ABSTRACT

White, Sharon Lea. Investigation of Pasture and Confinement Dairy Feeding Systems Using Jersey and Holstein Cattle. (Under the direction of Dr. Steven P. Washburn.)

Today, dairy farmers in the U.S. are faced with the challenge of reducing the cost of producing milk. Milk prices have risen very little in the past decade, while the cost of producing milk has risen steadily. In North Carolina alone, dairy farm numbers have dropped more than 30% in the last ten years, and the trend is expected to continue. Dairy farmers have been forced to increase their profitability to stay in business. In addition, farmers have been forced to comply with stricter environmental regulations. Over the past few years, interest has been shown in intensive management rotational grazing systems. This four-year comparison trial was designed to compare the milk production, herd health, reproductive performance, and environmental impacts of pasture-based and confinement feeding systems using Holstein and Jersey cattle for the Mid-Atlantic region.

The project had both Spring and Fall calving herds with breeding via artificial insemination in 75-day periods. Each seasonal herd replicate had 36 cows on pasture and 36 cows in the confinement group. Similar numbers of Holsteins and Jerseys were included in each year. Paddocks grazed comprised 29 ha of cool and warm season pasture species in 37 paddocks for year-round grazing. Pasture-fed cows received variable amounts of grain and baled silage as needed depending upon pasture availability. Confinement cows were housed in a covered freestall barn with access to an exercise lot and received a total mixed ration with corn silage as the primary forage. Confinement cows produced significantly more milk than pasture-fed cows, both for total lactation and average daily production. Reproductive performance of the two treatments did not differ with an overall 75-day pregnancy rate of 68%. Jerseys in both systems did have higher percentages of cows inseminated (96.5%), conception rate (59.6%), and 75-day pregnancy rate (78%) compared to Holsteins (86%, 49%, 57.9% respectively). The percentage of cows infected with at least one case of clinical mastitis was higher in the confinement herd than the pasture-fed herd (43% vs. 24%) with Holsteins higher than Jerseys (41% vs. 26%). Interactions of breed and feeding system and average somatic cell
count scores were not significantly different. Pasture-fed cows had lower average body condition scores than confinement cows, ranging from 0.2 to 0.6 points lower on a 5-point scale.

In a short-term trial, intake measurements were taken from pasture-fed Holsteins and Jerseys consuming a grain supplement. This supplement was similar to those that were fed to the pasture-fed cows during the four-year trial. It was determined that Jerseys could consume as much as Holsteins at three different feeding levels (6.8, 4.5, and 2.3 kg/cow per feeding). This experiment showed that in certain time frames, Jersey cattle can consume equal amounts of supplements compared to Holsteins. Therefore in mixed groups Jerseys can consume relatively more supplemental energy relative to body size and milk production compared the Holsteins.

In another short-term trial using cows from a spring season replicate, milk samples were obtained from pasture-fed and confinement-fed cattle and analyzed for fatty acid composition. The pasture grazed was a warm-season pasture, while the confinement-fed cattle consumed a corn-silage based TMR. The major fatty acid of interest was conjugated linoleic acid (CLA), which has been shown to be a potent anticarcinogen. Concentrations of CLA were 80% higher in pasture-fed cattle compared to the confinement-fed cattle. In addition concentrations of CLA were higher in Holsteins compared to Jerseys.

To study the distribution of manure in a pasture-based system, pastured cows were observed for several 24-h periods. Data included: (1) times and location of all feces and urine events from eight cows, observed while in the pasture, feed area, milking parlor or in transit; and (2) all urine and feces events on pasture for all 36 cows each grazing period. The locations of urine and feces events were surveyed, mapped and analyzed. Percentages of the manure events in each area were highly correlated with time spent in each area (r= .99). Feces and urine (estimated at .12 m² and .36 m², respectively) from six observational periods covered 10% of the total paddock. Within 30 m² of the portable waterer and gate, concentrations of feces and urine from the warm season observations were significantly greater than concentrations during the cool season observations.
Manure on pasture was relatively evenly distributed over multiple grazing periods with the exception of the area around the water tank during summer grazings.

These experiments showed that when compared to confinement-fed cattle, pasture-fed cattle produced less milk, produced more conjugated linoleic acid, had less mastitis and had lower body condition scores, while reproductive performance did not differ between the two groups. Jerseys had less mastitis, produced less conjugated linoleic acid, and performed better reproductively when compared to Holstein cattle. In addition, pasture-fed Jersey cattle can consume as much supplemental grain in certain time frames as pasture-fed Holstein cattle. Manure distribution on a pasture-based system is highly correlated with time spent in an area and is fairly evenly distributed over the paddock area over multiple grazing periods except for the area around the water tank during heat stress temperatures.
Investigation of Pasture and Confinement Dairy Feeding Systems Using Jersey and Holstein Cattle

by

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A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Master of Science Animal Science

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DEDICATION

This thesis is dedicated to my parents, who always encouraged and believed in me to accomplish many things, and who showed me how to love animals and the outdoors.

I also would like to dedicate it to my advisors, Steve Washburn and Jim Green, who opened up a whole new world for me.
Sharon Lea White was born on May 17, 1972 in Newport News, Virginia, the only daughter of Ralph R. White and Donna C. White. She grew up in the mountains of Patrick County, Va. where she help her parents garden and enjoyed being with her grandparents, “Grandpa and Nannie”.

The books of James Herriot inspired her interest in large animals, along with her Mom’s love of horses and riding. Sharon and her family lived “down east” in Bladen County and then moved to Guilford County where she attended Northwest Guilford High School.

N.C. State was a natural choice for the Animal Science program and family tradition. While at NCSU Sharon worked for Drs. Leece and Gomez with the Autosow, worked at the Dairy Unit, and assisted in the Animal Science Administrative Office. After graduation, Sharon was fortunate to fill an opening as a Research Technician with the department. Sharon worked with Dr. Jeff Armstrong on ultrasound use for pregnancy detection in swine and with Drs. Steve Washburn and Jim Green on a long-term sustainable dairy project, which later became her graduate research project. Through this technician position and her graduate work Sharon was able to learn many different skills and was exposed to many different ways of thinking about agriculture.
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General Introduction

With the economic challenges facing dairy farming today, dairy farmers have been forced to find ways to increase their profitability to stay in business. Feed is the largest cost in producing milk. Some interest has been shown in pasture-based systems where grazing fresh pastures provides the majority of the cow’s feed. In addition to reduced feed costs, pasture-based systems can have lower capital costs for machinery, manure systems, and facilities.

There have been a very limited number of multi-year comparisons between pasture-based and confinement based dairy systems. Most research that has been conducted has been short-term comparison trials. To truly evaluate the possible economic and environmental advantages of pasture-based dairying, there is a need for multi-year whole lactation comparison trials. These studies should employ the directive of a system-wide comparison as opposed to individual comparisons. This experiment was designed and carried out as a system-wide comparison.

In addition, most U.S. pasture studies have been located in the Northeast or Midwest. The Mid-Atlantic and Southeastern regions of the U.S. offer long growing seasons and many types of pasture species. This experiment was designed to compare confinement and pasture systems with the soils, forages and climate of the Mid-Atlantic region.

Both short and long-term trials have reported that confinement-fed cows produce more milk than pasture-fed cattle (Rust et al., 1995; Kolver and Muller, 1998a), while Bela et al. (1995) did not report significant differences between the two systems. Studies that have transitioned confinement-fed cattle to a pasture feeding system have noted steep declines in milk production (Hoffman et al. 1993; Fales et al. 1995). Comparison trials have shown differences in favor of pasture systems with reproductive performance (Bela et al, 1995; Phillips, 1990), mastitis and somatic cell counts (Bela et al, 1995; Goldberg et al., 1992), hoof health (Hahn et al., 1996; Phillips et al. 1990), general cow health (Bela et al, 1995; Brown, 1990). Trials have also shown pasture-fed cattle tend to have lower body condition scores (BCS) compared to confinement-fed cattle. (Kolver and Muller,
Other trials have not shown differences between the two systems with somatic cell counts (Rust et al., 1995), general herd health (Parker et al., 1993), and BCS (Rust et al. 1995).

Few studies have examined the rate at which cattle of different breeds can consume a grain-based concentrate ration. Harshbarger (1949) and Stallcup et al. (1959) have reported that Holsteins cows consume grain faster than Jersey cattle. The rate and amount of feed consumed by different cows is important when cows of different breeds are fed as a group and the total amount of grain available is restricted. Such situations occur with pasture based dairy systems where groups of cattle are fed small amounts of grain. When grazing cattle are eating a limited amount of a corn-based supplemental grain ration, it is possible that Jerseys may be able to eat as much supplement as Holsteins can. If this is true, it is possible that Jerseys can consume relatively more of their energy needs from the supplement compared to Holsteins, which may affect the comparative performance of Jersey cattle. In addition, if cattle consume grain at different rates erroneous inferences may be drawn about the productivity of cows of different breeds under intensively managed grazing systems.

The effect of pasture intake on conjugated linoleic acid (CLA) levels in bovine milk has also been examined. Many research studies have shown CLA to be a potent anticarcinogen (Ha et al., 1990; Ip et al., 1991; Ip et al., 1994). The National Academy of Sciences (N.R.C, 1996) has identified CLA as the only known fatty acid to inhibit cancer in experimental animals. Conjugated linoleic acid has also been linked to lean body mass-enhancing properties (Park et al., 1997; Park et al., 1999; West et al., 1998). Conjugated linoleic acid is found primarily in the meat and milk of ruminants. Milk fat is considered the richest natural source of CLA (Parodi, 1977). Some studies have shown that pasture intake can increase the levels of CLA in cow’s milk (Timmen and Patton, 1988; Jahreis et al., 1997; Kelly et al., 1998b; Dhiman et al., 1999b).

Grazing livestock play an important role in the ecology of pasturelands. Livestock consume nutrients in the form of forages and excrete these nutrients back onto the pasture in the form of feces and urine. In addition, some of the nutrients consumed during supplemental feeding are also deposited onto the pasture. The deposition of
nutrients can be an environmental problem from the standpoint of non-point source pollution. Non-point source pollution can occur from grazed pastures and conventional drylots in the form of surface water runoff that occurs during rain storm events. According to Line et al. (1998), some conventional-type dairy farms can contribute significant sources of non-point source pollution. However the use of rotational grazing systems can lessen the impacts (Correll, 1996; Line et al., 1998; Goetz, 1999).

The objective of this four-year trial was to comprehensively compare the performance of Holsteins and Jerseys under a pasture-based or confinement system. Factors evaluated included: milk production, udder health, herd health, and reproduction. A second objective was to examine the rate at which pasture-fed Holsteins and Jerseys consumed a grain supplement. A third objective was to compare levels of milk components and fatty acid levels between Holsteins and Jerseys under a pasture-based or confinement system. The final objective of this multi-year study was to study manure distribution within a pasture-based system, specifically to determine the relative amounts of manure that were deposited on the pasture compared to the barn areas and to study the manure distribution within the grazed area to determine any patterns or effects.
Literature Review

Pasture-Based Systems

Introduction

Feed costs can make up to 60% of the cost of producing milk when all purchased feeds and supplements and the cost of production of crops grown for feed are included. The cost of producing crops includes: planting, harvesting, storage, and feed distribution, and the maintenance and fuel costs of the machinery used. Other costs of running a dairy farm are land charges, housing, milking, manure handling facilities, seed, fertilizer, labor, chemicals, equipment, and machinery costs. Over the past 15 years, many of the input costs of producing milk have increased, while average milk prices dairy farmers are paid have not increased. These trends have greatly reduced the profitability of dairy operations. The only way dairy farms can increase net farm income would be to reduce input costs per unit of production. One approach is herd expansion to distribute some costs over larger production units. Another approach is to adopt systems with lower investments and operating costs. Because of the lower input costs grazing systems can have, farmers have looked toward management intensive rotational grazing to help increase profitability. This in turn, could help dairy farmers become more competitive in today’s market (Rust et al., 1995).

History

The Eastern native grasses the first settlers found when they came to America were not very high in quality. Most of the land was in forest, and the native marsh and lowland type grasses were low in digestibility and protein. In many cases, livestock were turned out to fend for themselves and often would overgraze and destroy native grasses. In addition, most native grasses were not high enough in herbage mass or quality to make enough hay to support livestock through the winter season (Edwards, 1948). The European grasses that were imported did well in the more temperate climate of the US (Fales, 1994). In fact, most of the major pasture species used in the US originated from Europe. As development occurred, pasture management got a little more attention, but
hay making was still the major focus (Fales, 1994). During the industrial period, cities increased in size and roads became more developed, allowing milk and milk products to be sold to a larger population. Because of this demand for fluid milk, the incentive was to produce more milk, so farmers looked for ways to boost milk production through the feeding of grains and high quality hay. The development of corn silage occurred in 1880 and by 1885 nearly 50,000 silos had been built, with even more built over the next 10 years. Along with this came the emergence of the Holstein as the “milk production” breed. These factors helped keep the focus on high levels of milk production. The existing pastures were in poor condition and were not properly managed, so pastures did not produce the optimum quality or quantity of forage. During the 1930’s and 1940s, there was some movement towards what P. V. Cardon called a “grass consciousness” (1939). Universities promoted grasslands and pastures as erosion control for areas where cropland was being severely eroded. Some research was conducted on the use of pasture for grazing dairy cattle, but the majority of farmers still used silage and hay. After WWII, there were many types of machinery available and a labor shortage, so farmers continued to rely on hay and silage making equipment. The demand for fresh milk and milk products increased as the population grew. Ration balancing became more common place and hay and silage were forms of feed that were easy to use in rations. With the use of hay, silage and grain, it was possible to maintain high milk production all year round.

In more recent years, it was still more profitable to use machinery to harvest forages compared to using grazed pasture (Fales, 1994). However the increase in petroleum prices in the 1970’s changed the cost of machinery a great deal. In addition, the milk price has not increased to help offset the increased cost of machinery and upkeep.

There are major differences between the grass movement of today compared to the one in the 1930’s and 40’s. Today the movement is farmer driven, truly a grassroots movement, compared to the extension/university focus in the 30’s and 40’s. Much of the knowledge that farmers obtained was through André Voisin’s book “Grass Productivity”, published in 1959 (Fales, 1994). Voisin was himself a farmer and a pioneer in what he called “rational grazing” (Voisin, 1959). Another difference is that today’s interest is
being driven by economics instead of soil conservation, although soil impacts are still important today (Fales, 1994; Bertrand, 1997). Finally, the old system of pasture grazing consisted of just “turning the cows out” on pasture, but today they are highly managed systems (Bertrand, 1997). Easy to use, low cost fencing and watering systems, and the availability of high quality pasture species have made pasture systems more productive and attractive to some producers (Bertrand, 1997).

**Milk Production**

Most studies and surveys have shown a drop in levels of milk production compared to confinement feeding when pasture is used as the primary forage for dairy cattle (Parker et al., 1993). Rust et al. (1995) conducted a 2-year comparison trial between rotationally grazed and confinement-fed lactating cows. The cows, which were Guernsey and Guernsey/Holstein crosses, were fed in a traditional confinement system or grazed for about 4 months in Northern Minnesota. The grazing cows were fed a balanced grain supplement during the grazing period. Averaged across both years, the confinement cows produced 7% more fat-corrected milk compared to the grazing cows. Percentages of fat and protein in the milk produced were similar between the two groups. The grazing cows consumed less grain than the confinement cows, indicating that the pasture cows were consuming a higher percentage of their ration as forage than the confinement cows. This would mean that the grazing cows were consuming less energy, which may explain the lower levels of milk production (Rust et al., 1995). Pasture-fed cows can also have a higher maintenance energy requirement than confinement-fed cattle due to the extra walking that is required to get to and from paddocks and for grazing activity itself. This means the pasture-fed cows have less energy available for milk production. In contrast, Bela et al. (1995) reported no significant differences between pasture and confinement fed cows in a multi-year comparison study in Hungary. In addition, there were no significant differences in fat and protein content. Zartman and Shoemaker (1994) conducted a four-year observational grazing study using Holstein and Jersey cattle in Ohio. Cattle calved in the spring and were grazed from April until November and fed a grain supplement year round. Production patterns were similar to
those of other Ohio herds, with Holsteins producing 98.6% of the state average and Jerseys producing 106% of the state average. Cows in both breeds tended to peak at 60 days in milk, with a slow but steep decline in milk production during lactation. Overall fat and protein percentages were slightly lower than for breed averages. During a 24-week trial, Hoffman et al. (1993) examined production of grazed Holstein cows fed three different supplemental grain rations. No differences in milk production were seen between grain rations, but the authors noted that milk production declined rapidly during the first 8 weeks of the trial for all treatments. Cows declined 25% in milk production during the first 8 weeks, which is nearly twice the expected amount (Hoffman et al., 1993). This steep decline in milk production was also noted in a 6-month grazing study using three different stocking rates and grain supplementation using Holstein cows (Fales, 1995).

In a short-term study, pasture-fed cows were compared to cows fed a total mixed ration (TMR) (Kolver and Muller, 1998a). Cows were transitioned from a total TMR feeding system to an all pasture feeding system (no supplemental feed) by reducing the amount of TMR fed over a 4-week period. Performance was compared between the two groups during the transition and actual experimental periods. During the experimental period, the pastured cows produced 33% less milk than the TMR-fed cows (29.6 vs. 44.1 kg/d, respectively). The pasture-fed cows dropped in milk production from 46.3 kg/d to 29.6 kg/d over the 4-week period. There was no difference in fat percentage between the two groups, however the TMR-fed cows did have a significantly higher protein percentage than the pasture-fed cows (2.8 vs. 2.61, respectively). In an effort to determine the reason for the milk production difference between the two treatments, the authors used the Cornell Net Carbohydrate and Protein System model (Fox et al., 1992) to examine the nutrient intakes of the two groups. The Cornell Net Carbohydrate and Protein System model has been evaluated for use on pasture-fed dairy cattle and it was determined the model could be used to make realistic predictions and evaluations of performance (Kolver et al., 1998c). They determined that the amount of metabolizable energy consumed was the limiting factor in the pasture-fed cows, and was the reason for the lower milk production. The type and supply of metabolizable protein and amino
acids did not appear to be a major factor in the reduced production among the pasture-fed cows.

**Reproduction**

Reproductive performance of grazing dairy cattle is thought to be enhanced by the improved footing that pasture offers. Cattle are more likely to show estrus on surfaces that have stable footing and where they are confident to walk (Britt et al., 1986). In addition, the improved overall health of the cow may aid in improving reproductive performance. However, the fact that pasture-fed cows tend to be in a more negative energy balance for extended periods may have a detrimental effect on reproduction.

There have been few research grazing trials that have looked at reproductive performance specifically. In Hungary, a multi-year comparison between pasture- and confinement-fed dairy cattle was conducted on two different farms. Pastured cows had significantly lower insemination indexes and calving intervals, and produced significantly more calves than the confinement cows (Bela et al., 1995). In another study conducted in England, spring and fall-calving cows were either grazed or fed grass silage at night and were grazed during the day (Phillips, 1990). The spring-calving silage-fed cows had a significantly lower pregnancy rate compared to the other groups (68% vs. 87%), resulting in a much higher number of open cows (13) compared to the other groups (5). The spring silage-fed group also required more services per pregnancy than the other groups (2.43 vs. 1.76). There was no difference between the groups for the calving-to-conception interval. The authors stated that the infertility of the cattle was not due to the failure to exhibit estrus, because all cows were observed in heat and bred at least once. The authors also stated that the poor reproductive performance of the spring silage-fed cattle was due to the low metabolizable energy intake during the breeding season. The grass silage fed was of moderate quality and was restrictive in energy intake (Phillips, 1990).

Some breeding strategies with pasture fed cattle include seasonal breeding, with the majority of the calving being concentrated in the spring or fall months. This calving pattern is to take advantage of the increased growth rates of forages during the spring and fall. Fall calving can be used to avoid heat stress during the hot summer months, while
spring calving can be used to better match pasture growth and to avoid cold stress in the winter season. Seasonal breeding can pose a challenge to new or start-up operations due to the intensive breeding and calving seasons. In addition, reproductive culling may be severe during the first years to ensure the calving pattern will stay seasonal. However, countries such as New Zealand, Australia and Ireland are able to maintain seasonal breeding patterns. In addition, once the reproductive culls have been removed, the reproductive performance of a herd can improve. Over a four-year grazing study using spring calving, Zartman and Shoemaker (1994) found that 1st service pregnancy rate increased, total percent pregnant increased, and services per conception decreased. Reproductive culling rates also decreased over the four years, from 40% the first year to 12% the final year. Another example is the whole herd reproductive statistics from Dave Forgey, a dairy grazier in Indiana. Dave Forgey has been a grazier for several years, and began his seasonal breeding program in 1995. The percentage of his herd calving by his target calving date of April 15th has increased from 68% to 87% (Dave Forgey, 1999 Personal Communication).

