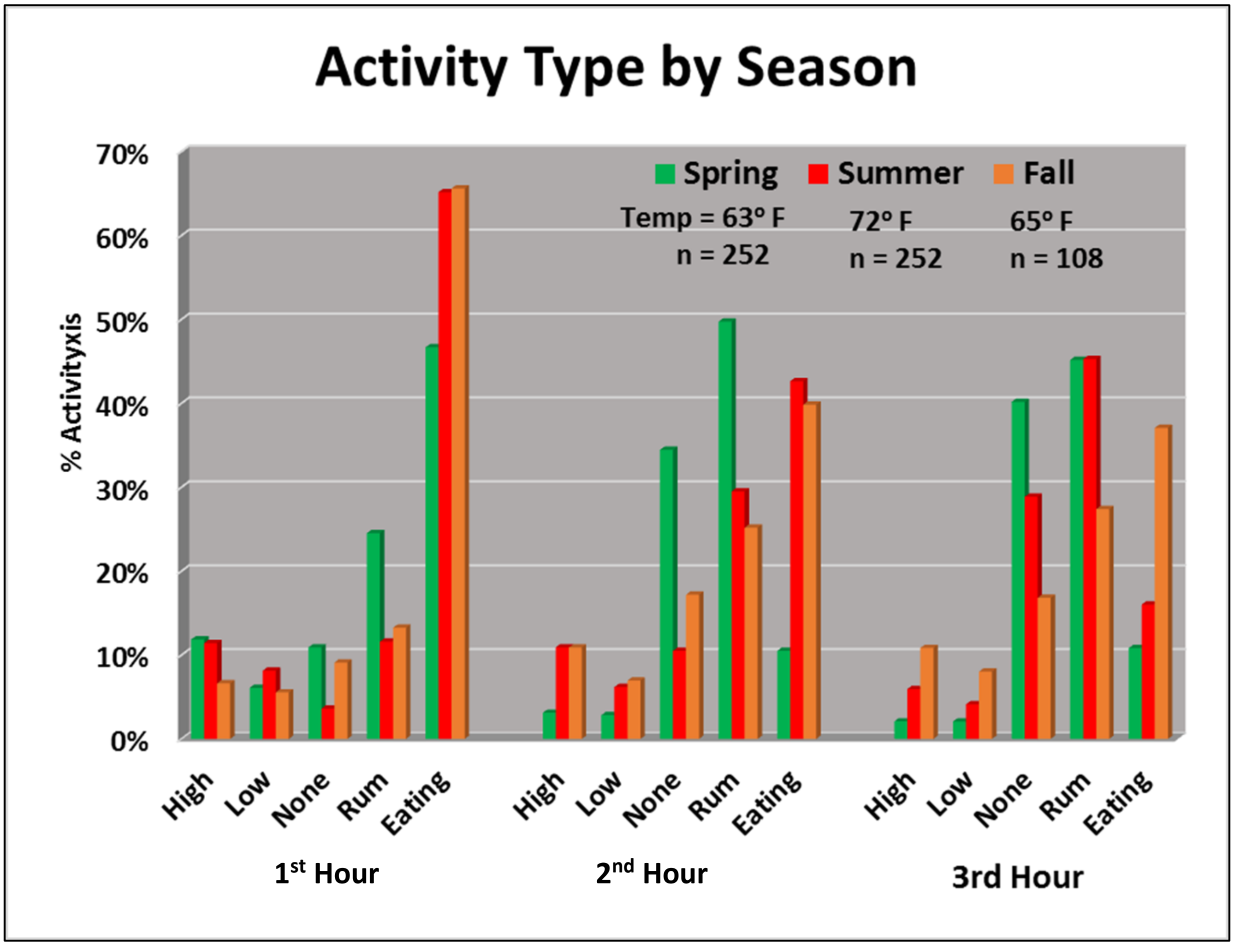

Figure 6. Comparison of Grazing activity type by season.

Figure 3 summarizes the activity type by season. What should be noted here is that during the first hour, the activity of eating dominated the cow's time during every trial. However, there was less eating and more ruminating in the spring in proportion to the summer and fall trials. For the second hour, the cows were mainly ruminating and having no activity during the spring trial, but were still mostly eating in the summer and fall trial. In the third hour for the spring trial, the cows were once again mostly ruminating and having no activity. During the summer, the cows were ruminating and having no activity in greater percentages than during the fall trial. Finally, the third hour for the fall was still dominated by eating.

Discussion

The results displayed in figure 1 were not surprising. In dairy management it is common knowledge that cattle quickly eat when initially given access to pasture. This is followed by rumination, because it is an evolutionary response for cattle to hide from predators and regurgitate and re-masticate the food they just consumed. Since the cattle are "hiding" or lying down as they ruminate, this would also explain why the amount of time the cattle spent having no activity also increased. Although this is not new knowledge, it is interesting to see that the dairy herd at Stateland Dairy followed the expected model of eating first then finding a safe place to lie down and ruminate.