Another aspect with seasonal calving is the use of non-Holstein breeds and crossbreeding programs to improve reproductive performance. Some studies have shown reproductive performance differences between Holsteins and Jerseys (Fonseca et al., 1983; Silva et al., 1992). In a study conducted in New Zealand, Friesian and Jersey cattle were stocked at high or low stocking rates on ryegrass (Lolium perenne) and white clover (Trifolium repens) pasture (McDougall et al., 1995). Jerseys were stocked at rates of 3.5 (low) and 4.5 (high) cows/ha and Friesians were stocked at 3.0 (low) and 4.0 (high) cows/ha. The pasture was the only feed available to the cows during the trial. The Jerseys had shorter intervals from calving to first ovulation and from calving to first estrus than the Friesians. Stocking rate also had a negative effect on reproductive performance. The stocking rate by breed interaction approached significance, with the high stocking rate having a greater negative effect on the Friesians. For example, the high stocking rate Friesians had a much higher incidence of no ovulation (50%) and no estrus (62%) compared to the high stocking rate Jerseys (10.6% and 15.1%, respectively). Friesians did produce more milksolids/cow per day than the Jersey cows, and the low stocking rate
groups produced more milksolids/cow per day than the high stocking rate group. Body condition score was also examined, and it was shown that the average BCS for Jersey was higher than for Friesians. When the BCS and reproductive trait interactions were examined for each breed, it was found that BCS was negatively related to the interval from calving to first ovulation and from calving to first estrus for the Friesians, but not related in Jerseys. This evidence led the authors to propose that reproductive performance among Friesians may be more sensitive to the restriction of nutrient intake, and that the two breeds may partition nutrients differently. These differences may have an effect on the reproductive and production performance of different breeds in grazing systems.

One study has looked at the effects of genetic selection on the reproductive performance of grazing dairy cattle. In a study conducted at Moorepark Research Centre in Ireland, the reproductive performance of medium and high genetic merit cows grazing pasture was compared for two seasons (Dillon and Buckley, 1998). High genetic merit cows were cows that had been selected for high milk production with the use of Dutch/US genetics for at least two generations. The medium genetic merit cows were cows that were bred for moderate to high milk production and had at least one generation of Dutch/US genetics. The breeding season lasted for 13 weeks in both years. Both medium and high genetic merit cows were on three different feeding levels. The first level consisted of ryegrass (Loilum perenne) pasture at a stocking rate of 2.54 cows/ha and a concentrate feeding level of 780 kg/cow per lactation. The second level was also ryegrass pasture stocked at 2.54 cows/ha and a feeding level of 1400 kg/cow per lactation. The third level was unrestricted high quality ryegrass pasture and a feeding level of 780 kg/cow per lactation. There was no evidence that the feeding systems had any effect on reproductive performance, however the high genetic merit cows had a greater number of services per conception, lower 1st and 2nd service conception rates, and higher infertility rates. The high genetic merit cows had an overall conception rate of 48% while the medium merit cows had a rate of 56%. Twenty-five percent of the high merit cows had to be culled due to infertility while only 5% of the medium merit cows
had to be culled. The authors stated that the lower reproductive performance of the high genetic merit cows was of concern and would need further investigation.

**Mastitis**

The occurrence of mastitis is thought to be lower in pasture-fed cows because pastured cows are exposed to fewer environmental pathogens compared to confinement-housed cows (Smith and Hogan, 1994). Pasture-fed cows in intensive management systems are usually moved one to two times a day, which means they are moved to a fresh clean area which would house lower concentrations of pathogens. In addition, in situations where pasture-fed cows tend produce less milk, the risk of mastitis could be lower.

In a trial conducted in Northern Minnesota during the summer growing season, pasture-fed cows had similar somatic cell counts compared to the confinement-fed cows (Rust et al., 1995). Bela et al. (1995) compared somatic cell counts between pasture-fed and confinement cows over a few years on two farms. The results reported significantly lower somatic cell counts for pasture-fed cows on one farm during the entire study. The second farm reported significantly lower somatic cell counts for pasture-fed cows for two of the four years monitored. Smith and Hogan (1994) reported low incidences of mastitis cases in a 4-year grazing study. Monthly bulk tank samples were taken from 15 different Vermont farms over a 1-year period (Goldberg et al., 1992). The rotationally grazed herds had the lowest mean standard plate counts during the grazing season. In addition, the lowest counts of Streptococci other than *Streptococcus agalactiae* occurred in the rotationally grazed herds.

**Health**

Brown (1990) surveyed four Pennsylvania dairy farms which reported that animal health was improved with the use of intensive rotational grazing. During a 4-year grazing demonstration project, the occurrence of metabolic diseases was at or below levels expected from a well-managed herd (Hoblet, 1994). Data collected from a dairy farmer survey performed in Pennsylvania did not show any herd health differences between pasture-fed and confinement-fed animals (Parker et al., 1993). Results did show
a wide variation of health status among both types of herds. Bela et al. (1995) conducted a multi-year study and reported changes in culling ages between the pasture and confinement groups. The grazing cows were culled at higher ages than the confinement cows (68.6 months vs. 62.8 months). As a result, the pastured cows had higher lifetime milk production compared to the confinement cows.

Hoof wear and hoof health have been examined in pasture studies. Hahn et al. (1996) examined hoof growth and wear between cows housed on pasture/dirt lots and in a concrete freestall barn. Cows housed on concrete had less wear and higher rates of hoof growth compared to the pasture housed cows. This could have implications on the need and cost for hoof trimming services for pasture housed cows. Phillips (1990) reported higher rates of under-run heel and laminitis in grass silage-fed cows compared to pasture-fed cows.

Differences in body condition score (BCS) have been reported between pasture and confinement-fed dairy cattle. Kolver and Muller examined BCS in a short-term study between pasture-fed cows and TMR-fed cows (1998a). Pasture cows were transitioned from a total TMR system to an all pasture system by reducing the amount of TMR fed over a 4-week period. The TMR-fed cows had a significantly higher BCS (2.5) compared to the pasture-fed cows (2.0). The pasture-fed cows dropped in BCS from 2.5 at the start of the trial to 2.0. The pasture-fed cows also lost the most live weight, averaging a drop of 41 kg. Some blood metabolites were examined, and it was found that ß-hydroxybutyrate and nonesterified fatty acids were both significantly higher in the pasture-fed cows compared to the TMR-fed cows. ß-hydroxybutyrate and nonesterified fatty acids are used as indicators of adipose tissue mobilization. The authors used the Cornell Net Carbohydrate and Protein System model to examine the nutrient intakes of the two treatments, and it was determined that the intake of metabolizable energy was the limiting factor in the pasture-fed cows. This lack of energy intake helped play a factor in the lower BCS scores. Rust et al. (1995) did not report any differences in body condition score between pasture-fed and confinement-fed groups. The pasture-fed cows were fed a grain supplement during the 4-month trial.
During a 24-week trial, performance of pasture-fed cows fed different supplements were examined (Hoffman et al., 1993). BCS was generally low for all three treatments, and did not reach above a score of 3.0. Other grazing trials have reported fairly low BCS scores that are at or below 3.0 (Hongerholt et al., 1997; Jones-Endsley et al., 1997; Holden et al., 1994; McDougall et al., 1995; Fales et al., 1995).

**Supplemental Feeding**

Many researchers think pasture alone is not able to provide enough nutrients to provide for the genetic potential of most high producing US dairy cows (Muller et al., 1998). Using a total pasture system, the US type dairy cow cannot maintain an optimal level of milk production, body condition score, and reproductive performance, especially for the high genetic merit Holstein. Studies performed in other countries has shown that pasture alone can support milk production at 25 to 30 kg/d (Mayne, 1996). Most of New Zealand’s dairy industry is based on pasture-only systems. There the high cost of grain supplementation and the low prices paid for milk make grain feeding uneconomical. However in the U.S. because grain prices are usually low relative to milk prices, grain supplementation of pasture-fed dairy cattle can be profitable and beneficial in maintaining milk production, BCS and reproductive performance.

One reason to increase or maintain the level of milk production per cow is the idea of “fixed cost” (Muller et al., 1998). Each cow has a “fixed cost” or her maintenance requirement. If the cow produces a higher amount of milk, the production efficiency increases and fixed costs decrease as a percent of total costs for that cow. Most researchers recommend that some form of supplement be fed to the grazing dairy cow. Studies have shown the limiting factor is the supply of energy to the grazing cow (Muller et al., 1998; Kolver and Muller, 1998a; Jones-Endsley et al., 1997). This lack of energy can have negative effects on milk production, BCS, and perhaps reproductive performance.

There have been a limited number of supplemental grain feeding studies performed with for pasture-fed dairy cattle. Salinas et al. (1983) fed concentrates to supply 33%, 66% or 100% of energy requirements to multiparous dairy cows who were
grazed on cool season pastures for 140 days. Milk production was not different among the three groups, however the cows used in the study were mid lactation cows that were already past peak milk production. The low-grain group (33%) did lose the most body weight, but treatment differences in weight gains and losses were not statistically different. Jones-Endsley et al. (1997) grazed fourteen mid lactation Holstein cows for 80 days from June to September in Indiana. Cows were fed a supplement that contained 12 or 16% CP on a DM basis and at an amount of 6.4 or 9.6 kg/d. Milk production did not differ between the groups, and no differences in fat or protein percentages were reported. Cows in all groups did lose BCS, indicating that the cows were in negative energy balance (Jones-Endsley et al., 1997).

Dhiman et al. (1997b) performed a 2-year grazing study with spring/early summer calving Holsteins in Wisconsin. Cows were grazed during the growing season and were assigned to three treatment groups: all pasture, 2/3 pasture, or 1/3 pasture, with the balance of the feed for the 2/3 and 1/3 pasture groups being made up with a grain supplement. Milk production did increase with increased grain supplementation. The cows in the pasture, 2/3 pasture and 1/3 pasture groups produced 17.3, 21.2, and 26.3 kg/cow per day respectively. The authors reported that the pasture-only group had lower BCS scores compared to the supplemented groups. In addition, the pasture-only cows had more reproductive failure, which could indicate a low energy balance.

Another factor that affects the performance of pasture-fed cattle is the stocking rate at which cows are grazed. High stocking rates help maximize the use of the pasture, but if too high can have a negative effect on cow performance by limiting the pasture intake of the cows. There have been some studies that have examined different supplemental feeding levels along with different stocking rates.

In a study conducted at Moorepark Research Centre in Ireland, the performance of medium and high genetic merit first lactation cows grazing pasture was compared for two seasons (Dillon and Buckley, 1998). Both medium and high genetic merit cows were on three different feeding regimens. The first regimen consisted of ryegrass (Loilum perenne) at a stocking rate of 2.54 cows/ha and a concentrate feeding level of 780 kg/cow per lactation. The second regimen was also ryegrass pasture stocked at 2.54 cows/ha and
a feeding level of 1400 kg/cow per lactation. The third regimen was unrestricted high quality ryegrass pasture and a feeding level of 780 kg/cow per lactation. The high genetic merit cows did produce more milk than the medium genetic merit cows (5496 kg/cow vs. 6441 kg/cow for the first season). In addition, cows on the second feeding regimen produced more milk than those on the other two regimens (7681 kg/cow vs. 7104 and 7152 kg/cow for the first and third regimens, respectively). There was no interaction between feeding regimen and genetic merit, as both genetic groups of cows responded similarly to the feeding treatments. However, the high genetic merit cows did gain less liveweight and had lower BCS during lactation. This was true of all feeding groups. At the end of the second lactation, the average BCS for the medium genetic merit group was 3.65 vs. 3.11 for the high genetic merit cows. In addition, at all feeding regimens the high genetic merit cows had lower reproductive performance than the medium genetic merit cows. These factors may indicate that despite the higher level of supplement feeding, the high genetic merit cows were in a more severe negative energy balance during early lactation compared to the medium genetic merit cows. Stocking rate did not appear to have an effect in this study.

Robaina et al. (1998) fed different levels of grain supplements to mid to late lactation grazing cows during the summer in Australia. In experiment 1, treatments were high and low pasture allowance with or without grain. In experiment 2, grazed cows were fed 4 different levels of crushed barley: 0, 2, 4, and 8 kg/cow per day. In experiment 1, the high pasture allowance and grain feeding group produced 16.4 L/cow per day compared to 14.0 L/cow per day for the high pasture, no grain group while the low pasture, grain group produced 14.8 L/cow per day and the low pasture, no grain group produced 10.6 L/cow per day. In experiment 2, the group fed 8 kg of barley produced more milk (18.4 L/cow per day) compared to the other levels of feeding (16.1, 15.7, and 12.9 L/cow per day, respectively). The cows at the higher pasture allowance and higher grain levels also had the higher BCS. The authors concluded that if milk price is at least equivalent to the grain price, the moderate use of grain supplements can be profitable with grazing cows during the summer and early autumn. Summer and early autumn tend to be times of low pasture growth and low pasture quality in that area of
Australia. The authors caution that grain feeding should not be used as a substitute for skilled pasture management, but grain feeding can be used economically during low pasture growth. The grain feeding can help substitute for pasture by reducing grazing pressure during low growth times so that the pasture can grow and be used for future grazing.

One study performed with supplementing pasture-fed dairy cows examined the economics of the supplemental feed and milk response. Hoffman et al. (1993) fed three different supplemental grain rations to 54 Holstein cows (average 82 DIM) that were grazed for 24 weeks in Pennsylvania. The three grain levels were: (1) 1 kg of grain/3 kg milk (2) 1 kg of grain/4 to 5 kg of milk; adjusted weekly based upon the quantity of pasture available and (3) 1 kg of grain/4 to 5 kg of milk; adjusted weekly based upon the quantity of pasture available and bimonthly based upon quality analysis of the pasture. Rations 1 and 2 were not reformulated during the trial; only the amount of the supplements were changed. Ration 3 was reformulated based on the quality analysis of the pasture. There were no significant differences in milk production or milk fat percentage amount the three rations. The cows on ration 1 receiving the higher concentrate did have a significantly higher protein percentage compared to the other two groups. When the economic returns were calculated on each ration, ration 3 was the most profitable due to the lower cost of the ingredients and the lower level of total grain fed when compared to ration 1. Because of the high pasture quality during parts of the trial, the amount of ground shelled corn fed in the ration was able to be adjusted to better match the cow’s nutrient needs. Soybean meal (48% crude protein) was only needed to be fed during 4 weeks of the 24-week trial. The amounts of corn distillers grain and corn gluten meal fed were also varied during the trial. This flexibility in the amounts and type of ingredients fed gave ration 3 a net income over feed cost of $6.09 per cow per day compared to $5.67 for ration 1 and $5.75 for ration 2. Adding this net income over feed costs for all 18 cows over the 24 week period, ration 3 netted $18,414 compared to $17,146 and $17,388 for rations 1 and 2 respectively. Although it may be impractical for a dairy producer to sample for pasture quality and reformulate a grazing cow ration every two weeks, it may be possible to use published pasture quality estimates to make ration
adjustments. Even if pasture quality and ration reformulation occurs only monthly, the flexibility of the type and amount of ingredients fed should improve the net income over feed costs for grazing rations.

Rate of Intake

One issue concerning the feeding of supplemental grain to pasture-fed cows is the rate of intake of the supplements. If different cows are able to consume the supplement at different rates, some cows could possibly consume more supplement which would affect the performance of the cow, which would affect the economic evaluation of the cows.

There have been very few studies that have recorded the rate of intake of concentrate supplements for dairy cattle. Most of intake studies have been with hays and silage-based total mixed rations. There have been some studies that examined the rate of eating with grains and other concentrate diets. The rate of consumption depends on the physical characteristics of the feed eaten. Schalk and Amadon reported in 1928 that it took dairy cattle 10 minutes to consume 2.3 kg of whole oats, 14 minutes to consume 2.3 kg of ground grain and 15 minutes to consume 2.3 kg of hay. Harshbarger (1949) compared the eating rates of different feeds among Ayrshire, Brown Swiss, Guernsey, Holstein and Jersey cows. The average rates of consumption ranged from 2 to 3 min per .45 kg of grain, or .15 kg/min to .23 kg/min. In addition, it was reported that the rate of eating was highest for Holsteins and lowest for Jerseys. Dalton et al. (1953) used 12 dairy cattle to determine the intake rates of a grain ration that had three different fineness of grinds (fine, medium, and coarse) and different water-to-concentrate ratios. They observed that as more water was added to the concentrate, the time required to consume the grain mix decreased. This was due to the fact that as the water-to-concentrate ratio increased, cows were able to actually “drink” the grain instead of using the tongue to grab the grain. Fineness of grind did not have an effect on the rate of consumption. Dalton et al. (1953) data showed a range from 37 seconds to 2 minutes and 25 seconds to consume .45 kg of grain, or .73 kg/min to .19 kg/min. For the grain rations that did not have any water added (control ration) times ranged from 1 minute 32 seconds to 2 minutes 31
18 seconds, or .18 kg per minute to .28 kg per minute. The longer eating times were obtained from cattle that had been turned out to good pasture for grazing and may have been less hungry. In another study that used different water-to-concentrate ratios in grain rations, the dairy cattle had an average eating rate of .29 kg per minute for the control (no water added) treatment (Hupp and Lewis, 1958). Byers (1952) found that the rate of consumption changed with the amount fed. Cows ate at a rate of .23 kg per minute when fed 2.36 kg of grain and ate .27 kg per minute when fed 3.3 kg of grain. Stallcup et al. (1959) examined the eating rates of different breeds of cows from 14 farms in Arkansas. The farms included parlor feeding and stanchion feeding systems that both fed a medium ground concentrate. Eating rates averaged from .15 kg per minute to .30 kg per minute overall. The data showed that cows ate faster in the milking parlor compared to the stanchion barns. Rates of consumption averaged .19 kg per minute in the stanchion barn and .25 kg per minute in the parlor. For both types of feeding systems, Holsteins consumed feed faster than the Jersey cows. Stallcup et al. (1959) also looked at eating rates for cattle that were being grazed on pasture, and found the eating rate changed from .34 kg per minute while on winter feeding to .19 kg per minute when the same cows were grazed on a high quality pasture. This was a similar decrease in rate of eating that Dalton et al. (1953) found for cows allowed access to pasture. Data from the Arkansas farms also showed a large amount of variation in rate of consumption among cows within breeds and between farms. These studies showed that rate of intake can be affected by breed, type of feed and level of pasture feeding. The rate of intake of different cows can affect the profitability of the systems.

**Economics**

Many factors affect the economics of a dairy farm. These include: milk production, milk price and market status, seasonal effects, type and amounts of forages and grains fed, stocking rate, herd health, facilities, equipment and labor costs, and the scale of the operation. As has been noted before in many studies, pasture-fed dairy cattle have produced less milk than confinement-fed cattle. This is generally true even if the pasture-fed cows are fed a supplemental grain. However, the potential economic
advantage that grazing systems have are lower input costs. Dairy farmers cannot control milk prices or the prices of purchased inputs, but one way a dairy farmer can increase profit is to reduce input costs per unit of production.

Steve Ford (1996) cited several factors that can reduce input costs on a grazing dairy. These include reductions of: crop production costs, purchased feed, machinery ownership costs and repairs, bedding costs, veterinary costs, storage needs, fuel expenses, and fewer replacements needed due to reduced culling rates. Reduced costs with machinery come from the fact that most grazing dairy farms will not need the long list of equipment needed to plant and harvest silage, and may only need minimal equipment for harvesting. The grazing dairy may not even need hay making equipment at all if custom-hire equipment and labor is available. Other factors may include reduced free stall barn upkeep and reduced manure handling and storage costs. Factors that may decrease profits for a grazing system would be increased purchased feed, lost excess crop and hay sales, and added investment in fencing, lanes and watering systems (Ford, 1996). Ford also points out that the advantage of a pasture system will be higher when row crop and hay costs of production and/or grain prices are high. During low forage and grain prices, pasture will not have as great as an advantage.

Parker et al. (1992) used linked spreadsheet models to compare a pasture and confinement type system for a typical Pennsylvania dairy farm with 80 ha and 53 cows. Total operating expenses were lower for the pasture system. The reasons for the lower expenses were: cropping expenses were lower because less hay was harvested, concentrates were less expensive during the grazing season, the requirement for the grazing animals was lower, and there was less bedding material needed. The confinement system required 280 more hours of forage labor, which was due to the labor intensive task of making hay. The final result was that the pasture system had a $121 net income per cow advantage over the confinement system.

King (1997) used a computer simulation model to determine the optimal stocking and feeding rates for a pasture-based system located in North Carolina. King used data from a four-year comparison pasture trial that was conducted at North Carolina State University. The computer model used was UDDER (1996) which was tested and verified
for modeling a North Carolina system. King found that optimal profitability for the pasture-based farm was high stocking rates in combination with high levels of supplement feeding. The high stocking rate allowed for maximum use of the forage available (80% to 90%), which would increase milk production and maximize the gross margin per hectare. High levels of supplement feeding would increase profitability by further increasing milk production and milk income, leading to a high net income per hectare. Stocking rates were dependent on the type and level of supplemental feeding system. King showed that stocking rates and supplementary feeding levels must be jointly determined for maximum profitability.

From a survey of Pennsylvania dairy farms, Parker et al. (1993) reported that operating costs were $78 per cow lower for the pasture dairies compared to the confinement type operations. While purchased feed costs were about the same for the two systems, the pasture farms had lower costs for veterinary and medicine, fertilizer and machinery repairs and maintenance. This $78 advantage is lower than other reported advantages of $153 per cow (Emmick and Toomer 1991) and $121 per cow (Parker et al. 1992). However the authors state the data should be viewed with caution since not all income and expenses were included and the data were from one grazing season only. Factors such as inventory changes, farm equity, the capital value of the land, and the farm resources were not included in their analysis.

Smith (1994) compared grazing and confinement type New York farms using Dairy Farm Business Summary data. Milk output per cow and per worker was lower on the pasture farms. Total cost of producing milk from the grazing system was $.28 per hundredweight lower than the confinement type systems. Debt per cow was higher on the grazing farms, and net income per cow was about the same, $402 for the pasture and $407 for the confinement. Smith also looked at economic data for the grazing farms that had began grazing in 1993. Over a period of three years, the pasture farms increased net farm income per cow from $240 to $421. This shows that grazing farms can improve economic performance over a few years and it is expected that multiple years of experience in a pasture system would improve efficiency.
Hanson et al. (1998) collected data from different dairy farms in a dairy region in Pennsylvania. Farms that employed some grazing achieved a $129/acre return to operator management compared to $20 for an all hay system and $58 for a corn silage system. The factors identified for this difference were: no storage loss of grazed forage, lower purchased fertilizer and crop chemicals, and the lower repair expense for equipment. These data also showed that farms increasing the use of grazing in their feeding systems produced about 3% less milk per cow but were able to increase their annual return per cow by 9%.

Rust et al. (1995) compared a confinement and pasture system for 2 seasons during the relatively short growing season in Northern Minnesota. Cows were grazed from May until October, and receipts and expenses for both systems were compared. Over the two seasons, during the four-month period, the pasture system had lower gross receipts but also had lower costs of feeding, facilities and labor, which resulted in a higher net return per cow than the confinement system. Averaged over the two seasons, the net return per cow for the pastured cows was $48 more than the confinement cows. This net return per cow was lower than other reported returns, but the authors cautioned that the number may be lower due to several factors: (1) the study was done during a short grazing season (2) the pastures could have been higher quality, including a higher legume content (3) milk production was lower due to the use of Guernsey and Guernsey Holstein crosses, and (4) the value of the excess forage harvested as hay or grazed by dry cows and heifers was not accounted for in the pasture system receipts (Rust et al., 1995). The authors also cautioned that the comparison was done just for the short grazing season and did not account for year round differences. The authors concluded that even in Northern Minnesota with a short grazing season, pasture feeding may be a reasonable option for those farmers who wish to expand or those looking to start a new farm.

It should be noted that the use of a certain type of system does not guaranteed the profitability and success of a dairy farm. Many reports have shown that profitability varies widely among farms of similar sizes, systems and even locations. Reports have also shown variations in the net income per cow among grazing operations.
based systems can help the economics of a farm but management is still the most important factor.

Conjugated Linoleic Acid

A unique factor with pasture-fed dairy cattle is the increased production of conjugated linoleic acid (CLA) in the milk fat. This is seen as a potential opportunity to enhance the marketability and value of milk from pasture-fed dairy cows.

Conjugated linoleic acid refers to various positional and geometric isomers of the fatty acid linoleic acid (cis-9, cis-12 octadecadienoic acid) each with a conjugated double bond arrangement. These bonds can be at several different positions such as 9 and 11, 10 and 12, and 11 and 13. Conjugated linoleic acid began gaining interest when in 1983, Michael W. Pariza and his research team discovered that a compound in raw and ground beef had anti-mutagenic properties (Pariza et al., 1983). This compound was later identified as conjugated linoleic acid (Pariza, 1997). Laboratory animal research conducted in the past few years has shown CLA to be a potent anticarcinogen (Ha et al., 1990; Ip et al., 1991; Ip et al., 1994). The National Academy of Sciences (N.R.C, 1996) has identified CLA as the only known fatty acid to inhibit cancer in experimental animals such as rats and mice. Conjugated linoleic acid has also been linked to enhancing lean body mass (Park et al., 1997; Park et al., 1999; West et al., 1998). CLA is found primarily in the meat and milk of ruminants. Milk fat is considered the richest natural source of CLA (Parodi, 1977). It appears that CLA remains stable in processed dairy products (Lin et al., 1995) and so is a direct function of the concentration of CLA in raw milk. The potentially positive health benefit of CLA offers the dairy industry an exciting opportunity to increase the consumption of dairy products. Further research is being conducted to identify the most beneficial isomers of CLA, how to enhance the production of CLA in bovine milk, and to confirm the health benefits in human studies.

Several naturally occurring isomers of CLA have been identified. According to Ip et al. (1991) and Ha et al. (1990), all the isomers can be incorporated into tissue triglycerides, but the cis-9 trans-11 isomer was found to be the only one incorporated into
membrane phospholipids. Therefore this isomer is considered to be the biologically active isomer. The cis-9 trans-11 isomer is the major isomer of milk fat CLA (Parodi, 1977).

Consumption of CLA in the form of milk products may affect circulating levels of CLA in humans. Huang et al. (1994) showed that the consumption of 112 g of cheddar cheese daily for four consecutive weeks did significantly elevate plasma CLA levels. Jiang et al. (1999) surveyed one hundred twenty-three men on their dietary intakes of milk fat products. Adipose tissue and blood serum samples were obtained and were analyzed for fatty acid composition. They concluded that milk fat intake was significantly related to the amount of CLA in adipose tissue.

Conjugated linoleic acid is a product of the incomplete biohydrogenation of dietary linoleic acid by rumen bacteria. In the next step of the pathway, CLA is further biohyrdrogenated into trans-11-octadecenoic acid, and then finally to stearic acid. The rumen bacteria *Butyrivibrio fibrisolvens* has been identified as able to produce CLA from linoleic acid (Kepler and Tove, 1967) although it is likely that several other species of bacteria are also able to do this. In addition, Corl et al. (1999) have shown that the mammary gland of the cow is able to produce CLA from fatty acids involving the Delta 9 desaturase enzyme system.

To increase the amount of CLA in milk fat produced by dairy cows, many research trials have been conducted to discover what factors affect the amount of CLA produced. These factors include forage to concentrate ratio (Jiang et al., 1996), intake of dietary fatty acids (Kelly et al., 1998a; Dhiman et al., 1997a; Dhiman et al., 1999a; Lawless et al., 1998) season (Reil, 1963; Jahreis et al., 1997) and pasture intake (Timmen and Patton, 1988; Dhiman et al., 1996; Jahreis et al., 1997; Kelly et al., 1998b; Dhiman et al., 1999b) Feeding dietary oils to dairy cattle does have a direct effect on the levels of CLA produced in the milk. Dhiman et al. (1997a) concluded that the amount of CLA in milk fat could be increased by the feeding of linolenic acid in the form of linseed oil. Kelly et al. (1998b) fed peanut oil (high in oleic acid), sunflower oil (high in linoleic acid) and linseed oil (high in linolenic acid) to lactating Holstein cows and found that the sunflower oil diet resulted in the highest amount of CLA in the milk fat. Lawless et al.
used pasture-fed cattle and found that cows that were fed full fat rapeseed and soybean oils produced higher amounts of CLA in the milk fat compared to the control group which was fed pasture and beet pulp. Dhiman et al. (1999a) compared the CLA content of milk fat from cows fed a control diet of soybean meal with cows fed diets containing extruded cottonseed and soybeans. The cows fed the extruded oilseeds produced more CLA compared to the control group.

There is evidence that CLA content of milk fat can vary by season. Reil (1963) examined milk samples from Canadian dairy herds and found levels of CLA were higher during the summer than in winter, presumably due to the availability of fresh pasture during the summer months. It has also been noted that Australian and New Zealand milk products contain higher levels of CLA than American products (Parodi, 1999). This may be due to the extensive use of pasture systems for feeding dairy cattle in that area of the world (Parodi, 1999). Table 1 lists comparative results for a few studies that examine effects of pasture on amounts of CLA in milk. Timmen and Patton (1988) found CLA levels of milk fat were higher from grazing Holsteins compared to Holsteins fed grain and silage. Jahreis et al. (1997) took monthly samples from the bulk tanks of three different German dairy farms for a year’s time. The three dairy farms had different management practices. The first dairy farm was a conventional type farm with cows being housed indoors year round and fed corn silage and grain-based rations; the second was a conventional type farm (corn and grass silages) during the winter months but used pasture during the summer months; the third farm was a pastured-type dairy on which cows grazed during the summer months and were fed clover/alfalfa/grass silages during the winter months. The pastured-type dairy had the highest levels of CLA in the milk, followed by the summer grazing dairy. The conventional type dairy had the lowest levels of CLA produced. Jahreis et al. (1997) also showed a seasonal effect, with the pasture dairy producing the highest levels of CLA in the grazing months of May to September. The summer grazing dairy also showed an increase in CLA produced during the grazing season in contrast to the conventional type dairy where CLA concentrations in milk remained steady throughout the year. The authors stated that the CLA levels were highest in milk from the grazing dairy due to the high levels of consumption of fresh pasture.
grass and grass silages that are high in polyunsaturated fatty acids. High levels of these polyunsaturated fatty acids provide more substrates to be converted into fatty acids such as CLA.

Dhiman et al. (1999b) conducted a trial in which three groups of cows consumed either 1/3, 2/3 or their entire daily feed from pasture. Pasture was grazed from March and May and consisted of bluegrass, quackgrass, bromegrass and white clover. The balance of the feed for the 1/3 and 2/3 groups was made up with a supplement that contained alfalfa hay, corn, and soybeans. The 100% pasture group produced more CLA than the 1/3 and 2/3 pasture groups, 22.1 mg/g of milk fatty acids compared to 8.9 and 14.3 for the 1/3 and 2/3 pasture groups, respectively.

In a trial to see the effect pasture consumption had on amounts of CLA, Kelly et al. (1998b) paired sixteen Holstein cows according to milk yield, live weight, and days in milk and divided them into a grazing or control group. The trial had three phases: initial, transition and final. Though the entire trial, the control group consumed a TMR that consisted of corn silage, legume silage, legume hay, shelled corn and cottonseed. The grazing group also consumed this TMR during the initial 2-week phase. During the 2-week transition phase the grazing group was allowed access to pasture and the amount of TMR fed was reduced. Pastures grazed consisted of 53% ryegrass, 19% white clover, and a mixture (21%) of other cool season grasses. The final phase of the trial also lasted for 2 weeks, during which time the grazing group was fed pasture only. Milk samples were taken at the end of each phase and analyzed for fatty acid composition. Amounts of CLA were similar for the two groups during the initial phase. Samples from the transition phase showed that CLA had increased for the grazing group. Samples taken during the final phase showed that the grazing group had even higher amounts of CLA, and produced more CLA than the control group (1.09% of total fatty acids vs. 0.46 %). The study showed that CLA could be enhanced by fresh pasture over the relatively short time period of 2 to 4 weeks.

While the intake of fresh pasture can enhance CLA amounts, it is not known if all common pasture species are likely to have similar effects. Pasture species that have been studied to date are all cool season species the use the C-3 pathway for photosynthesis. It
is not known what effect warm season species that use the C-4 pathway for
photosynthesis may have on CLA levels in milk fat.
TABLE 1. Comparative results for a few recent studies that examine effects of pasture on amounts of CLA in milk.

<table>
<thead>
<tr>
<th>Authors, year</th>
<th>Treatments</th>
<th>n</th>
<th>CLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timmen and Patton, 1998</td>
<td>Individual samples from: Pasture-fed, supplemented with corn silage. Barn-fed, fed grass or wheat silage and grain. Underfed animals, fed 1 wk wheat straw only</td>
<td>?</td>
<td>Pasture: .77 Barn: .34 Underfed: .46</td>
</tr>
<tr>
<td></td>
<td>Bulk tank samples from: Pasture-fed Barn-fed</td>
<td>?</td>
<td>Pasture Bulk: 1.34 Barn Bulk: .27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reported as %, wt/wt</td>
</tr>
<tr>
<td>Jahreis et al., 1997</td>
<td>Monthly bulk milk samples from: Pasture-fed, supplemented with grass silage. Summer graze, supplemented with corn and grass silage. Confinement, fed corn silage and grain.</td>
<td>12 each</td>
<td>Pasture: .80a 1 Summer Pasture: .61b Confine: .34c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reported as %, wt/wt</td>
</tr>
<tr>
<td>Kelly et al, 1998b</td>
<td>Transition from TMR (fed corn and alfalfa silage) to total pasture in 2wk periods. Pasture was: Ryegrass, Orchardgrass, fescue, white clover. (cool season)</td>
<td>8 per treatment</td>
<td>Initial Final Pasture: .54 1.09a 1 Confine: .47 .46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reported as %, wt/wt</td>
</tr>
<tr>
<td>Dhiman et al, 1999b</td>
<td>1/3 Pasture 2/3 Pasture 100% pasture Supplement was alfalfa hay and corn Pasture: bluegrass, bromegrass, white clover. (cool season)</td>
<td>18 per treatment</td>
<td>1/3 Pasture 8.9a 1 2/3 Pasture 14.3b 100% pasture 22.1c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reported as %, mg/g of fatty acids</td>
</tr>
</tbody>
</table>

*% , mg/g of fatty acids cannot be directly compared to %, wt/wt

1Numbers with different letters in columns are significantly different at (P > .05)
Dairy Farm Waste

Grazing livestock play an important role in the ecology of pasturelands. Livestock consume nutrients in the form of forages and excrete these nutrients back onto the pasture in the form of feces and urine. In addition, some of the nutrients consumed during supplemental feeding are also deposited onto the pasture. Grazing livestock consume nutrients from a relatively large area and deposit them in a small area (King, 1998). A portion of these excreted nutrients are used by the pasture plants for growth, where in turn the nutrients are consumed and recycled through the grazing animal. However, the deposition of nutrients can be an environmental problem from the standpoint of non-point source pollution. Non-point source pollution can occur from pasturelands and conventional drylots in the form of surface water runoff that occurs during rain storm events. Other pollution that occurs from pasturelands is the leaching of nutrients from soil into groundwaters. Different pastureland practices can have different effects on the environment. Low intensity grazing of unfertilized pastures have relatively little or no impact on surface and groundwaters, while high intensity continuous grazing of pastures that are heavily fertilized can have significant impacts (Correll, 1996). Use of rotational grazing can lessen these impacts (Correll, 1996).

According to Line et al. (1998), dairy farms can contribute significant sources of non-point source pollution. Line et al. sampled runoff from a dairy farm in southwestern North Carolina. The sampling areas consisted of a pasture area that supplied supplemental forage to replacement heifers and also a mostly denuded heavy use area that had very little grass on it. The denuded area was used as a lounging area for adult dry cows and occasionally by the lactating cows. It was also used as an area for feeding
supplements or stored forages. Line et al. found that the nitrogen and phosphorus runoff rates from the mostly pasture area were much lower than from the heavy use area of the farm.

Runoff samples were taken by automatic samplers over a period of 2.58 years from the N.C. State University Field Laboratory Dairy Educational Unit. (Goetz, 1999). The two areas sampled were a rotationally grazed pasture area and a heavy use area that had no vegetation on it. The sediment, nitrogen and phosphorus runoff levels from the heavy use area were much higher than the pasture area even when levels were adjusted for the number of animals that used these areas. This study showed that runoff can be greatly reduced by using a pasture management system.

**Manure Distribution**

For maximal plant use of the nutrients excreted in manure, the distribution of the manure should be as uniform as possible (Peterson and Gerrish, 1996). Uniform distribution of the manure would also help with reducing runoff pollution. If the manure is evenly distributed around a pasture that has a reasonable amount of ground cover, the herbage mass can act as a buffer for the runoff occurring from each individual feces or urine spot.

On average, cattle defecate about 12 times a day and urinate about 8 times a day (Petersen et al., 1956). The frequency and number of the defections and urinations can depend on the handling of the cattle. The areas of coverage of each event has been reported as 0.05 to 0.14 m$^2$ for feces and .14 to .39 m$^2$ for urine (Petersen et al., 1956; Wilkinson and Lowery, 1973; Dalrymple et al., 1994).
The area affected by the excreted nutrients can be much larger than the actual area covered. During and Weeda (1973) applied cattle manure containing high and low levels of P to unfertilized pasture. The manure was applied as simulated piles that measured 0.05 m². The soil and forage response was measured around each pile, and it was shown that the dry matter yields and P levels of the forage were increased compared to the unaffected (no manure) areas. During and Weeda estimated the area affected by the manure nutrients was five times larger than the area covered. The researchers stated that possible reasons for this effect could be the lateral wash of rainfall, the lateral spread of roots, and the presence of stoloniferous plants such as white clover. The action of insects and earthworms can also affect the movement of nutrients. They also pointed out that this affected area could be even larger in the spring and fall grazing seasons when the feces tend to be wetter and therefore are spread out more. The transport of feces on cattle hooves could also spread the nutrient effect (During and Weeda, 1973).

Most of the research on spatial distribution of cattle manure has been done with beef cattle. The location of the water source, shade, and the topography of the pasture have the most effect on the manure distribution (Peterson and Gerrish, 1996). The location of the water source in a pasture has been linked to increased levels of nutrients in the soil (West et al., 1989; Gerrish et al., 1995; Peterson and Gerrish, 1995). West et al. (1989) took soil samples from 3 rotationally grazed pastures that were grazed from early May to late October for 4 years. The soil samples showed higher P and K concentrations in an area within 10-20 m from the water source compared to the rest of the paddock. Gerrish et al. (1993) monitored P and K levels in the soils of pastures that were part of a 3 paddock rotational system. After 4 years of grazing by beef cattle, an area about 12 m
from the water source had elevated levels of P and K compared to the remainder of the paddock. Peterson and Gerrish (1995) counted manure spots in pastures grazed by beef cattle over a 2-year period. From these counts, contour maps were made of the paddocks which showed the concentration of manure to be higher near the water sources (Peterson and Gerrish, 1995). There were nearly 10-20 more manure piles per 47 m² around the water tanks compared to the rest of the paddock.

Shade has also been a factor affecting manure distribution in a paddock. Cattle seek shade for relief from heat stress but are also known to camp under shade during cloudy and/or cool weather, when no heat stress would be expected. Because of this camping behavior, nutrients can build up under and around shade areas. Gerrish et al. (1993) found higher levels of P and K in areas close to a single shade tree. Manure maps developed by Peterson and Gerrish (1995) also showed more manure around shade trees. Wilkinson et al. (1989) surveyed manure piles in a .7 ha pasture that had been continuously grazed by beef cattle. In one end of the pasture was the water source, shade and the mineral feeder. The concentration of feces was found to be nearly 3 times higher at this end of the paddock compared to the rest of the paddock.

Topography plays a role in manure distribution by affecting the site where livestock congregate. Cattle will tend to camp on high ground during wet or warm conditions, while seeking low areas during cold conditions. Peterson and Gerrish (1995) found relatively uniform manure distribution in a flat pasture. In another pasture that had a shallow ditch running through it, manure concentrations were higher on either side of the ditch. Those pastures were part of a 12 paddock rotational system and were observed for a 2-year period. Yasue et al. (1997) reported that grazing cattle generally avoided
resting on very steep slopes, and would rest in lower elevations during the day and rest on higher elevations during the nighttime.

**Challenges**

Despite some of the advantages of pasture use for dairy cattle, many challenges face the grazing dairy farmer. Pasture-type dairy farmers from Pennsylvania listed variability in pasture yield, balancing grazing cow rations and providing water to grazing animals as the most serious challenges faced by grazing dairy farmers (Parker et al., 1993). Muller et al. (1998) lists the constant change in quality and quantity of pasture, the lack of control of feeding the grazing cow, and the lack of US research as challenges. In the Southeastern United States, long periods of high environmental temperatures and droughts of various lengths are challenges that must be faced.

**Summary**

Today’s dairy industry is facing many challenges from the trend in relatively flat average annual milk prices and increasing costs of production. Dairy farmers, especially small-scale family farms, must increase net income to compete in today’s market. One method of dairying to reduce costs of production is management intensive rotational grazing. Intensive grazing was not employed in the past because the mechanization of hay and silage making allowed farmers to produce reasonable amounts of milk all year round at a reasonable cost. With increased costs of machinery and maintenance, grazing is seen as a lower cost method of producing milk. Research and surveys have been conducted to measure cow response to intensive grazing. Compared to conventional-fed dairy cattle, pasture-fed cattle tend to produce less milk, have less incidences of mastitis and have lower body condition scores (BCS). Seasonal calving is often used with
grazing systems to take advantage of forage growth patterns, to avoid heat or cold stress, and to concentrate labor needs. Most researchers agree that grain supplementation is both needed and economical for the high genetic merit US grazing cow. Studies have shown that the limiting factor with dairy cattle is the intake of metabolizable energy. Supplementation can be used to help support milk production and overall health in the grazing dairy cow. Some studies have shown differences in the rate of intake of supplemental grain between breeds of pasture-fed dairy cattle. If balanced correctly, supplementation can be economical for the grazing dairy. Most economic studies with grazing systems have shown higher net incomes per cow compared to conventional systems.

A potential enhancement for milk from pasture-fed dairy cattle is conjugated linoleic acid (CLA). Research has shown CLA is a potent anticarcinogen. The National Academy of Sciences has identified CLA as the only known fatty acid to inhibit cancer in experimental animals. Conjugated linoleic acid has also been linked to enhancing lean body mass. The potentially positive health benefit of CLA offers the dairy industry an exciting opportunity to increase the consumption of dairy products. Many factors have been identified as increasing CLA levels in milkfat; some of these factors include forage to concentrate ratio, intake of dietary fatty acids, and pasture intake. Additional research is needed to determine optimal feeding strategies. In particular, it is not known if all common pasture species are likely to have similar effects on CLA levels.

Grazing livestock play a crucial role in the ecology of pasturelands. Nutrients excreted in the form of feces and urine are used by the pasture plants for growth, but under some circumstances nutrients can be a potential source of non-point source
pollution. The proper use and management of rotational grazing can help reduce this impact. Research has shown that the location of water source, shade and topography of the area grazed can affect the distribution of manure in pasture systems.