The results displayed in figure 2, on the other hand, represents new knowledge gained on the impact of breed on grazing patterns. These results suggest that Brown Swiss cows continue to graze longer in comparison to the Holstein cows. This information may be pertinent to a dairy farmer because if the Brown Swiss cows are let out to graze, they are able to utilize more pasture in a given amount of time. This efficient use of forage helps reduce feed costs for the producer.

The results displayed in figure 3 give clues on how to manage a dairy herd based on season. For the spring, since the cattle are only eating for the majority of the time during the first hour, the herd should be allowed back inside the barn to get out of the heat. By the second hour, the cows were mainly ruminating and had no activity. Since they are lying down and chewing their cud, they should return to the barn to cool off and reduce the effects of heat stress. However, during the summer, the cows continued mostly grazing through the second hour. This trend in grazing leads to the suggestion that the herd can be allowed to graze for at least two hours before returning to the barn. This will allow for maximum utilization of pasture as a feed source, while again decreasing the chances of heat stress. Finally, during the fall, the cattle continued to graze well into the third hour. This leads to the recommendation that the herd can be allowed to graze for longer during the fall months in order to gain maximum utilization of forages available. Another note to be made pertaining figure 3 is the confounding variable of time of day that the cows were let out to graze each season. In the spring the cows were let out in the morning to early afternoon, so they were exposed to direct sunlight. However, during the summer and fall, the cows grazed in the evening after the sun had set. With this knowledge in mind, a more accurate recommendation may be to let the dairy herd out to graze during hours of no direct sunlight. Once again, this would allow for maximum utilization of pasture while decreasing the effects of heat stress.

The remaining factors that were evaluated that have an impact on grazing patterns include month in lactation and pounds of milk produced. More research would need to be done in order to fully understand the extent to which these factors influence grazing. However, it can be predicted that the factors of month in lactation and pounds of milk impact grazing based on how close the cow is to her postpartum period. A cow that has just recently given birth to a calf and is in peak lactation is in a negative energy balance. Since grass forage does not meet the nutritional demands of a cow’s body in this situation, it may be recommended she be given a TMR or supplement in addition to grazing.

After combining the results of all three figures and comparing it to previous research, an overall recommendation is for dairy managers to choose a grazing system and breed of dairy cow based on individual needs. A large conventional dairy with limited access to pasture would benefit by incorporating mainly Holstein dairy cattle into their business. This is because Holsteins don’t utilize pasture as well as Brown Swiss cows, especially during their postpartum period. A large dairy could invest in advanced technology, such as milking robots in the dairy parlor, in order to produce as much milk as possible per cow. The more milk that can be produced per cow will increase the net income value of each cow. This will allow the farmer to cover the higher feed costs that come along with feeding a TMR. On the other hand, a small-scale dairy enterprise with greater access to grazing pasture would benefit by incorporating more Brown Swiss cows in their business. This is because Brown Swiss cows have better utilization of pasture. Since Brown Swiss cows graze for longer, even in hotter climates, the farmer is able to save in feed costs. Even though Brown Swiss cows produce less milk on average, feed costs are low, so the farmer is still able to adequately cover all expenses. Also, a farmer may be paid a premium for selling grass fed or certified organic products.

Conclusion

In conclusion, this study evaluated the factors of breed, season, production characteristics, temperature and humidity, and their impact on the grazing patterns of high activity, low activity, no activity, eating and ruminating. This study was carried out using the dairy herd at Eastern Kentucky University's Stateland Dairy. The data collected was statistically analyzed, with the end goal of making management recommendations to dairy farmers. These final recommendations include management practices based on breed and season. For breed, it is recommended that the Brown Swiss cows be allowed to graze longer than Holsteins because of their superior utilization of forage as a low cost feed source. For season, it is recommended that the dairy herd be allowed to graze longer in the summer and fall than in the spring. However, it is probably a more accurate recommendation to graze during hours of no direct sunlight, such as early morning and evening, rather than grazing midday. In addition, it is suggested that individual farm managers evaluate their net income per cow relative to feed costs. On one hand, an individual farm may be able to cover the cost of a TMR by having higher production per cow. However, another farm may find it more financially beneficial to have lower producing cows that are capable of utilizing pasture as a cheaper feed source. Finally, if a dairy farm is able to incorporate grazing into their management system, they should see an increase in hoof and udder health. Once again, this will save money for the farmer in the long run by cutting back on veterinary costs and increasing cow longevity. Together these management practices will allow individual dairy farms to function more efficiently in order to remain competitive in today's dairy market.

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