Major challenges to grazing systems include: variability in pasture yield and quality, balancing supplement rations, and the steep learning curve of grazing management. Potential advantages of grazing systems include reduced mastitis, improved net income, improved lifestyle and the flexibility grazing offers.
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Milk Production, Reproduction, Udder Health and Body Condition Scores Among Spring and Fall Calving Dairy Cows in Pasture or Confinement Feeding Systems.

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Abstract

This multiple year study examined total lactation performance of dairy cows in two feeding systems; a pasture-based system and a confinement system using total mixed rations. The project had both Spring and Fall calving herds with breeding via artificial insemination in 75-day periods. Each seasonal herd replicate had 36 cows on pasture and 36 cows in the confinement group. During the first year, groups had more Holsteins but similar numbers of Holsteins and Jerseys were included in subsequent years. Paddocks grazed comprised 29 ha of cool and warm season species in 37 paddocks for year-round grazing. Pasture-fed cows received variable amounts of grain and baled silage as needed depending upon pasture availability. Confinement cows were housed in a covered freestall barn with access to an exercise lot and received a total mixed ration with corn silage as the primary forage. Data were collected on milk production, reproduction, udder health, body condition score and general cow health and analyzed by SAS. Confinement cows produced significantly more milk than pasture-fed cows, both for total lactation and average daily production. Reproductive performance of the two treatments did not differ with an overall 75-day pregnancy rate of 68%. Jerseys in both systems did have higher percentages of cows inseminated (96.5%), conception (59.6%), and 75-day pregnancy (78%) compared to Holsteins (86%, 49%, 57.9% respectively). The percentage of cows infected with at least one case of clinical mastitis was higher in the confinement herd than the pasture-fed herd (43% vs 24%) with Holsteins higher than Jerseys (41% vs 26%). Interactions of breed and feeding system and average somatic cell count scores were not significantly different. Pasture-fed cows had lower average body condition scores than confinement cows, ranging from 0.2 to 0.6 points lower on a 5-point scale. Other disease

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and health problems were not remarkable between the two treatments. This experiment showed that when compared to confinement-fed cattle, pasture-fed cattle produced less milk, had less mastitis and had lower body condition scores, while reproductive performance did not differ between the two groups.

Keywords:  Pasture, Seasonal Reproduction, Mastitis, Breed differences.

Introduction

With the economic challenges facing dairy farming today, dairy farmers have been forced to find ways to increase their profitability to stay in business. Feed is the largest cost in producing milk. Some interest has been shown in pasture-based systems where grazing fresh pastures provides the majority of the cow’s feed. In addition to reduced feed costs, pasture-based systems can have lower capital costs for machinery, manure systems, and facilities.

There have been a very limited number of multi-year comparisons between pasture-based and confinement based dairy systems. Most research that has been conducted are short-term comparison trials. In addition, no large-scale trials have examined pasture-based systems in the Mid-Atlantic region. Both short and long-term trials have reported that confinement-fed cows produce more milk than pasture-fed cattle (Rust et al., 1995; Kolver and Muller, 1998a), while Bela et al. (1995) did not report significant differences between the two systems. Studies that have transitioned confinement-fed cattle to a pasture feeding system have noted steep declines in milk production (Hoffman et al. 1993; Fales et al. 1995). Comparison trials have shown differences in favor of pasture systems with reproductive performance (Bela et al., 1995; Phillips, 1990), mastitis and somatic cell counts (Bela et al., 1995; Goldberg et al., 1992), hoof health (Hahn et al., 1996; Phillips et al. 1990), general cow health (Bela et al., 1995; Brown, 1990). Trials have also shown pasture-fed cattle tend to have lower BCS compared to confinement-fed cattle. (Kolver and Muller, 1998a). Other trials have not shown differences between the two systems with somatic cell counts (Rust et al., 1995), general herd health (Parker et al., 1993), and BCS (Rust et al. 1995).
This study was designed to investigate and compare the performance of Holstein and Jersey dairy cattle managed in a pasture-based or confinement feeding system with the soils and climate of the Mid-Atlantic region.

Materials and Methods

This experiment was conducted from March 1995 until November 1998 at North Carolina State University’s Lake Wheeler Road Dairy Educational unit located near Raleigh, NC. To establish the pasture system, 29 hectares of cropland were converted into 37 paddocks of approximately .8 hectares each. The cropland was previously used for corn silage and alfalfa/orchardgrass hay. Waterlines, fencing and lanes were built and pastures were seeded in the fall of 1994. No shade was provided in any of the paddocks, with the exception of three paddocks where a line of tall trees provided shade in the afternoon hours. Water was available in each paddock. Lanes were constructed with 7.5 to 15 cm of crusher run gravel with Geo-textile cloth (Contech, Inc.) placed under the gravel layer in high traffic areas.

Several combinations of cool season and warm season grasses and legumes were used to allow for grazing throughout the year. Perennial species included Benchmark orchardgrass (*Dactylis glomerata*) and Will Ladino white clover (*Trifolium repens*), Forager and Triumph endophyte-free fescue (*Festuca arundinacea*) and Will Ladino white clover (*Trifolium repens*), matua bromegrass (also known as rescuegrass) (*Bromus catharticus*), Red River crabgrass (*Digitaria sanguinalis*) and Tifton 44 bermuda grass (*Cynodon dactylon*). Marshall rye (*Secale cereale*) was used for late winter and early spring grazing while caucasian bluestem (*Bothricloa caucasica*) and a sorghum sudan hybrid (*Sorghum bicolor*) were used for summer grazing. Areas of each species varied from year to year, but on the average, 18 ha were in cool season perennial species, 5 ha were in warm season perennial species, and 8 ha each were planted to summer and winter annuals. No irrigation was used but limited quantities of dairy lagoon effluent were applied on a few of the paddocks as a source of nutrients. Pastures were clipped to maintain pasture quality during the growing season. Excess growth from the pastures was harvested as wrapped round bale silage (haylage). This haylage was fed to the
pastured cows during droughts and during the winter months and when grass production was limited.

To study the feasibility of seasonal milk production, half the cows were bred to calve from January through early March (Spring) with the other half calving from August through early October (Fall). During the first seasons, cows were selected from the existing dairy herd based on their expected calving dates. Cows were then paired based on milk production, age and parity to control for any genetic effects. The paired cows were assigned at random to the two treatments, confinement feeding (CONFINE) or pasture feeding (PASTURE). Each treatment consisted of about 36 cows each season. Table 1 describes the cow numbers and average parity for the four Spring and three Fall calving groups. For the Spring 95 group there were 24 Holstein cows and 12 Jersey cows and in the Fall 95 and Fall 96 groups there were 21 Holsteins and 15 Jerseys but during the other years and seasons there were 18 Holsteins and 18 Jerseys. If cows became pregnant during the breeding window they were used in subsequent years within the same treatment group. Cows that failed to become pregnant during the breeding window or were culled were replaced by heifers when possible or by low parity cows calving at the appropriate time.

Both treatments were managed by the same workers and milked in the same parlor. The two treatments and seasonal groups were managed as separate groups, with the two breeds managed together for all PASTURE groups and all CONFINE groups except for Fall 95 and Spring 96. Cows from the two treatments were managed together during the dry period. The cows in CONFINE were housed in a freestall barn with access to a dirt exercise lot. The CONFINE ration was fed as a total mixed ration (TMR) and consisted of corn silage, alfalfa silage, ground corn, soybean meal, whole cottonseed, minerals, and vitamins and sometimes included cottonseed hulls. The silages fed provided all of the CONFINE cows forage needs. Table 2 shows the ingredients for a typical TMR fed to the CONFINE cows. Rations were balanced with the DART ration program (Smith et al., 1994) and adjusted throughout the year as season and stage of lactation changed. The total TMR and corn and alfalfa silages were submitted to the
North Carolina Forage Testing Laboratory for analysis periodically. Table 3 summarizes the quality of the silages fed during the project.

Cows in the PASTURE system were housed on pasture and were brought into the barn to be fed a supplement and milked. The PASTURE supplemental ration consisted of ground corn, soybean meal, whole cottonseed, minerals, and vitamins. Tables 4 and 5 show the ingredients for a typical spring and winter grazing supplemental ration. Rations were balanced using the DART ration program (Smith et al., 1994) and adjusted as pasture availability and stages of lactation changed. Grab samples of fresh pasture were submitted to the North Carolina Forage Testing Laboratory for analysis periodically. The grab samples were collected in a manner to mimic the selection of the grazing cow so the sample would represent what the cows were consuming. Table 6 shows the average quality of the forages grazed by species. Figure 2 also shows the quality of the forages graphically. Supplemental grain and round-bale haylage samples were also submitted to the North Carolina Forage Testing Laboratory for analysis. Table 7 summarizes the quality of the round bale haylage fed during the project.

The supplemental grain ration was fed in a covered feeding area before each milking. When pasture supply was limiting, higher levels of the supplemental grain were fed in addition to hay or round-bale silage that had been harvested from the pasture system. The hay or round-bale silage was unrolled and fed on pasture paddocks using a looped electric wire to keep the forage from being trampled and spoiled. In periods of extreme heat and humidity, pasture-based cows were allowed to stay in the covered feeding area for shade for an extra hour or two after milking.

The breeding window for each season was for a 76-day period and corresponded to the calving seasons. Table 8 shows the calving and breeding windows for each seasonal group. Both PASTURE and CONFINE cows had 76-day periods in which to be detected in estrus and inseminated. Cows were checked after calving by a veterinarian to ensure reproductive soundness and those with a corpus luteum were synchronized with prostaglandin F₂α to enhance estrus detection. A testosterone-treated heifer was also used in each of the groups to increase mounting behavior when cows were in estrus. Tail paint
was also used to help detect cows in estrus. Cows were routinely checked for pregnancy via rectal palpation by a veterinarian.

**Data Collection**

Daily milk yields from each cow were obtained from the dairy unit’s computer system. Milk yields were examined for errors and the milk discarded due to mastitis treatments were subtracted from each cow’s records. The amounts were then summed to obtain total lactation yields for each cow. Lactation yields for each cow were divided by the number of days each cow was milked to obtain average daily milk production. Monthly concentrations of fat, protein, and somatic cell counts in milk were obtained from DHI herd records. Fat, protein, and SCS values from DHI records were averaged over each lactation for each cow.

Mastitis cases, health problems and culling reasons were routinely recorded by reviewing written and computerized herd health records. Mastitis cases recorded were based on treatment of the mastitis by a commercial mastitis treatment product. Parameters for mastitis computed for each group were: percentage of cows infected, infections per cow, and percentage of mastitis cows that were culled or died. Weights and body condition scores of cows were recorded once or twice a month by one of the authors (White). The five-point scale body condition scoring system was used, with a score of one being very thin and a score of five being very fat. Body condition scores were averaged over each lactation for each cow. For reproductive data, insemination dates and pregnancy status records were routinely obtained from written and computer herd records. Parameters computed for each group were: first service conception rate, all services conception rate, percentage of cows inseminated within the 76-day breeding window, and overall 76-day pregnancy rate. During the seasons of Fall 95 and Spring 96, CONFINE Holsteins were shared in another research trial that required cattle to be housed in a freestall barn with concrete floors without excess to a drylot. Although production responses were comparable, this caused poor estrus display and detection, which affected the reproduction numbers for those groups. Therefore the data for
percentages of cows inseminated within the 76-day breeding windows and overall 76-day pregnancy rates from these groups were not used in the statistical analysis.

**Statistical Analyses**

Total lactation production, average daily milk production, reproduction, mastitis data, body condition score, general cow health and DHI data were analyzed by general linear models procedures in SAS. Treatment, breed, and treatment×breed interactions were included in the model as independent variables. Seasonal group was the experimental unit for analyses across years for reproduction, mastitis, and DHI data and cow was the experimental unit for analyses within seasonal groups for milk production, body condition scores and somatic cell count scores. In models within season, treatment, breed and treatment×breed interactions were in the main plot with cow (treatment) as the error term. Repeated measures across time and interactions with main effects were in the subplot with residual error as the error term.

Due to reproductive and general culling, some cows were only used in the study for a single lactation while other cows remained in the study from season to season. The first statistical model for milk production compared the response of the cows used once and the repeat lactation cows. The model showed that both groups of cows responded similarly and so the model was simplified. Linear and quadratic effects of parity were also included in the model for milk production to adjust for potential differences in maturity of cows among treatment groups due to culling. Table 1 shows the average parities for each treatment and seasonal group.

**Results**

**Milk production**

Treatment, breed, season, and linear and quadratic effects of parity were all significant ($P < .01$) for total lactation milk (TOTMILK) production and average daily lactation (AVGMILK). Significant interactions included parity×treatment, parity×breed, and parity×treatment×breed. Least squares means for milk production for each treatment and breed group are shown in Table 9. Tables 10 and 11 show least squares means
lactation production by treatment and the percentage difference for Holsteins and Jerseys respectively. Figures 3 and 5 show these data graphically, while figures 4 and 6 show the least squares means for average daily production for the Holsteins and Jerseys. Total lactation and average daily lactation was higher for the CONFINE cows for each season and year except for TOTMILK for Fall 95. Overall the PASTURE cattle produced 10.1% less milk for TOTMILK and 12.1% less AVGMILK compared to CONFINE. Jerseys produced 21.8% less TOTMILK and 25% less AVGMILK compared to the Holstein cattle. Across both treatments the fall season groups produced more milk than the spring season groups with the exception of the Spring and Fall 97 groups.

There were no significant differences between treatments for monthly fat or protein percentages in all seasons with the exception of protein in Fall 1997, where PASTURE cows did have a higher protein percentage than the CONFINE cows. Jerseys did have significantly ($P < .05$) higher values for fat and protein in all seasons.

**Mastitis**

There were significant ($P < .05$) breed and treatment effects on incidences of mastitis in this trial. There was not a significant seasonal (spring vs fall calving) effect, nor were there any interactions. Table 12 shows the summarized mastitis data for all groups. Holsteins in CONFINE had the highest percent of cows infected, infections per cow, and the percentage of mastitis cows culled or died. Jerseys in CONFINE had the next highest numbers, followed by PASTURE Holsteins and finally PASTURE Jerseys. Out of PASTURE Jerseys, only 17% of the cows had a case of mastitis, and none of these cows had to be culled or died because of mastitis. This is in contrast to CONFINE Holsteins, where 9.7% of the cows were culled or died. When averaged together, the CONFINE groups had nearly twice as many mastitis cases as did the PASTURE groups (42.8% vs 24.2%, $P < .01$). Holstein cows had a higher ($P < .05$) incidence of mastitis compared to the Jersey cows (41.2% vs 25.8%). Despite these clinical differences, there were no significant differences between the treatments or breeds in monthly DHI somatic cell count scores.
Body Condition Score

There were differences in body condition scores between the two treatment groups and breeds (Figures 7-13). In general, body condition scores varied across time as expected, with a slight drop post calving but then a slow increase as lactation progressed. The sharp drop in BCS for the Spring 95 pasture cows (Figure 7) can be partially explained by the inexperience of the authors’ and herd workers with managing and feeding cattle on pasture. Subsequent PASTURE groups did not experience such sharp drops. Table 13 shows the summarized BCS scores for each group by season. CONFINE cows tended to have higher ($P < .05$) condition scores compared to PASTURE cows. There was a significant treatment effect ($P < .05$) within each seasonal group except for Fall 97. Both CONFINE and PASTURE Jersey cows scored higher ($P < .05$) than the CONFINE or PASTURE Holstein cows. Breed was significant ($P < .05$) within all seasonal groups except for Spring 95. There were no significant breed×treatment interactions. Date was significant for each season, which is expected due to the pattern of BCS change in the typical lactation of a cow. The treatment×date interaction was significant ($P < .05$) for all seasons. Other interactions (breed×date, breed×treatment×date) were significant in some seasonal groups but not for others.

Reproduction

Reproductive differences were not significant between the treatment groups or seasons but there was a significant breed effect. Table 14 shows the summarized reproductive data for all groups. In this experiment Holsteins and Jerseys had an overall conception rate of 49.5% and 59.6% respectively. The PASTURE cows had numerically higher percentages of first service conceptions, all services conceptions, cows inseminated within the 76-day breeding window, and overall pregnancy rate. The difference between the overall pregnancy rate was by about 7.5 percentage points (PASTURE 71.7% vs CONFINE 64.2%). Both CONFINE and PASTURE Jerseys had significantly ($P < .05$) higher percentages of cows inseminated (96.5%), conception (59.6%), and 76-day pregnancy (78%) compared to Holsteins (86%, 49.5%, 57.9% respectively). Holsteins in CONFINE were numerically the poorest in each reproductive
measure. Effects of season (spring vs fall) were not significant and there were no significant interactions.

**Herd Health**

Most disease and health problems were not remarkable between the two treatments. During the first year of the project, several Holstein cows in the PASTURE groups experienced some lameness due to sharp gravel in the travel lanes. The cows were able to form “trails” within the lanes that were free of the sharp gravel, and so lameness was only a transient problem with the pasture cows. It was recorded that no PASTURE Jersey cows experienced lameness. One PASTURE cow (a Jersey) died of frothy bloat while grazing alfalfa in 1995 and a few others had to be treated for bloat during that same season. Changes in management practices of cows grazing alfalfa and heavy clover pastures prevented such problems. A commercial product was briefly included in the concentrate ration to prevent bloat but its use was discontinued because of cost. Incidences of foot rot, displaced abomasums, and culling due to feet and leg problems were very low and did not differ between the two groups.

**Discussion**

In this four-year study, milk production was lower for the PASTURE cows compared to the CONFINE cows. This has been shown in other pasture-based experiments as well (Rust et al., 1995; Kolver and Muller, 1998a). Fall-calving cows may have produced more milk because of little to no heat stress and the increased supplemental feed supplied to the PASTURE cows in fall and winter. Milk production for the Spring 1995 PASTURE group may have been especially low due to the inexperience of the authors’ and herd workers in managing and feeding cattle on pasture. Parity was also a significant factor with interactions with breed, treatment and treatment×breed. These interactions may have been due to the difference in parities between groups (Table 1). Differences in culling rates and availability of cows for replacements affected the average parity of the groups.
Mastitis was significantly \( (P < .05) \) higher in the CONFINE cows compared to the PASTURE cows. This could be because pastured cows are exposed to fewer environmental pathogens compared to confinement-housed cows (Smith and Hogan, 1994). Pastured cows are moved to fresh areas of pasture where fewer pathogens may exist, as opposed to cows that are housed in freestalls. In addition, the pastured cows produced less milk, which could lead to lower incidences of mastitis. The lower mastitis rates for the PASTURE cows reflect an advantage to the pasture system. Across the entire study, CONFINE cows had a total of 202 cases of mastitis, compared to 107 cases for the PASTURE cows.

High rates of mastitis cases can substantially contribute to lost income. Most of the income lost is due to the milk from the treated cows that must be dumped. Total values for milk production can be affected because as many as 8 days of milk must be discarded after a mastitis treatment. Because the CONFINE-fed cattle had a much higher mastitis rate than the pasture-fed cattle, it can be concluded that mastitis had an effect on the absolute total milk production for the CONFINE cows. We did subtract the discarded milk from mastitis treatments from each cow's milk record to account for this lost income.

Another substantial loss is the replacement cost of cows that are culled due to mastitis. A total of 17 (10%) CONFINE Holstein cows were culled or died from mastitis, compared to only 2 (1.6%) of the PASTURE cows that had to be replaced due to mastitis. Mastitis was the major health problem in both treatments and caused the majority of culls. There was also a breed effect with mastitis, with Jersey cows having less mastitis compared to the Holstein cows. This may have been due in part to the Jerseys’ lower milk production. We could not detect any significant differences between the treatments or breeds in somatic cell count scores (SCS). Rust et al. (1995) also did not report SCS differences between confinement and pasture-fed cows in a 2-year trial in northern Minnesota. Other experiments had shown differences in SCS between confinement and pasture fed cows. Bela et al. (1995) compared somatic cell counts between pasture fed and confinement cows over a few years on two farms. The results reported significantly lower somatic cell counts for pasture fed cows on one farm during the entire study. The
second farm reported significantly lower somatic cell counts for pasture fed cows for two of the four years. Bulk tank samples from 15 different farms in Vermont showed the pasture-based farms had the lowest mean standard plate counts during the grazing season (Goldberg et al., 1992).

Possible reasons for the differences in findings for SCS between this study and others is that in this study somatic cell count scores were taken from monthly DHI tests and may not capture accurately the status in each group. In addition, cows that have a case of clinical mastitis are not tested, which would result in biased somatic cell count scores. It is possible that a different result would have been obtained if samples were taken several times a month from each group.

CONFINE cows had higher body condition scores compared to the PASTURE cows. This was also reported with a short-term comparison trial between confinement-fed and pasture fed cows (Kolver and Muller, 1998). In our experiment PASTURE cows tended have an average score of at or below 3.0 throughout the lactation. Several other grazing trials have reported condition scores at or below 3.0. (Hongerholt et al., 1997; Jones-Endsley et al., 1997; Holden et al., 1994; McDougall et al., 1995; Fales et al., 1995). This difference between BCS may be explained by the different energy balances between the two groups of cows. As other studies have shown, pasture cows consume less net energy than confinement cows. Dry matter intake can be physically limiting due to the water content of fresh pasture forage. Sources report that a grazing dairy cow fed no supplement can consume only 80 kg of fresh forage per day (Holden et al., 1994). In addition, pasture cows most likely expend more energy than a confinement-fed cow because of walking to and from grazing paddocks. Some grazing cows may walk more than one mile to reach certain paddocks, which can have an impact on the cow’s energy balance. The consistently lower BCS and milk production for the PASTURE cows may indicate that the PASTURE cows were in a longer and more severe negative energy balance compared to the CONFINE cows. Lower BCS in pasture-fed cows were not considered as a problem unless the condition score remained very low during the entire lactation or if reproduction or health is affected. In spite of lower BCS, PASTURE cows
did not have impaired fertility compared to CONFINE cows and most of the PASTURE cows did gain body condition as their lactation progressed (Figures 7-13).

When BCS for each breed are examined (Table 13), it can be seen that during some seasons, the difference between the PASTURE and CONFINE Jerseys is not as severe as the difference between the PASTURE and CONFINE Holsteins. Reasons for these differences in our experiment are not clear. One possible factor is grazing behavior. In some grazing circles, Jerseys have a reputation for being more aggressive grazers than other breeds, especially Holsteins. However a trial that was performed with a grazing group in the Spring of 1999 may explain some of the differences (White et al., 2000). Intake measurements were taken from pasture-fed Holsteins and Jerseys consuming a grain supplement. This supplement was similar to those that were fed to the PASTURE cows during the four-year trial. It was determined that the Jerseys could consume as much as the Holsteins at three different feeding levels (6.8, 4.5, and 2.3 kg/cow per feeding) during the same amount of time. During the four-year trial, the pasture-fed cattle were fed together in the barn. This means that the Jersey cattle could have eaten equal amounts of supplements and therefore, would have consumed more energy than the Holsteins relative to body size and milk production. This could help explain the relative difference in performance between the breeds in the pasture groups.

Bela et al. (1995) had reported that pasture-fed dairy cows had higher reproductive performance compared to the confinement fed cows. We did not find any significant differences between the two groups, although the PASTURE cows had the numerical advantage for overall pregnancy rate (71.7% vs 64.2%) despite having consistently lower BCS. This numerical advantage of about 10 percentage points for the reproductive measures of the PASTURE Holsteins compared to the CONFINE Holsteins (63% vs. 52.8%) may be economically important if this difference is consistent for larger groups of cows. This difference can be especially important if seasonal calving is used. Holsteins in this experiment had an average conception rate of 49.6%, while Jerseys averaged 59.6%, which is higher compared to the current U.S. average of 32% for Holsteins and Jerseys (Washburn et al., 2000). This indicates that herd techniques for detection of estrus and insemination were acceptable. We did find that a significantly
higher number or Jerseys had a higher level of reproductive performance compared to the Holsteins (Table 14). Some studies have also shown reproductive performance differences between Holsteins and Jerseys (Fonseca et al., 1983; Silva et al., 1992). The higher fertility of the Jersey breed does have implications if a seasonal breeding system is used. Jerseys had a 76-day pregnancy rate of 78% compared to the Holsteins at 57.9%, therefore, Jerseys or possibility Jersey crosses might fit better into a seasonal calving pattern due to better reproductive performance. A more aggressive strategy of estrous synchronization may have increased the pregnancy rates within the 76-day breeding period. It should be noted that reproductive performance of both groups was affected during the Fall 1997 season due to a respiratory virus that affected the entire herd during the breeding season. Even though no reproductive differences were found in this trial, some reproductive advantages may be seen in pasture systems due to better estrus detection. Cattle that have sound feet and legs and that are sure of their footing are more likely to exhibit mounting behavior. Cattle that are restricted on concrete footing for long periods of time and that have significant feet and leg problems for most of time will be less likely to exhibit mounting behavior.

Summary

In this four-year seasonal calving study, pasture-fed cows produced less milk, had lower BCS, had less incidence of mastitis, and fewer mastitis culls compared to the confinement-fed cows. There were no significant differences in reproductive performance, although the pasture-fed cows had the numerical advantage. Jerseys produced less milk, had less incidence of mastitis, fewer mastitis culls, and had higher reproductive performance than Holsteins. Although pasture-fed cows produced less milk, the cost of lost milk due and the higher culling rate in the confinement-fed cows could partially offset the apparent advantage to the confinement feeding system. To truly evaluate both systems, an economic analysis should be performed to account for lost income due to mastitis and the cost of replacement cows. The higher level of reproductive performance of the Jersey cows suggests a significant advantage under a seasonal calving system compared to Holsteins.
TABLE 1. Dates, number of days, average number of cows, and average parity for seasonal calving groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Experimental Period</th>
<th>Confinement</th>
<th>Grazing</th>
<th>Confinement</th>
<th>Grazing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Days</td>
<td>Avg. no. of cows</td>
<td>Average Parity</td>
<td>Avg. no. of cows</td>
<td>Average Parity</td>
</tr>
<tr>
<td>Spring 1995</td>
<td>3/15/95-11/20/95</td>
<td>251</td>
<td>21.4</td>
<td>2.3</td>
<td>22.4</td>
</tr>
<tr>
<td>Fall 1995</td>
<td>9/27/95-7/16/96</td>
<td>305</td>
<td>15.9</td>
<td>2.2</td>
<td>17.6</td>
</tr>
<tr>
<td>Spring 1996</td>
<td>2/15/96-12/5/96</td>
<td>294</td>
<td>15.0</td>
<td>2.6</td>
<td>15.6</td>
</tr>
<tr>
<td>Fall 1996</td>
<td>8/24/96-7/22/97</td>
<td>338</td>
<td>16.6</td>
<td>2</td>
<td>15.6</td>
</tr>
<tr>
<td>Spring 1997</td>
<td>1/25/97-11/30/97</td>
<td>304</td>
<td>16.6</td>
<td>1.2</td>
<td>16.7</td>
</tr>
<tr>
<td>Fall 1997</td>
<td>8/26/97-7/21/98</td>
<td>326</td>
<td>16.5</td>
<td>2.5</td>
<td>15.0</td>
</tr>
<tr>
<td>Spring 1998</td>
<td>1/14/98-11/1/98</td>
<td>291</td>
<td>12.3</td>
<td>1.7</td>
<td>15.2</td>
</tr>
</tbody>
</table>
TABLE 2. Formulation and nutrient content of typical TMR fed to CONFINE group.

<table>
<thead>
<tr>
<th>Formulation, % of Total Ration DM</th>
<th>Nutrient Content, DM basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage 51.1</td>
<td>Dry Matter, % 44.5</td>
</tr>
<tr>
<td>Wilted Alfalfa silage 11.4</td>
<td>Crude protein, % 16.0</td>
</tr>
<tr>
<td>Whole cottonseed 13.0</td>
<td>Acid detergent fiber, % 23.2</td>
</tr>
<tr>
<td>Cottonseed hulls 6.4</td>
<td>Total Digestible Nutrients, % 74.8</td>
</tr>
<tr>
<td>Bentonite 1 .57</td>
<td>NE L, Mcal/kg 1.54</td>
</tr>
<tr>
<td>Ground corn grain 3.7</td>
<td></td>
</tr>
<tr>
<td>48% Soybean Meal 11.2</td>
<td></td>
</tr>
<tr>
<td>Defluorinated phosphate .59</td>
<td></td>
</tr>
<tr>
<td>Calcium carbonate .66</td>
<td></td>
</tr>
<tr>
<td>Sodium bicarbonate .59</td>
<td></td>
</tr>
<tr>
<td>Trace mineral salt 2 .47</td>
<td></td>
</tr>
<tr>
<td>Vitamin A, D, E supplement 3 .11</td>
<td></td>
</tr>
<tr>
<td>Dyna-Mate ®4 .09</td>
<td></td>
</tr>
</tbody>
</table>

1 Volclay (American Colloid Co., Arlington Heights, IL)  
2 Contained 14,400 ppm Zn; 11,064 ppm Mn; 26 ppm Fe; 2016 ppm Cu; 425 ppm I; 75 ppm Se; and 111 ppm Co.  
3 Contained 9,056,000 IU/kg of vitamin A, 22,048 IU/kg of vitamin E, and 1,963,000 IU/kg of vitamin D.  
4 Contained 22%S, 18%K, and 11% Mg. (Pitman-Moore, Mundelein, IL)
TABLE 3. Average nutrient content of silages used in CONFINE rations.

<table>
<thead>
<tr>
<th>Silage</th>
<th>number of samples</th>
<th>DM ± SE</th>
<th>CP ± SE</th>
<th>ADF ± SE</th>
<th>TDN ± SE</th>
<th>NE L, Mcal/kg ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Silage</td>
<td>12</td>
<td>30.2 ± 1.2</td>
<td>7.1 ± .44</td>
<td>25.9 ± 1.1</td>
<td>69.8 ± .73</td>
<td>1.6 ± .03</td>
</tr>
<tr>
<td>Alfalfa Silage</td>
<td>11</td>
<td>34.7 ± 1.7</td>
<td>20.9 ± .62</td>
<td>36.5 7± 1.6</td>
<td>61.4 ± 1.0</td>
<td>1.3 ± .04</td>
</tr>
</tbody>
</table>
TABLE 4. Formulation and nutrient content of typical spring supplemental ration fed to PASTURE group.

<table>
<thead>
<tr>
<th>Formulation, % of Total Ration DM</th>
<th>Nutrient Content, DM basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Corn grain 85.8</td>
<td>Dry Matter, % 87.3</td>
</tr>
<tr>
<td>Whole cottonseed 6.0</td>
<td>Crude protein, % 9.9</td>
</tr>
<tr>
<td>Magnesium oxide .51</td>
<td>Acid detergent fiber, % 7.9</td>
</tr>
<tr>
<td>Calcitic Limestone 5.5</td>
<td>Total Digestible Nutrients, % 77.6</td>
</tr>
<tr>
<td>Trace mineral salt 1.8</td>
<td>NE L, Mcal/kg 1.78</td>
</tr>
<tr>
<td>Vitamin A, D, E supplement .41</td>
<td></td>
</tr>
</tbody>
</table>

1 Contained 14,400 ppm Zn; 11,064 ppm Mn; 26 ppm Fe; 2016 ppm Cu; 425 ppm I; 75 ppm Se; and 111 ppm Co.
2 Contained 9,056,000 IU/kg of vitamin A; 22,048 IU/kg of vitamin E; and 1,963,000 IU/kg of vitamin D.
TABLE 5. Formulation and nutrient content of typical winter supplemental ration fed to PASTURE group.  

<table>
<thead>
<tr>
<th>Formulation, % of Total Ration DM</th>
<th>Nutrient Content, DM basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Corn grain</td>
<td>51.7</td>
</tr>
<tr>
<td>48% Soybean Meal</td>
<td>9.8</td>
</tr>
<tr>
<td>Whole cottonseed</td>
<td>24.3</td>
</tr>
<tr>
<td>Cottonseed hulls</td>
<td>6.4</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>.17</td>
</tr>
<tr>
<td>Deflourinated Phosphate</td>
<td>1.7</td>
</tr>
<tr>
<td>Sodium Bicarbonate</td>
<td>.99</td>
</tr>
<tr>
<td>Calcitic Limestone</td>
<td>.83</td>
</tr>
<tr>
<td>Trace mineral salt</td>
<td>.66</td>
</tr>
<tr>
<td>Vitamin A, D, E supplement</td>
<td>.15</td>
</tr>
</tbody>
</table>

1 Approximately 2.6 kg/cow/day of baleage was fed on pasture
2 Contained 14,400 ppm Zn; 11,064 ppm Mn; 26 ppm Fe; 2016 ppm Cu; 425 ppm I; 75 ppm Se; and 111 ppm Co.
3 Contained 9,056,000 IU/kg of vitamin A; 22,048 IU/kg of vitamin E; and 1,963,000 IU/kg of vitamin D.
TABLE 6. Average nutritive value of major forage species grazed.

<table>
<thead>
<tr>
<th></th>
<th>number of samples</th>
<th>DM%</th>
<th>S. E.</th>
<th>CP%</th>
<th>S. E.</th>
<th>ADF%</th>
<th>S. E.</th>
<th>TDN%</th>
<th>S. E.</th>
<th>NE(Lac) Mcal/kg</th>
<th>S. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>9</td>
<td>23.03</td>
<td>1.56</td>
<td>25.56</td>
<td>1.13</td>
<td>23.71</td>
<td>1.52</td>
<td>69.50</td>
<td>0.90</td>
<td>1.61</td>
<td>0.05</td>
</tr>
<tr>
<td>Bermuda</td>
<td>6</td>
<td>28.92</td>
<td>1.66</td>
<td>18.19</td>
<td>1.01</td>
<td>29.29</td>
<td>0.31</td>
<td>64.69</td>
<td>0.56</td>
<td>1.46</td>
<td>0.01</td>
</tr>
<tr>
<td>Bluestem</td>
<td>9</td>
<td>26.7</td>
<td>2.9</td>
<td>16.3</td>
<td>0.43</td>
<td>31.7</td>
<td>1.14</td>
<td>67.2</td>
<td>.91</td>
<td>1.34</td>
<td>.04</td>
</tr>
<tr>
<td>Crabgrass</td>
<td>10</td>
<td>21.09</td>
<td>1.53</td>
<td>19.29</td>
<td>1.00</td>
<td>27.13</td>
<td>0.89</td>
<td>70.24</td>
<td>0.58</td>
<td>1.50</td>
<td>0.03</td>
</tr>
<tr>
<td>Fescue</td>
<td>37</td>
<td>22.86</td>
<td>0.74</td>
<td>22.85</td>
<td>0.58</td>
<td>23.79</td>
<td>0.58</td>
<td>73.27</td>
<td>0.50</td>
<td>1.60</td>
<td>0.02</td>
</tr>
<tr>
<td>Matua</td>
<td>4</td>
<td>19.60</td>
<td>3.22</td>
<td>26.78</td>
<td>2.81</td>
<td>21.96</td>
<td>3.13</td>
<td>75.03</td>
<td>2.50</td>
<td>1.66</td>
<td>0.10</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>37</td>
<td>22.14</td>
<td>0.72</td>
<td>23.89</td>
<td>0.48</td>
<td>24.40</td>
<td>0.57</td>
<td>72.64</td>
<td>0.47</td>
<td>1.57</td>
<td>0.02</td>
</tr>
<tr>
<td>Rye, cereal</td>
<td>14</td>
<td>19.37</td>
<td>0.63</td>
<td>27.17</td>
<td>1.28</td>
<td>19.51</td>
<td>1.05</td>
<td>77.35</td>
<td>1.31</td>
<td>1.74</td>
<td>0.03</td>
</tr>
<tr>
<td>Sorghum Sudan</td>
<td>5</td>
<td>17.7</td>
<td>.85</td>
<td>19.2</td>
<td>1.86</td>
<td>29.8</td>
<td>1.45</td>
<td>68.7</td>
<td>1.15</td>
<td>1.40</td>
<td>.03</td>
</tr>
</tbody>
</table>
TABLE 7. Average nutrient content of round-bale haylages fed to PASTURE group.

<table>
<thead>
<tr>
<th>Haylage Type</th>
<th>number of samples</th>
<th>DM ± SE</th>
<th>CP ± SE</th>
<th>ADF ± SE</th>
<th>TDN ± SE</th>
<th>NE L, Mcal/kg ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fescue</td>
<td>9</td>
<td>59.0 ± 4.0</td>
<td>18.1 ± .58</td>
<td>31.8 ± 1.1</td>
<td>67.2 ± .89</td>
<td>1.3 ± .04</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>10</td>
<td>50.5 ± 3.9</td>
<td>19.6 ± 1.4</td>
<td>30.5 ± 1.2</td>
<td>65.4 ± .74</td>
<td>1.5 ± .03</td>
</tr>
</tbody>
</table>
TABLE 8. Calving and breeding windows for the seasonal calving groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calving Period</th>
<th>Breeding Period</th>
<th>Length of Breeding Period, days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 95</td>
<td>12/27/94-3/17/95</td>
<td>3/28/95-6/11/95</td>
<td>76</td>
</tr>
<tr>
<td>Fall 95</td>
<td>7/10/95-10/29/95</td>
<td>11/6/95-1/20/96</td>
<td>76</td>
</tr>
<tr>
<td>Spring 96</td>
<td>1/2/96-3/23/96</td>
<td>4/1/96-6/10/96</td>
<td>71</td>
</tr>
<tr>
<td>Fall 96</td>
<td>8/6/96-10/12/96</td>
<td>11/6/96-1/20/97</td>
<td>76</td>
</tr>
<tr>
<td>Spring 97</td>
<td>12/13/96-3/31/97</td>
<td>3/28/97-6/11/97</td>
<td>76</td>
</tr>
<tr>
<td>Fall 97</td>
<td>7/10/97-10/21/97</td>
<td>11/3/97-1/17/98</td>
<td>76</td>
</tr>
</tbody>
</table>
TABLE 9. Least squares means ± S.E. of milk production by treatment and breed.

<table>
<thead>
<tr>
<th>Group</th>
<th>Total Lactation, kg&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Percentage Difference</th>
<th>Average Daily Production, kg&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Percentage Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONFINE Holsteins</td>
<td>7609.7 ± 242.4</td>
<td>7.9%</td>
<td>29.2 ± .56</td>
<td>11.3%</td>
</tr>
<tr>
<td>PASTURE Holsteins</td>
<td>7008.5 ± 231.6</td>
<td></td>
<td>25.9 ± .54</td>
<td></td>
</tr>
<tr>
<td>CONFINE Jerseys</td>
<td>6108.0 ± 254.9</td>
<td>12.9%</td>
<td>22.1 ± .59</td>
<td>12.2%</td>
</tr>
<tr>
<td>PASTURE Jerseys</td>
<td>5321.6 ± 250.3</td>
<td></td>
<td>19.4 ± .58</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>Total lactation includes averages of total milk production within the project period including cows with short lactations due to culling. In addition, discarded milk due to mastitis has been subtracted.

<sup>2</sup>Average daily production is the total milk production divided by the number of days milked for each cow.

TABLE 10. Holsteins: Least squares means ± S.E. of total lactation production by treatment and season, kg.

<table>
<thead>
<tr>
<th>Group</th>
<th>CONFINE</th>
<th>PASTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 95</td>
<td>6395.7 ± 341.8</td>
<td>5477.7 ± 344.4</td>
</tr>
<tr>
<td>Fall 95</td>
<td>6963.7 ± 376.5</td>
<td>7596.5 ± 383.1</td>
</tr>
<tr>
<td>Spring 96</td>
<td>7246.6 ± 382.3</td>
<td>6812.2 ± 405.1</td>
</tr>
<tr>
<td>Fall 96</td>
<td>9411.7 ± 386.0</td>
<td>7651.0 ± 386.1</td>
</tr>
<tr>
<td>Spring 97</td>
<td>6997.7 ± 410.3</td>
<td>7981.4 ± 392.1</td>
</tr>
<tr>
<td>Fall 97</td>
<td>8758.2 ± 393.6</td>
<td>6586.3 ± 392.1</td>
</tr>
<tr>
<td>Spring 98</td>
<td>7494.4 ± 453.0</td>
<td>6954.6 ± 404.6</td>
</tr>
</tbody>
</table>
TABLE 11 Jerseys: Least squares means ± S.E. of total lactation production by treatment and season, kg.

<table>
<thead>
<tr>
<th>Group</th>
<th>CONFINE</th>
<th>PASTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 95</td>
<td>5389.3 ± 481.2</td>
<td>4516.9 ± 462.9</td>
</tr>
<tr>
<td>Fall 95</td>
<td>5517.9 ± 429.9</td>
<td>4901.6 ± 430.5</td>
</tr>
<tr>
<td>Spring 96</td>
<td>5969.5 ± 393.8</td>
<td>4895.1 ± 392.6</td>
</tr>
<tr>
<td>Fall 96</td>
<td>6861.8 ± 430.1</td>
<td>5752.8 ± 429.9</td>
</tr>
<tr>
<td>Spring 97</td>
<td>7179.7 ± 419.5</td>
<td>6088.8 ± 393.4</td>
</tr>
<tr>
<td>Fall 97</td>
<td>5923.8 ± 406.2</td>
<td>5520.2 ± 403.8</td>
</tr>
<tr>
<td>Spring 98</td>
<td>5913.9 ± 404.4</td>
<td>5576.0 ± 405.5</td>
</tr>
</tbody>
</table>
TABLE 12. Least squares means ± S.E of mastitis measurements for treatment and breed.

<table>
<thead>
<tr>
<th>Group</th>
<th>% of cows infected(^{a,b}) ±S.E.</th>
<th>infections/cow (all cows)(^{a,b}) ±S.E.</th>
<th>% of mastitic cows culled/died(^{a,b}) ±S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONFINE Holsteins</td>
<td>51.0 ± 4.5</td>
<td>1.06 ± .10</td>
<td>9.7 ± 1.6</td>
</tr>
<tr>
<td>PASTURE Holsteins</td>
<td>31.4 ± 4.5</td>
<td>.57 ± .10</td>
<td>1.6 ± 1.6</td>
</tr>
<tr>
<td>CONFINE Jerseys</td>
<td>34.6 ± 4.5</td>
<td>.51 ± .10</td>
<td>3.4 ± 1.6</td>
</tr>
<tr>
<td>PASTURE Jerseys</td>
<td>17.0 ± 4.5</td>
<td>.30 ± .10</td>
<td>0.0 ± ---</td>
</tr>
</tbody>
</table>

\(^a\) Significant Breed effect, \(P < .05\)

\(^b\) Significant Treatment effect, \(P < .01\)

The interaction of breed X treatment was not significant
TABLE 13. Least squares means ± S.E of body condition scores for treatment and breed groups within season and year. \(^{a,b,c}\)

<table>
<thead>
<tr>
<th>Group</th>
<th>Spring 95</th>
<th>Fall 95</th>
<th>Spring 96</th>
<th>Fall 96</th>
<th>Spring 97</th>
<th>Fall 97</th>
<th>Spring 98</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holsteins</td>
<td>2.9 ± .08</td>
<td>2.6 ± .11</td>
<td>2.6 ± .11</td>
<td>2.9 ± .09</td>
<td>2.9 ± .09</td>
<td>2.6 ± .13</td>
<td>2.4 ± .10</td>
</tr>
<tr>
<td>PASTURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holsteins</td>
<td>2.3 ± .08</td>
<td>2.3 ± .08</td>
<td>2.3 ± .07</td>
<td>2.4 ± .09</td>
<td>2.5 ± .08</td>
<td>2.6 ± .13</td>
<td>2.3 ± .09</td>
</tr>
<tr>
<td>CONFINE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jerseys</td>
<td>2.9 ± .10</td>
<td>2.9 ± .11</td>
<td>3.0 ± .07</td>
<td>3.1 ± .11</td>
<td>3.0 ± .09</td>
<td>3.0 ± .14</td>
<td>2.8 ± .09</td>
</tr>
<tr>
<td>PASTURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jerseys</td>
<td>2.4 ± .10</td>
<td>2.7 ± .10</td>
<td>2.8 ± .07</td>
<td>2.9 ± .11</td>
<td>2.8 ± .09</td>
<td>3.0 ± .12</td>
<td>2.5 ± .09</td>
</tr>
</tbody>
</table>

\(^{a}\) Significant Treatment effect (P < .05) for all seasons except Fall 97.

\(^{b}\) Significant Breed effect (P < .05) for all seasons except Spring 95; no Breed X Treatment Interactions.

\(^{c}\) Significant Interactions involving time included Treatment X Date (P < .05) for each seasonal group. Other interactions (Breed X Date, Breed X Treatment X Date) were significant in some seasonal groups but not others.
TABLE 14. Least squares means ± S.E for reproductive measures by treatment and breed.

<table>
<thead>
<tr>
<th>Group</th>
<th>% First Service Conception&lt;sup&gt;a&lt;/sup&gt; ±S.E.</th>
<th>% All Services Conception&lt;sup&gt;a&lt;/sup&gt; ±S.E.</th>
<th>% Cows Inseminated within 75 days&lt;sup&gt;a&lt;/sup&gt; ±S.E.</th>
<th>% 75-day Overall Pregnancy Rate&lt;sup&gt;a&lt;/sup&gt; ±S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONFINE Holsteins</td>
<td>39.0 ± 6.5</td>
<td>44.6 ± 4.7</td>
<td>84.8 ± 3.5</td>
<td>52.8 ± 6.2</td>
</tr>
<tr>
<td>PASTURE Holsteins</td>
<td>51.4 ± 6.5</td>
<td>54.5 ± 4.7</td>
<td>87.0 ± 2.9</td>
<td>63.0 ± 5.2</td>
</tr>
<tr>
<td>CONFINE Jerseys</td>
<td>60.0 ± 6.5</td>
<td>59.0 ± 4.7</td>
<td>94.8 ± 2.9</td>
<td>75.7 ± 5.2</td>
</tr>
<tr>
<td>PASTURE Jerseys</td>
<td>59.0 ± 6.5</td>
<td>60.2 ± 4.7</td>
<td>98.3 ± 2.9</td>
<td>80.5 ± 5.2</td>
</tr>
</tbody>
</table>

<sup>a</sup> Significant Breed effect, P < .05.
Figure 2. Comparison of Pasture Forages Grazed

<table>
<thead>
<tr>
<th>Species</th>
<th>CP%</th>
<th>TDN%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>25.6</td>
<td>69.5</td>
</tr>
<tr>
<td>Bermuda</td>
<td>18.2</td>
<td>64.7</td>
</tr>
<tr>
<td>Crabgrass</td>
<td>19.3</td>
<td>70.2</td>
</tr>
<tr>
<td>Fescue</td>
<td>22.8</td>
<td>73.3</td>
</tr>
<tr>
<td>Matua</td>
<td>26.8</td>
<td>75.0</td>
</tr>
<tr>
<td>Orchard Grass</td>
<td>23.9</td>
<td>72.6</td>
</tr>
<tr>
<td>Rye</td>
<td>27.2</td>
<td></td>
</tr>
</tbody>
</table>
Figure 3. Holsteins: Least Squares Means Total Lactation, kg

Total lactation includes averages of total milk production within the project period including cows with short lactations due to culling. In addition, discarded milk due to mastitis has been subtracted.
Figure 4. Holsteins: Least Squares Means Average Daily Production\(^2\), kg

Average daily production is the total milk production divided by the number of days milked for each cow.

\(^2\) Average daily production is the total milk production divided by the number of days milked for each cow.
Figure 5. Jerseys: Least Squares Means Total Lactation$^1$, kg

<table>
<thead>
<tr>
<th>Seasonal Group</th>
<th>Total Lactation, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 95</td>
<td></td>
</tr>
<tr>
<td>Fall 95</td>
<td></td>
</tr>
<tr>
<td>Spring 96</td>
<td></td>
</tr>
<tr>
<td>Fall 96</td>
<td></td>
</tr>
<tr>
<td>Spring 97</td>
<td></td>
</tr>
<tr>
<td>Fall 97</td>
<td></td>
</tr>
<tr>
<td>Spring 98</td>
<td></td>
</tr>
</tbody>
</table>

$^1$Total lactation includes averages of total milk production within the project period including cows with short lactations due to culling. In addition, discarded milk due to mastitis has been subtracted.
Average daily production is the total milk production divided by the number of days milked for each cow.
Figure 7.

Spring 1995 Holstein BCS

Spring 1995 Jersey BCS
Figure 8.
Figure 9.
Figure 10.

Spring 1998 Holstein BCS

Spring 1998 Jersey BCS
Figure 11.

Fall 1995 Holstein BCS

Fall 1995 Jersey BCS
Figure 12.
Figure 13.


Fales, S. L. 1994. Role of alfalfa as a grazing crop in animal diets. 6-16 National Alfalfa Grazing Conference. Certified Alfalfa Seed Council, Nashville, TN.


computerized grain feeder for lactating cows grazing grass pasture. J. Dairy Sci. 80: 3271-3282.


Comparative timed intakes of grain supplements for lactating Jerseys and Holsteins on pasture.

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North Carolina State University, Raleigh, NC

Abstract

This experiment compared intakes of grain supplement between Jerseys (n=9) and Holsteins (n=9) managed on pasture. Cows calved in September and were offered supplement twice a day before each milking. Supplement consisted primarily of ground corn, whole cottonseed, and soybean meal (42, 27, and 15 % of DM, respectively). Intake measurements were taken for six consecutive days in January (Period 1), March (Period 2), and May (Period 3). Amounts offered to each cow at each feeding were 6.83 kg, 4.55 kg, and 2.27 kg for Periods 1, 2, and 3, respectively. Supplements were reduced in spring because of greater availability of pasture. The experiment was a Latin square with two squares within each period. During the first 3 days (square 1) intakes were measured at 2.5, 7.5, and 12.5 min and during the next 3 days (square 2) intakes were measured at 5, 10, and 15 min. Sets of 3 cows of each breed were assigned within each square such that each cow was allowed access to the grain supplement for each of the six time intervals over each 6-day period. Cows were fed individually before the afternoon milking and intakes determined by measuring orts at appropriate time intervals. A calculated rate of eating was obtained for each cow from selected time intervals by dividing the amount eaten by respective time intervals to obtain kg/minute consumed. The general linear models procedure in SAS was used for statistical analyses within period. Cow within breed was used as the error term for testing breed effects. Amounts of feed eaten increased with time but did not differ significantly between the two breeds. Numerically, Holsteins averaged eating at least 0.3 kg more supplement several times, particularly during January when more feed was offered and less pasture was available. Rates of eating
were not significantly different between breeds but were numerically higher for Holsteins, particularly when more feed was fed.

Key words: Jersey, Holstein, intake, pasture

Introduction

Few studies have examined the rate at which cattle of different breeds can consume a grain ration. The rate and amount of feed consumed by different cows is important when the cows are fed as a group and the amount of grain fed is limiting. Such situations occur with pasture based dairy systems where groups of cattle are fed small amounts of grain. Sometimes with late lactation herds, the amount of grain fed can be as little as 2.3 kg/cow per feeding. How much supplemental grain a single cow consumes can influence her milk production and overall health, which affects the dairy farm’s overall profitability.

Total dry matter intake (DMI) of a dairy cow is influenced by several factors. These factors include days in milk, body weight, milk production, milk fat production, time of year, pregnancy status, and type of feed fed. Equations used to predict DMI use body weight as a main factor in the equation (N.R.C., 1997). The relationship of body weight to DMI is positively linear, that is as body size increases DMI increases. This would mean that the larger breeds of cattle consume more total feed than smaller breeds of cattle. Jersey cattle are smaller in stature and weight than Holsteins, and so Holsteins are expected to consume more than Jersey cattle. This concept is usually applied to cattle eating a TMR type ration. However when grazing cattle are eating a limited amount of a corn-based supplemental grain ration, it is possible that Jerseys may be able to eat as much as Holsteins can in mixed herds. When cattle are consuming a relatively small amount of grain during a short amount of time, the factor of body size and gut fill is less of an issue than when the cow is consuming a TMR or hay. This experiment was designed to test the hypothesis that grazing Jersey cattle may be able to consume the same amount of supplemental grain as grazing Holstein cattle.
Materials and Methods

Jersey (n=9; average parity and weight 2.6 and 431 kg) and Holstein (n=9; average parity and weight 2 and 609 kg) cows were used from a previous pasture-based trial that had been conducted at North Carolina State University’s Lake Wheeler Road Dairy Educational Unit near Raleigh, NC. The cows calved in the fall from 9/10/98 to 9/26/98 and were grazed on cool and warm season pastures during the lactation. In the winter when pasture was limiting, cows were fed grass haylage that had been harvested from the pastures during excess growth. Cows were fed a grain ration twice a day before each milking. The ration consisted of ground corn, soybean meal, whole cottonseed, minerals, and vitamins and was balanced using the DART ration program (Smith et al., 1994). Table 1 shows the ration composition and nutrient content expressed on a DM basis. The amount of the supplemental ration fed was adjusted as pasture availability changed but the ration composition was kept the same throughout the trial.

Intakes were taken three times during the lactation. Cows were fed a different amount of grain for each intake period. Intake measurements were taken for six days in January (Period 1), March (Period 2), and May (Period 3) of 1999. The amounts fed during each period were 6.83 kg/cow per feeding, 4.55 kg/cow per feeding, and 2.27 kg/cow per feeding for Periods 1, 2 and 3 respectively. The amount of supplement was reduced in spring because of greater availability of pasture and these times and amounts fed were chosen to examine intakes over a range of pasture availability. The experimental design was a Latin square with two squares. During the first 3 days (1st square) intakes were measured at 2.5, 7, and 12 minutes. During days 4 through 6 (2nd square) intakes were measured at 5, 10, and 15 minutes.

Three cows of each breed were randomly assigned to groups A, B, or C for each intake period. Each group (A, B, or C) of six cows total was then assigned such that each group had feed intakes measured at each time interval across the 6 days.

Intakes were measured in the following manner: The same amount of feed was placed in a metal feed tub and placed in front of a open space in a unlocked headlock in a freestall barn. Tubs were placed far enough from the headlock so that
cows could not eat from the tub but could see the feed. Openings on either side of the open headlock were locked shut so that cows were forced to place their head into an open headlock, separated at a distance of 1.8m (center to center). Once all cows were locked in the headlocks, cows were identified by color coded cards indicating the time group to which they had been assigned. Within 2 to 5 seconds, all the tubs were moved up to the cows where they could consume the feed and a stopwatch was started. At the predetermined time, each cow’s tub was moved back out of the cow’s reach. Grain that spilled during eating was collected and placed in the appropriate tub. Each cow’s orts were weighed and recorded. Cows were then released from the headlocks and allowed to consume the remainder of the grain once it had been weighed. Cows were fed in a similar manner five feedings prior to the data collection to accustom the cow’s to the feeding method. There were three to four observers during each data collection.

In addition to amount eaten, a calculated rate of eating was obtained for each cow. This rate was calculated by dividing the amount eaten by each time interval to obtain kg/minute consumed. This was done by using data obtained from all of the time intervals from the Period 1 intakes (6.83 kg/cow per feeding), data from the 2.5, 5, and 7.5 minute intervals for the Period 2 intakes (4.55 kg/cow per feeding), and only data from the 2.5 and 5 minute time intervals for Period 3 (2.27 kg/cow per feeding). All of the data from Period 1 was used for these calculations because there was enough feed left at the end of all of the time intervals to calculate an accurate rate of consumption. For Period 2 a majority of the cows had finished most of the grain by 10 minutes, so calculating a rate of eating for the longer time intervals (10, 12.5 and 15 minutes) would produce an erroneous rate of eating because for those time intervals there was some “dead time” after all the feed had been eaten. Only data from the 2.5 and 5 minute time intervals were used from Period 3 (2.27 kg/cow per feeding).

**Statistical Analyses**

The amount of feed eaten and the rate of eating were analyzed using the general linear models procedure in SAS (SAS, 1997) within each intake period.
Variation among cows within breed was used as the error term for testing breed effects. Breed, square, time, and breed×square effects were tested in the model.

Results

Amount of Feed Consumed

For all three intake periods, square was significant in the model. The independent variable of square was expected to be significant since different time interval intakes were measured for squares 1 and 2; 2.5, 7.5 and 12.5 minutes for square 1 and 5, 10 and 15 minutes for square 2.

For all intake periods, breed was not significant in the model. Interactions tested were not significant either. Table 2 shows the amounts of feed consumed for each time interval. Figures 1-3 show these results graphically. During Period 1, Holsteins did consume numerically higher amounts of supplement at each time interval, but the effect was not significant. For Periods 2 and 3, Holsteins consumed a numerically higher amount at time intervals 5 and 7.5, minutes, but again the effect was not significant.

Rate of Eating

For the calculated rate of eating, breed was not significant for any time intervals. Holsteins did eat at a slightly higher numerical rate for each time interval during Period 1. The averaged rate of eating was .40 kg/minute for Holsteins and .35 kg/minute for the Jerseys in Period 1, .32 kg/minute for Holsteins and .31 kg/minute for Jerseys in Period 2, and .40 kg/minute for Holsteins and .39 kg/minute for Jerseys in Period 3. Rates of eating for both breeds are shown in Table 3. Figures 4 and 5 show the rates of eating for each breed graphically. For all of the periods, rates of eating ranged from .21 kg/minute to .81 kg/minute among individual Holstein cows and .20 kg/minute to .50 kg/minute among individual Jersey cows.

Discussion

Other research has shown that individual dairy cows can consume ground grain feed at rates that vary from .18 kg per minute to .72 kg per minute (Harshbarger, 1949; Hupp and Lewis, 1958; Dalton et al., 1953). Our findings
showed that individual Holstein and Jersey cattle can consume from .20 kg to .81 kg of grain feed per minute. Harshbarger (1949) and Stallcup et al. (1959) had reported the rate of consumption for Jersey cattle to be slower than that for Holstein cattle. In contrast, our research showed that at some feeding levels, Jerseys cows can eat at a similar rate as Holsteins. When the rates of eating were calculated from the shorter time intervals for the two breeds, there was no difference between the breeds. This implies that at certain grain feeding levels, and with equal an unrestricted access to the grain, Jersey cows can consume as much supplemental feed as larger Holstein cattle.

Byers (1952) reported that rate of consumption varied with amount fed. Byers showed that cows ate at a rate of .23 kg per minute when offered 2.36 kg of feed and ate .27 kg per minute when offered 3.3 kg of feed. Through 7.5 minutes, cows in our experiment ate at an average rate of .33 kg per minute when fed 4.55kg. When cows were fed 6.83 kg, the average rate of consumption was .38 kg per minute. Our results showed that the cows from each breed (Table 3) did eat at a slightly faster rate when offered larger quantities of grain and when less pasture was available. These findings also agree with other trials where it was shown that cattle that had been turned out to pasture took longer to consume a grain supplement (Dalton et al., 1953; Stallcup et al., 1959). However we did not offer different amounts of feed during each intake period so these rates of eating should be compared with caution.

**Summary**

These findings have implications to dairy systems where different breeds are housed and fed together. Theoretically a Jersey cow, being a smaller breed, should not be able to eat as much as a full-size Holstein cow. This likely is true for total daily DMI but this research suggests this is not the case when relatively small amounts of supplemental concentrates are provided. Jersey cows may be able to consume more than their proportional “share” of supplemental feed and therefore may be consuming relatively more of the energy dense ration. This in turn may allow Jerseys to consume more net metabolizable energy than the Holstein cows and
may allow them to perform better in terms of relatively more milk production, higher BCS, and better reproductive performance.
TABLE 1. Formulation and nutrient content of supplemental ration fed to pasture group.

<table>
<thead>
<tr>
<th>Formulation, % of Total Ration DM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Corn grain</td>
<td>42.5</td>
</tr>
<tr>
<td>48% Soybean Meal</td>
<td>15.3</td>
</tr>
<tr>
<td>Whole cottonseed</td>
<td>27.0</td>
</tr>
<tr>
<td>Cottonseed hulls</td>
<td>6.3</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>.4</td>
</tr>
<tr>
<td>Deflourinated Phosphate</td>
<td>1.2</td>
</tr>
<tr>
<td>Sodium Bicarbonate</td>
<td>1.11</td>
</tr>
<tr>
<td>Calcitic Limestone</td>
<td>1.3</td>
</tr>
<tr>
<td>Trace mineral salt</td>
<td>.7</td>
</tr>
<tr>
<td>Vitamin A, D, E supplement</td>
<td>.2</td>
</tr>
</tbody>
</table>

Nutrient Content, DM basis

| Dry Matter, % | 88.4 |
| Crude protein, % | 19.8 |
| Acid detergent fiber, % | 18.4 |
| Total Digestible Nutrients, % | 73.6 |
| NE L, Mcal/kg | 1.65 |

1 Contained 14,400 ppm Zn; 11,064 ppm Mn; 26 ppm Fe; 2016 ppm Cu; 425 ppm I; 75 ppm Se; and 111 ppm Co.

2 Contained 9,056,000 IU/kg of vitamin A; 22,048 IU/kg of vitamin E; and 1,963,000 IU/kg of vitamin D.
TABLE 2. Least squares means for amounts of supplement consumed by Holsteins (H) and Jerseys (J) for each time interval by experimental period.

<table>
<thead>
<tr>
<th>Eating Time (minutes)</th>
<th>Period 1- January (6.83 kg offered)</th>
<th>Period 2- March (4.55 kg offered)</th>
<th>Period 3- May (2.27 kg offered)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>J</td>
<td>H</td>
</tr>
<tr>
<td>2.5</td>
<td>1.07</td>
<td>0.96</td>
<td>0.81</td>
</tr>
<tr>
<td>5</td>
<td>2.22</td>
<td>1.86</td>
<td>1.73</td>
</tr>
<tr>
<td>7.5</td>
<td>2.97</td>
<td>2.50</td>
<td>2.29</td>
</tr>
<tr>
<td>10</td>
<td>4.16</td>
<td>3.65</td>
<td>2.79</td>
</tr>
<tr>
<td>12.5</td>
<td>4.47</td>
<td>3.97</td>
<td>3.28</td>
</tr>
<tr>
<td>15</td>
<td>5.39</td>
<td>5.02</td>
<td>3.78</td>
</tr>
<tr>
<td>S. E.</td>
<td>± .13 kg eaten</td>
<td>± .16 kg eaten</td>
<td>± .04 kg eaten</td>
</tr>
</tbody>
</table>

TABLE 3. Least squares means for rate of eating grain supplement by Holsteins (H) and Jerseys (J) for each time interval by experimental period.

<table>
<thead>
<tr>
<th>Rate of Eating (kg/minute)</th>
<th>Period 1- January (6.83 kg offered)</th>
<th>Period 2- March (4.55 kg offered)</th>
<th>Period - May (2.27 kg offered)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>J</td>
<td>H</td>
</tr>
<tr>
<td>2.5</td>
<td>.43</td>
<td>.38</td>
<td>.33</td>
</tr>
<tr>
<td>5</td>
<td>.44</td>
<td>.37</td>
<td>.36</td>
</tr>
<tr>
<td>7.5</td>
<td>.40</td>
<td>.33</td>
<td>.31</td>
</tr>
<tr>
<td>10</td>
<td>.41</td>
<td>.37</td>
<td>-</td>
</tr>
<tr>
<td>12.5</td>
<td>.36</td>
<td>.32</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>.36</td>
<td>.34</td>
<td>-</td>
</tr>
<tr>
<td>S. E.</td>
<td>± .03 kg/minute</td>
<td>± .03 kg/minute</td>
<td>± .02 kg/minute</td>
</tr>
</tbody>
</table>
FIGURE 1.
Period 1: Graph of LS means for amount of grain supplement eaten in respective time intervals.
6.82 kg fed

---

FIGURE 2.
Period 2: Graph of LS means for amount of grain supplement eaten in respective time intervals.
4.55 kg fed
FIGURE 3.
Period 3: Graph of LS means for amount of grain supplement eaten in respective time intervals.
2.27 kg fed
FIGURE 4.
Period 1: Graph of LS means for rate of grain consumption per minute by breed.
6.82 kg fed
FIGURE 5.
Period 2: Graph of LS means for rate of grain consumption per minute by breed.
4.55 kg fed
Literature Cited


Comparison of fatty acid content of milk from Jersey and Holstein cows consuming pasture or a total mixed ration.

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¹ North Carolina State University, Raleigh, ² Clemson University, Clemson ³ Purdue University, West Lafayette.

Abstract

Holstein (n=19) and Jersey (n=18) cows were used to study effects of two feeding systems on fatty acid composition of milk. Cows were part of a trial that began in January 1998. Cows assigned to the confinement (CONFINE) group were fed a TMR with corn silage and alfalfa silage as the forage sources while those assigned to pasture (PASTURE) had access to crabgrass (90%) and clover (10%) pasture and were allowed 5.5 kg grain/head daily. Two milk samples were collected from each cow at a.m. and p.m. milkings one day each week for 4 consecutive weeks in June/July 1998. One set of samples was analyzed to determine fatty acid composition and the second set was used for crude protein and total fat analyses. Data were analyzed by the general linear models procedure of SAS using a split-plot model with breed, treatment, and breed by treatment as main effects and time of sampling and week as subplot effects along with interactions involving those variables. Pasture-fed cattle were higher (P < .05) than confinement cattle for the cis-9, trans-11 octadecadienoic acid isomer (CLA). In addition, Holsteins were higher (P < .05) than Jerseys for c16:1, c18:1, and for CLA and lower (P < .05) than Jerseys for c6:0, c8:0, c10:0, c12:0, and c14:0. Several treatment by week interactions existed but main effects were still important; for example, proportions of CLA in PASTURE cows were relatively constant across weeks (.66, .64, .64, .69, SEM .02) respectively, while the CLA of TMR cows increased in week 4 (.35, .31, .31, .48, SEM .02). This study found potentially important differences in fatty acid composition of milk from cows consuming a warm season pasture species compared to milk from cows consuming a TMR, as well as differences between Holstein and Jersey breeds.

Key words: Conjugated linoleic acid, Pasture, Fatty acids
Introduction

Conjugated linoleic acid (CLA) refers to various positional and geometric isomers of the fatty acid linoleic acid (cis-9, cis-12 octadecadienoic acid) each with a conjugated double bond arrangement. These bonds can be at several different positions such as 9 and 11, 10 and 12, and 11 and 13. Recent interest in CLA has stemmed from animal research conducted in the past few years that has shown CLA to be a potent anticarcinogen (Ha et al., 1990; Ip et al., 1991; Ip et al., 1994). The National Academy of Sciences (N.R.C, 1996) has identified CLA as the only known fatty acid to inhibit cancer in experimental animals. Conjugated linoleic acid has also been linked to lean body mass-enhancing properties (Park et al., 1997; Park et al., 1999; West et al., 1998). Conjugated linoleic acid is found primarily in the meat and milk of ruminants. Milk fat is considered the richest natural source of CLA (Parodi, 1977). It appears that CLA remains stable in processed dairy products (Lin et al., 1995) and so is a function the concentration of CLA in raw milk. The potentially positive health benefit of CLA offers the dairy industry an exciting opportunity to increase the consumption of dairy products. Many studies have been conducted to discover what factors control the amount of CLA produced. These studies have shown that pasture intake can increase the levels of CLA in cow’s milk (Timmen and Patton, 1988; Jahreis et al., 1997; Kelly et al., 1998b; Dhiman et al., 1999b). Timmen and Patton (1988) found CLA levels of milk fat were higher from pasture-fed Holsteins compared to conventional fed (grain and silage) Holsteins. Jahreis et al. (1997) took monthly samples from the bulk tanks of three different German dairy farms for a year’s time. The year-round grazing dairy had the highest levels of CLA in the milk, followed by the summer grazing dairy. The conventional type dairy had the lowest levels of CLA produced. Jahreis et al. (1997) also showed a seasonal effect, with the grazing dairy producing the highest levels of CLA in the grazing months of May to September. Dhiman et al. (1999b) conducted a trial in which three groups of cows consumed either 1/3, 2/3 or all of their daily feed from pasture. Pasture consisted of bluegrass, quackgrass, bromegrass and white clover, all of which are cool season forage species. The balance of the feed for the 1/3 and 2/3 groups were made up with a supplement that contained alfalfa hay, corn, and roasted soybeans. Relative amounts of CLA were highest for cows on 100% pasture and lowest for the cows receiving 1/3 pasture, 22.1 mg/g of milk fatty acids compared to 8.9 and 14.3 for the 1/3 and 2/3 pasture groups, respectively.
The objective of this experiment was to determine the levels of CLA and other milk components in the milk fat of Holstein and Jersey cows grazing a warm-season pasture species or consuming a TMR.

Materials and Methods

Cows were part of an ongoing trial designed to compare TMR and pasture feeding systems that began in January 1998 at the North Carolina State University Lake Wheeler Road Dairy Educational Unit near Raleigh, NC. Each treatment group included both Holstein and one Jersey cows. Cows calved from January to March 1998. During the milk sampling period confinement-fed cows averaged 134 days in milk and the pasture-fed group averaged 132 days in milk.

The pastures grazed consisted of crabgrass (*Digitaria sanguinalis*, > 90% of forage DM) and white clover (*Trifolium repens*, < 10% of forage DM). Cows grazed these pastures at least 5 days before each sampling. No irrigation was used but limited quantities of dairy lagoon effluent were applied on the paddocks as a source of nutrients to maintain pasture quantity.

Cows in both treatments were managed by the same workers and milked in the same parlor. The two treatments were managed as separate groups, with the two breeds managed together within each treatment.

The confinement (CONFINE) cows (n=17) were housed in a freestall barn with access to a dirt exercise lot. There were nine Holsteins and eight Jerseys sampled from the CONFINE group. The ration was fed as a total mixed ration (TMR) and consisted of corn silage, alfalfa silage, ground corn, soybean meal, whole cottonseed, minerals, and vitamins (Table 1). The TMR was offered at about 21 kg/cow per day (DM basis) as balanced with the DART ration program (Smith et al. 1994).

The pastured (PASTURE) cows (n=20) were housed on pasture and were brought into the barn to be fed a supplement and milked. There were ten Holsteins and ten Jerseys sampled from the PASTURE group. The pastured cows supplemental ration consisted of ground corn, soybean meal, whole cottonseed, minerals, and vitamins (Table 2). During the last week of sampling, 1.01 kg/cow per feeding of 48% CP soybean meal was substituted for an equal amount of corn. Rations were balanced using the DART ration program (Smith et al. 1994).
The amount of supplement fed was 5.5 kg/cow per day. Grab samples of fresh pasture were submitted to the North Carolina Forage Testing Laboratory for analysis periodically. The grab samples were collected in a manner to mimic the selection of the grazing cow so the sample would represent what the cows were consuming. Table 3 shows the average quality of the crabgrass/clover pasture grazed during the trial.

**Sample Collection and Analyses**

Two 59-ml milk samples were taken during a.m. and p.m. milkings one day each week for four consecutive weeks. Sample dates were: June 16, June 23, June 30 and July 7th, 1998. One set of samples were preserved with 2-bromo-2-nitropropane1,3 diol. These samples were packed in ice and shipped to the Minnesota DHIA Milk Analysis Laboratory in Zumbrota, MN. Those samples were analyzed for fat, protein, lactose, somatic cell count (SCC), milk urea nitrogen (MUN), other solids, and solids non fat. The second set of samples was stored at -20°C until analysis for fatty acid composition.

Fat was isolated from the milk samples to determine the fatty acid composition by centrifuging thawed milk at 21,000 × g for 30 min at 4°C. Fatty acids in milk fat were converted to methyl esters and separated by GLC (Sukhija and Palmquist, 1988). The GLC used was a 30-m × 0.25-mm i.d. polyamino glycol capillary column (Supelco, Inc., Bellefonte, PA). Column temperature was held at 90°C for 3 min and then raised 6°C/min to a final temperature of 220°C, which was then held for 10 min. Temperatures of the injector and flame-ionization detector were maintained at 250°C. Helium was the carrier gas; linear flow rate was set at 20 cm/s with a 100:1 split. The CLA isomer analyzed was the cis-9, trans-11 C18:2 isomer which has previously been reported as the major isomer in milk fat (Parodi, 1977).

Milk production data for each cow was obtained from the dairy’s computer system. BCS were taken before, during and after the trial.

Milk component and fatty acid analyses from a.m. and p.m. milkings were averaged for each week sampled.
Statistical Analyses

Data were analyzed by the general linear models procedure of SAS using a split plot model with breed, treatment and breed by treatment as main effects and time of sampling and week as subplot along with interactions involving those variables.

Results

Milk Yield and Composition

Data on milk yield and composition for each treatment are presented in Table 4, while Table 5 shows the data for each breed. Table 6 shows data for each treatment and breed group. CONFINE cows had significantly \( P < .05 \) higher milk yield, fat percentage and solids non-fat compared to the PASTURE group. Jerseys had significantly \( P < .05 \) higher levels of fat percentage, protein percentage and solids non-fat, while the Holsteins produced significantly \( P < .05 \) more milk than Jerseys. There was a significant \( P < .05 \) treatment×breed interaction with milk yield, with the CONFINE Holsteins producing more milk than the PASTURE Holsteins (36.7 kg vs. 27.5), but the PASTURE Jerseys and the CONFINE Jerseys had similar production (23.6 vs. 24.8) (Table 6). Treatment×breed interaction with protein tended to be significant \( P < .06 \) with CONFINE Holsteins producing a similar percentage of protein as the PASTURE Holsteins (2.87% vs. 2.94%), but the CONFINE Jerseys produced a higher percentage of protein compared to the PASTURE Jerseys (3.62% vs. 3.43%).

Concentrations of MUN were not significantly different between treatments or breeds, although Jerseys had numerically higher MUN. SCC were also not significantly different between treatments and breeds. The average SCC for all the cows was a 4. Week was significant with each variable tested.

Fatty Acid Composition

Fatty acid composition of milk from each treatment is presented in Table 7, while Table 8 shows data for each breed. Table 9 shows data for each treatment and breed group. Fatty acids are reported as percentage of total fatty acids measured. The PASTURE group produced
significantly ($P < .05$) higher concentrations of CLA compared to the CONFINE group (.66 vs. .36 % of total fatty acids). Pasture-fed cows also produced significantly ($P < .05$) more C$_{10:0}$, C$_{12:0}$, C$_{14:0}$, C$_{14:1}$, C$_{16:1}$, and C$_{18:3}$. CONFINE cows produced significantly ($P < .05$) more C$_{18:0}$, C$_{18:1}$, and C$_{20:0}$. Data from each breed shows that Jerseys produced significantly ($P < .05$) higher concentrations of C$_{6:0}$, C$_{8:0}$, C$_{10:0}$, C$_{12:0}$, and C$_{14:0}$. Holsteins produced significantly ($P < .05$) higher concentrations of CLA (.56 vs. .46 % of total fatty acids) and higher concentrations of C$_{16:1}$ and C$_{18:1}$. Week was significant with each variable tested, and the interactions of treatment×week and breed×week and treatment×breed×week were significant for some variables. Average BCS for each treatment and breed group are shown in Table 10. All four groups lost condition during the trial.

**Discussion**

Milk yield for the PASTURE Holsteins was significantly ($P < .05$) lower than for the confinement-fed Holsteins, which has been shown in other pasture-based studies (Kelly et al., 1998; Kolver and Muller, 1998a). The milk production of the Jersey groups did not differ during this trial but usually did differ for lactation length studies (White, 2000). Confinement cows did have a significantly ($P < .05$) higher total milk fat percentage compared to the pasture cows (3.71% vs. 3.45%), while the protein percentage did not differ between the two groups. Other pasture-based studies have shown no differences in milk fat and protein percentage between confinement-fed and pasture-based systems (Rust et al., 1995; Bela et al., 1995; White, 2000). Kelly et al. (1998) noted no fat percentage differences but did report the pasture group had a significantly ($P < .05$) lower protein percentage (2.61% vs. 2.8%).

The treatment×breed interaction with protein tended to differ ($P < .06$) with both treatments of Holsteins producing a similar percentage of protein but the CONFINE Jerseys produced a higher percentage of protein compared to the PASTURE Jerseys (3.62% vs. 3.43%). In addition, CONFINE Jerseys produced a numerically higher amount of fat percentage compared to the PASTURE Jerseys (4.10% vs. 3.68%).
PASTURE cows produced an 83% higher concentration of CLA (cis-9, trans-11 C_{18:2}) compared to the CONFINE cows (.66 vs. .36% of total fatty acids). This is in agreement with the grazing studies that have reported higher levels of CLA with pasture intake (Timmen and Patton, 1988; Jahreis et al., 1997; Kelly et al., 1998b; Dhiman et al., 1999b); however our study differed in the use of a warm season species of pasture.

Some of the fatty acid levels of the present study do not agree with previous work done with confinement and pasture-based systems. For example, there was no difference between the two groups in the production of short and medium chain fatty acids (C_{6:0} to C_{14:0}). Data from Dhiman et al., (1999b) also did not report any differences in the amounts of short and medium chain fatty acids, whereas Timmen and Patton (1988) and Kelly et al., (1998b) reported the production to be lower in the pasture-fed cows. In addition, pasture consumption has been reported to increase production of C_{18:1} (Timmen and Patton, 1988; Jahreis et al., 1997; Kelly et al., 1998b), whereas our study showed no difference between the CONFINE and PASTURE groups. However comparison between studies should be done with caution. Recent studies have had many different features and treatments. Differences include: types of confinement rations fed, types and levels of pasture supplements fed; amount and species of pasture grazed; sampling frequency and type; numbers of cows; days in milk of cows used; and laboratory procedures used. In addition, amounts of fatty acids are reported in several different ways. The present study is the first comparison study to examine fatty acid production from a warm-season pasture species (crabgrass) and the use of both Holsteins and Jerseys in each treatment.

There were several significant differences in fatty acid levels between the two breeds. Holsteins produced a significantly ($P < .05$) higher concentration of CLA (.56 vs. .46 % of total fatty acids) with no interaction with treatment. Both CONFINE Holsteins and PASTURE Holsteins produced more CLA compared to the CONFINE and PASTURE Jerseys, respectively. (Table 10) (Figure 1). Capps et al. (1999) also reported that Jerseys produced lower levels of CLA compared to Holsteins.

Palmquist and Beaulieu (1992) reported that Holstein cattle produced from 8 to 42% more short and medium chain fatty acids (C_{6:0} to C_{14:0}) compared to Jersey cattle. In contrast, Capps et al. (1999) reported that Jerseys had higher levels compared to Holsteins. Our data showed that Jerseys produced significantly ($P < .05$) higher levels of C_{6:0} to C_{14:0}. Palmquist
and Beaulieu (1992) also reported that Jerseys produced 13% more stearic acid (C\textsubscript{18:0}) and 15% lower oleic acid (C\textsubscript{18:1}). Our data showed no difference between breeds for levels of C\textsubscript{18:0}, but did show that Jerseys produced 13% lower C\textsubscript{18:1}. Further studies may show explanation of breed differences for fatty acid production. Preliminary work by Medrano et al. (1999) shows differences between breeds in the activity of the mammary enzyme stearoyl co-A desaturase (SCD). Stearoyl co-A desaturase (SCD) oxidizes palmitic (C\textsubscript{16:0}) and stearic (C\textsubscript{18:0}) to palmitoleic (C\textsubscript{16:1}) and (C\textsubscript{18:1}) oleic and involved in CLA production. (Medrano et al., 1999).

The effect of week was significant for every variable tested. Treatment×week interaction was significant ($P < .05$) for CLA. This effect on CLA levels was due to the increase in CLA produced in week 4 in all of the CONFINE cows. (Figure 2 and Figure 4). Percentages of CLA produced by the PASTURE group remained fairly even for weeks 1 through 4 (Figure 2 and Figure 3). The reason for this increase was not determined for sure; there was perhaps an unrecorded change in a ration ingredient that caused the increase. It should be noted that during the last week of sampling, 1.01 kg/cow per day of 48% soybean meal was substituted for corn in the PASTURE ration but no obvious effect was detected; perhaps due to the small amount of the ration change.

Other effects of weeks were examined and did not seem to fit a pattern; i.e. no one week affected all variables. Dhiman et al. (1999b) also reported unexplained treatment×week interactions for levels of CLA.

Kelly et al. (1998b) reported that there was more variation in the amount of CLA produced in the grazing cows compared to the confinement group. Jahreis et al. (1997) reported that the lowest variation of CLA was from confinement samples. Our data show moderate variation within the pasture-fed cows with the exception of two Holsteins who produced a higher concentration of CLA compared to the rest of the PASTURE group. (Figure 3). The confinement-fed group showed even less variation with the exception of the previously discussed increase in week 4 of CLA. (Figure 4). Standard errors for CLA averaged .04 as a percent of total fatty acids for the CONFINE group and .03 as a percent total of fatty acids for the pasture-fed group. Kelly et al. (1998b) reported a three-fold difference among individual cows for CLA concentration. Our data showed similar differences, the largest difference being a threefold increase from .21 % total fatty acids to .64 % total fatty acids for a CONFINE
Jersey. Conjugated linoleic acid concentrations for the CONFINE group ranged from .21 to .65 % total fatty acids over the 4 weeks while the PASTURE group ranged from .37 to 1.26 % total fatty acids (Figures 3 and 4).

Other experiments using oilseeds to alter the production of CLA in bovine milk have also reported large variations of CLA produced both within groups and within individual cows. (Kelly et al., 1998a; Jiang et al., 1996; Lawless et al, 1998; Stanton et al., 1997)

Body condition scores for the groups are shown in Table 10. It should be noted that all cows lost body condition during the trial, most likely due to the increasing temperatures during the trial and possible subsequent drop in dry matter intake. Maximum air temperatures were 34.0 °C, 36.6 °C, 38.6 °C, and 32.9 °C, for the four weekly sample days. The lowest minimum temperature for the sample days was 19.4°C, so there was very little night-time cooling. The energy balance of a cow can affect the milk fat fatty acid composition, and this factor could have played a part in our results. Some research has suggested that cows fed on a restricted diet will increase the production of CLA, although with the studies it is difficult to separate out treatment effects versus the restricted energy intake effects (Jiang et al., 1996; Stanton et al, 1997).

Summary

This study showed that supplemented pasture-fed cattle grazing a warm-season pasture species (crabgrass) produced significantly higher concentrations of CLA compared to confinement-fed cattle. In addition, Holsteins from both CONFINE and pasture groups produced more CLA than the respective Jersey treatments. There was little to moderate variation of CLA levels within the treatment groups or within individual cows.
TABLE 1. Formulation and nutrient content of TMR fed to CONFINE group.

<table>
<thead>
<tr>
<th>Formulation, % of Total Ration DM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td>29.3</td>
</tr>
<tr>
<td>Wilted Alfalfa silage</td>
<td>29.7</td>
</tr>
<tr>
<td>Whole cottonseed</td>
<td>17.8</td>
</tr>
<tr>
<td>Ground corn grain</td>
<td>13.4</td>
</tr>
<tr>
<td>Bypass Blend</td>
<td>4.6</td>
</tr>
<tr>
<td>48% Soybean Meal</td>
<td>3.5</td>
</tr>
<tr>
<td>Bentonite ¹</td>
<td>.71</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>.3</td>
</tr>
<tr>
<td>Defluorinated phosphate</td>
<td>.23</td>
</tr>
<tr>
<td>Trace mineral salt ²</td>
<td>.17</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>.13</td>
</tr>
<tr>
<td>Vitamin A, D, E supplement ³</td>
<td>.04</td>
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</table>

**Nutrient Content, DM basis**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Quantity</th>
</tr>
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<tbody>
<tr>
<td>Dry Matter, %</td>
<td>51.42</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>17.9</td>
</tr>
<tr>
<td>Acid detergent fiber, %</td>
<td>23.6</td>
</tr>
<tr>
<td>Total Digestible Nutrients, %</td>
<td>74.3</td>
</tr>
<tr>
<td>NE L, Mcal/kg</td>
<td>1.54</td>
</tr>
</tbody>
</table>

¹ Volclay (American Colloid Co., Arlington Heights, IL)
² Contained 14,400 ppm Zn; 11,064 ppm Mn; 26 ppm Fe; 2016 ppm Cu; 425 ppm I; 75 ppm Se; and 111 ppm Co.
³ Contained 9,056,000 IU/kg of vitamin A, 22,048 IU/kg of vitamin E, and 1,963,000 IU/kg of vitamin D.
TABLE 2. Formulation and nutrient content of supplemental ration fed to PASTURE group*.

<table>
<thead>
<tr>
<th>Formulation, % of Total Ration DM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Corn grain</td>
<td>85.8</td>
</tr>
<tr>
<td>Whole cottonseed</td>
<td>6.0</td>
</tr>
<tr>
<td>Calcitic Limestone</td>
<td>5.5</td>
</tr>
<tr>
<td>Trace mineral salt 1</td>
<td>1.8</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>.51</td>
</tr>
<tr>
<td>Vitamin A, D, E supplement 2</td>
<td>.41</td>
</tr>
</tbody>
</table>

Nutrient Content, DM basis

<table>
<thead>
<tr>
<th>Nutrient</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter, %</td>
<td>90.0</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>8.8</td>
</tr>
<tr>
<td>Acid detergent fiber, %</td>
<td>5.5</td>
</tr>
<tr>
<td>Total Digestible Nutrients, %</td>
<td>78.8</td>
</tr>
<tr>
<td>NE L, Mcal/kg</td>
<td>1.80</td>
</tr>
</tbody>
</table>

*During the last week of sampling, 1.01 kg/cow per day of 48% Soybean Meal was substituted for an equal amount of corn in the ration.

1 Contained 14,400 ppm Zn; 11,064 ppm Mn; 26 ppm Fe; 2016 ppm Cu; 425 ppm I; 75 ppm Se; and 111 ppm Co.

2 Contained 9,056,000 IU/kg of vitamin A; 22,048 IU/kg of vitamin E; and 1,963,000 IU/kg of vitamin D.

---

TABLE 3. Average nutrient content of crabgrass/clover pasture, DM basis, n=5.

<table>
<thead>
<tr>
<th>DM%</th>
<th>CP%</th>
<th>ADF%</th>
<th>TDN</th>
<th>NE Mcal/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.8 ± 2.6</td>
<td>22.1± .98</td>
<td>25.4 ±.88</td>
<td>70.6 ±.31</td>
<td>1.56± .03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>CONFINE</th>
<th>PASTURE</th>
<th>S. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield, kg</td>
<td>30.1*</td>
<td>26.1</td>
<td>0.93</td>
</tr>
<tr>
<td>Fat, %</td>
<td>3.71*</td>
<td>3.45</td>
<td>0.09</td>
</tr>
<tr>
<td>Protein, %</td>
<td>3.25</td>
<td>3.19</td>
<td>0.05</td>
</tr>
<tr>
<td>OS, %</td>
<td>5.76</td>
<td>5.64</td>
<td>0.05</td>
</tr>
<tr>
<td>SNF, %</td>
<td>9.05*</td>
<td>8.83</td>
<td>0.08</td>
</tr>
<tr>
<td>Lactose, %</td>
<td>4.84</td>
<td>4.70</td>
<td>0.05</td>
</tr>
<tr>
<td>MUN</td>
<td>16.00</td>
<td>16.10</td>
<td>0.51</td>
</tr>
</tbody>
</table>

* Indicates significant difference at $P < .05$ level.

TABLE 5. Least squares means for milk yield and milk composition for each breed.

<table>
<thead>
<tr>
<th></th>
<th>Holstein</th>
<th>Jersey</th>
<th>S. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield, kg</td>
<td>32.05*</td>
<td>24.21</td>
<td>0.90</td>
</tr>
<tr>
<td>Fat, %</td>
<td>3.28*</td>
<td>3.89</td>
<td>0.09</td>
</tr>
<tr>
<td>Protein, %</td>
<td>2.91*</td>
<td>3.53</td>
<td>0.05</td>
</tr>
<tr>
<td>OS, %</td>
<td>5.64</td>
<td>5.77</td>
<td>0.05</td>
</tr>
<tr>
<td>SNF, %</td>
<td>8.55*</td>
<td>9.32</td>
<td>0.08</td>
</tr>
<tr>
<td>Lactose, %</td>
<td>4.71</td>
<td>4.83</td>
<td>0.05</td>
</tr>
<tr>
<td>MUN</td>
<td>15.42</td>
<td>16.68</td>
<td>0.49</td>
</tr>
</tbody>
</table>

* Indicates significant difference at $P < .05$ level.
TABLE 6. Least squares means for milk yield and milk composition for each treatment and breed group.

<table>
<thead>
<tr>
<th></th>
<th>CONFINE Holstein</th>
<th>S. E.</th>
<th>PASTURE Holstein</th>
<th>S. E.</th>
<th>CONFINE Jersey</th>
<th>S. E.</th>
<th>PASTURE Jersey</th>
<th>S. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield, kg</td>
<td>36.7</td>
<td>1.3</td>
<td>27.5</td>
<td>1.2</td>
<td>23.6</td>
<td>1.3</td>
<td>24.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Fat, %</td>
<td>3.33</td>
<td>0.13</td>
<td>3.23</td>
<td>0.12</td>
<td>4.10</td>
<td>0.13</td>
<td>3.68</td>
<td>0.12</td>
</tr>
<tr>
<td>Protein, %</td>
<td>2.87</td>
<td>0.07</td>
<td>2.94</td>
<td>0.06</td>
<td>3.62</td>
<td>0.07</td>
<td>3.43</td>
<td>0.06</td>
</tr>
<tr>
<td>OS, %</td>
<td>5.74</td>
<td>0.07</td>
<td>5.53</td>
<td>0.07</td>
<td>5.78</td>
<td>0.08</td>
<td>5.75</td>
<td>0.07</td>
</tr>
<tr>
<td>SNF, %</td>
<td>8.63</td>
<td>0.11</td>
<td>8.47</td>
<td>0.10</td>
<td>9.46</td>
<td>0.11</td>
<td>9.19</td>
<td>0.10</td>
</tr>
<tr>
<td>Lactose, %</td>
<td>4.81</td>
<td>0.07</td>
<td>4.61</td>
<td>0.07</td>
<td>4.86</td>
<td>0.07</td>
<td>4.79</td>
<td>0.07</td>
</tr>
<tr>
<td>MUN</td>
<td>15.44</td>
<td>0.71</td>
<td>15.40</td>
<td>0.66</td>
<td>16.56</td>
<td>0.73</td>
<td>16.80</td>
<td>0.66</td>
</tr>
</tbody>
</table>

TABLE 7. Least squares means for fatty acid composition for each treatment.

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>CONFINE</th>
<th>PASTURE</th>
<th>S. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C 4:0</td>
<td>1.07</td>
<td>1.07</td>
<td>0.03</td>
</tr>
<tr>
<td>C 6:0</td>
<td>1.59</td>
<td>1.65</td>
<td>0.03</td>
</tr>
<tr>
<td>C 8:0</td>
<td>1.04</td>
<td>1.12</td>
<td>0.03</td>
</tr>
<tr>
<td>C 10:0</td>
<td>2.33*</td>
<td>2.55</td>
<td>0.08</td>
</tr>
<tr>
<td>C 12:0</td>
<td>2.74*</td>
<td>3.07</td>
<td>0.09</td>
</tr>
<tr>
<td>C 14:0</td>
<td>9.94*</td>
<td>10.84</td>
<td>0.17</td>
</tr>
<tr>
<td>C 14:1</td>
<td>0.60*</td>
<td>0.81</td>
<td>0.03</td>
</tr>
<tr>
<td>C 16:0</td>
<td>31.50</td>
<td>31.36</td>
<td>0.42</td>
</tr>
<tr>
<td>C 16:1</td>
<td>1.06*</td>
<td>1.16</td>
<td>0.03</td>
</tr>
<tr>
<td>C 18:0</td>
<td>15.42*</td>
<td>13.40</td>
<td>0.34</td>
</tr>
<tr>
<td>C 18:1</td>
<td>22.07</td>
<td>21.27</td>
<td>0.37</td>
</tr>
<tr>
<td>C 18:2</td>
<td>2.49*</td>
<td>1.84</td>
<td>0.06</td>
</tr>
<tr>
<td>CLA¹</td>
<td>0.36*</td>
<td>0.66</td>
<td>0.04</td>
</tr>
<tr>
<td>C 18:3</td>
<td>0.37*</td>
<td>0.73</td>
<td>0.01</td>
</tr>
<tr>
<td>C 20:0</td>
<td>.17*</td>
<td>.12</td>
<td>.004</td>
</tr>
</tbody>
</table>

* Indicates significant difference at P < .05 level.
¹ cis-9, trans-11 C 18:2 isomer only.
TABLE 8. Least squares means for fatty acid composition for each breed.

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>% of total fatty acids measured</th>
<th>Holstein</th>
<th>Jersey</th>
<th>S. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C 4:0</td>
<td>1.06</td>
<td>1.09</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>C 6:0</td>
<td>1.51</td>
<td>1.73*</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>C 8:0</td>
<td>0.96</td>
<td>1.20*</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>C 10:0</td>
<td>2.10</td>
<td>2.78*</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>C 12:0</td>
<td>2.50</td>
<td>3.31*</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>C 14:0</td>
<td>9.83</td>
<td>10.95*</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>C 14:1</td>
<td>0.70</td>
<td>0.71</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>C 16:0</td>
<td>31.43</td>
<td>31.43</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>C 16:1</td>
<td>1.18</td>
<td>1.03*</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>C 18:0</td>
<td>14.35</td>
<td>14.46</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>C 18:1</td>
<td>23.19</td>
<td>20.15*</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>C 18:2</td>
<td>2.15</td>
<td>2.17</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>CLA ¹</td>
<td>0.56</td>
<td>0.46*</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>C 18:3</td>
<td>0.54</td>
<td>0.56</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>C 20:0</td>
<td>0.15</td>
<td>0.14</td>
<td>0.004</td>
<td></td>
</tr>
</tbody>
</table>

* Indicates significant difference at $P < .05$ level.

¹ cis-9, trans-11 C 18:2 isomer only.
TABLE 9. Least squares means for fatty acid composition for each treatment and breed group.

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>CONFINE Holstein</th>
<th>S. E.</th>
<th>CONFINE Jersey</th>
<th>S. E.</th>
<th>PASTURE Holstein</th>
<th>S. E.</th>
<th>PASTURE Jersey</th>
<th>S. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C 4:0</td>
<td>1.05</td>
<td>.04</td>
<td>1.09</td>
<td>.04</td>
<td>1.06</td>
<td>.04</td>
<td>1.08</td>
<td>.04</td>
</tr>
<tr>
<td>C 6:0</td>
<td>1.47</td>
<td>.05</td>
<td>1.71</td>
<td>.05</td>
<td>1.56</td>
<td>.05</td>
<td>1.74</td>
<td>.05</td>
</tr>
<tr>
<td>C 8:0</td>
<td>.92</td>
<td>.04</td>
<td>1.17</td>
<td>.04</td>
<td>1.00</td>
<td>.04</td>
<td>1.23</td>
<td>.04</td>
</tr>
<tr>
<td>C 10:0</td>
<td>2.00</td>
<td>.10</td>
<td>2.68</td>
<td>.10</td>
<td>2.22</td>
<td>.10</td>
<td>2.89</td>
<td>.10</td>
</tr>
<tr>
<td>C 12:0</td>
<td>2.34</td>
<td>.12</td>
<td>3.14</td>
<td>.12</td>
<td>2.65</td>
<td>.12</td>
<td>3.48</td>
<td>.12</td>
</tr>
<tr>
<td>C 14:0</td>
<td>9.43</td>
<td>.24</td>
<td>10.44</td>
<td>.24</td>
<td>10.22</td>
<td>.24</td>
<td>11.47</td>
<td>.24</td>
</tr>
<tr>
<td>C 14:1</td>
<td>.59</td>
<td>.04</td>
<td>.60</td>
<td>.04</td>
<td>.80</td>
<td>.04</td>
<td>.82</td>
<td>.04</td>
</tr>
<tr>
<td>C 16:0</td>
<td>31.67</td>
<td>.60</td>
<td>31.32</td>
<td>.60</td>
<td>31.19</td>
<td>.60</td>
<td>31.53</td>
<td>.60</td>
</tr>
<tr>
<td>C 16:1</td>
<td>1.12</td>
<td>.04</td>
<td>1.00</td>
<td>.04</td>
<td>1.25</td>
<td>.04</td>
<td>1.07</td>
<td>.04</td>
</tr>
<tr>
<td>C 18:0</td>
<td>15.36</td>
<td>.49</td>
<td>15.47</td>
<td>.49</td>
<td>13.35</td>
<td>.49</td>
<td>13.45</td>
<td>.49</td>
</tr>
<tr>
<td>C 18:1</td>
<td>23.28</td>
<td>.53</td>
<td>20.87</td>
<td>.53</td>
<td>23.09</td>
<td>.53</td>
<td>19.44</td>
<td>.53</td>
</tr>
<tr>
<td>C 18:2</td>
<td>2.49</td>
<td>.08</td>
<td>2.49</td>
<td>.08</td>
<td>1.82</td>
<td>.08</td>
<td>1.86</td>
<td>.08</td>
</tr>
<tr>
<td>CLA&lt;sup&gt;1&lt;/sup&gt;</td>
<td>.41</td>
<td>.05</td>
<td>.32</td>
<td>.05</td>
<td>.72</td>
<td>.05</td>
<td>.59</td>
<td>.05</td>
</tr>
<tr>
<td>C 18:3</td>
<td>.38</td>
<td>.02</td>
<td>.37</td>
<td>.02</td>
<td>.71</td>
<td>.02</td>
<td>.75</td>
<td>.02</td>
</tr>
<tr>
<td>C 20:0</td>
<td>.17</td>
<td>.01</td>
<td>.17</td>
<td>.01</td>
<td>.13</td>
<td>.01</td>
<td>.11</td>
<td>.01</td>
</tr>
</tbody>
</table>

<sup>1</sup>cis-9, trans-11 C<sub>18:2</sub> isomer only.

TABLE 10. Mean BCS for each treatment and breed group.

<table>
<thead>
<tr>
<th>Date</th>
<th>CONFINE Holsteins</th>
<th>PASTURE Holsteins</th>
<th>CONFINE Jerseys</th>
<th>PASTURE Jerseys</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/2/98</td>
<td>2.63</td>
<td>2.28</td>
<td>2.84</td>
<td>2.64</td>
</tr>
<tr>
<td>6/22/98</td>
<td>2.52</td>
<td>2.13</td>
<td>2.72</td>
<td>2.44</td>
</tr>
<tr>
<td>7/7/98</td>
<td>2.40</td>
<td>2.27</td>
<td>2.64</td>
<td>2.38</td>
</tr>
</tbody>
</table>
Figure 1. Relative amounts of CLA by Treatment and Breed Group

Confine Holstien: 0.41
Confine Jersey: 0.32
Pasture Holstein: 0.72
Pasture Jersey: 0.59
Figure 2. Changes in relative amounts of CLA by Week and Treatment

![Bar chart showing changes in CLA over weeks for Confine and Pasture treatments.]

Confine: 0.35, 0.31, 0.31, 0.48
Pasture: 0.67, 0.64, 0.64, 0.69

Week: 1, 2, 3, 4

CLA, % of total fatty acids
Figure 3. Amounts of CLA for individual cows on Pasture*

* Not all cows are shown; cows with any missing data points were omitted
Figure 4. Amounts of CLA for individual cows in Confinement*

* Not all cows are shown; cows with any missing data points were omitted.
Literature Cited


Spatial and Time Distribution of Dairy Cattle Manure in an Intensive Pasture System

S. L. White, S. P. Washburn, L. D. King, R. E. Sheffield, J. T. Green, Jr.
North Carolina State University

Abstract

This study determined distribution of feces and urine from dairy cattle managed in a rotationally grazed pasture. Lactating Holsteins (n=18) and Jerseys (n=18) were grazed on a .74 ha endophyte-free fescue (*Festuca arundinacea*)/white clover (*Trifolium repens*) pasture. All cows were constantly observed for 24 h five times from July 1997 to April 1998, for 13.5 h in September 1997, and subgroups of eight cows were observed for 24 h in May 1997 and for each of the other 24-h observations. Cows had access to about 54% of the paddock during the first grazing period (12 h) and had access to the entire paddock during the second grazing period (8 h). Data included: (1) times and location of all feces and urine events from eight cows, observed while in the pasture, feed area, milking parlor or in transit; and (2) all urine and feces events on pasture for all 36 cows each grazing period. After each grazing day, urine spots and feces were surveyed and mapped for subsequent analyses. Among the 8-cow subgroups, percentages of the manure events in specific areas were highly correlated with time spent in each area (r = .99). Feces and urine (estimated at .12 m² and .36 m², respectively) from the six observations covered 10% of the total paddock area. The front 54% of the paddock was used exclusively for 60% of the total grazing period and contained approximately 62% of the urine and 69% of the feces. Within a 30-m radius of the portable waterer, concentrations of feces and urine from the warm season observations (July, August, September) were significantly greater than concentrations during the cool season observations (December, February, and April). Pasture systems can potentially reduce manure handling and storage requirements proportional to the time cows are kept on pasture. Manure on pasture was relatively evenly distributed over multiple grazing periods with the exception of the area around the water tank during summer grazings.
Introduction

Grazing livestock play an important role in the ecology of pasturelands. Livestock consume nutrients in the form of forages and use those nutrients to produce meat, milk and fiber which are exported off of the farm. Most of the ingested nutrients are excreted back onto the pasture in the form of feces and urine. A portion of excreted nutrients are used by the pasture plants for growth, where in turn the nutrients are consumed and recycled through the grazing animal.

Under some circumstances, this deposition of nutrients can be a potential source of non-point source pollution. Not all of the nutrients deposited by the animal are used by the growing plants. Non-point source pollution occurs from pasturelands and conventional drylots in the form of surface water runoff that occurs during rain storm events. According to Line et al. (1998), dairy farms can contribute significant sources of non-point source pollution. Goetz (1999) found that nutrient pollution in the form of runoff was much greater from a conventional drylot system than from a grazing system. There has been very little work done with the manure distribution within dairy cattle grazing systems. Work with beef cattle in less intensive grazing management systems (moving 2 to 3 times a week) has shown that the location of water source, shade and topography can affect the distribution of manure in pasture systems (Peterson and Gerrish, 1996).

One objective of this study was to determine the distribution of feces and urine from dairy cattle managed in a rotationally grazed pasture system. A second objective was to compare the proportions of feces and urine events in the pasture to those occurring in the feeding and milking areas.

Materials and Methods

The study was conducted at the North Carolina State University Lake Wheeler Road Dairy Educational Unit near Raleigh, NC. Cows were part of an ongoing research grazing trial that began in March 1995. Lactating Holsteins (n=18) and Jerseys (n=18) were grazed on 29 ha of cool and warm season forage species all year around. Most cows in the herd had been in the grazing trial for one or two seasons. Data were collected from a .74 ha endophyte-free fescue
(Festuca arundinacea)/white clover (Trifolium repens) pasture. Data were collected for five 24-h periods from July 1997 to April 1998, and for one 13.5-h period in September 1997. The September observation period was only 13.5h because of the limited pasture that was available. Cows were milked at about 03:00 and 13:00 h each day. Cows were fed a grain supplement in a covered barn area before each milking. Cows were given a fresh area of grass after each milking. For the 24-h observations, data collection began at approximately 11:30 h when cows were brought into the barn for the afternoon milking. Data collection ended 24 h later when cows were removed from the paddock being grazed. For the 13.5-h observation period (September 1997), data collection began after the afternoon milking and ended when cows were removed from the paddock being grazed the next morning.

For the 24 h observations, the first grazing period (12h) began at approximately 14:30 h and ended at approximately 02:30 h the next day when cows were brought in for the morning milking. The second grazing period (8h) began at about 04:00 h and ended about 12:00 h when cows were removed from the pasture. The grazing periods were of unequal times due to the milking schedule. Cows were given about 54% of the paddock during the first grazing period. The pasture was divided using electrified polywire. During the second grazing period the polywire was removed and cows had access to the entire paddock. For the 13.5 h observation (September 1997), data collection began at 15:30 h and ended about 05:00 h. Cows were given 100% of the paddock for the 13.5 h period. There was a portable water tank located in the north east corner of the paddock near the entrance of the paddock during each grazing. The paddock that was monitored contained no natural or artificial shade and had a slope of approximately 5%, with the slope rising from east to the west end of the paddock.

**Data Collected: Individual Cow Data**

The first type of data collected was the location and time of each manure and urine event over 24-h periods from 4 Holsteins and 4 Jerseys from the herd of 36. These data were collected in May 1997, July 1997, August 1997, December 1997, February 1998 and in April 1998. These dates were chosen to allow collection data during different seasons and environmental conditions. Data collected in May, July, and August of 1997 were from spring calving cows that had calved in January 1997. The other collection dates were from cows that
were in a fall calving group that had calved in September 1997. The same eight cows were used each observation period within each season. Cows were chosen to represent a range in daily milk production and age. Cows were numbered with livestock paint markers and observed very closely and continuously during each 24-h period. The data included any feces or urine events that occurred in the pasture, while in transit on the lanes, in the feeding area, and in the milking parlor in addition to the time spent in each area. Data from each cow were added together for each observation period from each season and averaged. Correlations between the average number of events and time spent in each area were determined within each observation period. The averaged number of events for each area were expressed as the percentage of total events. The percentages across observation periods were then averaged.

**Data Collected: Whole Herd Pasture Data**

The second type of data was the location of all feces and urine events that occurred in the pasture from all 36 cows. Data were collected in July 1997, August 1997, September 1997, December 1997, February 1998 and April 1998. Data were collected during different seasons and conditions of the year so that the effect of warm and cool temperatures could be compared. Observation periods when the temperature-humidity index was above 22 °C (72 °F) for at least seven hours per period were considered warm, while the other periods were considered cool. The warm season included July, August and September while the cool season was December, February and April. Each data collection period included grazing after the afternoon (12h) and morning (8h) milkings within a 24-h cycle, with the September data period being only 13.5 h. While in the pasture, cows were constantly observed. Care was taken not to disturb the cows, especially at night when cows were resting. Observers collecting the data were not allowed to help the farm crew with the movement or handling of the herd. Each urination from every cow was marked with a colored flag. The cow was allowed to finish urinating before the observer approached the cow to mark the spot. With the exception of the 13.5 h period, urine spots from the first (Urine 1) and second (Urine 2) grazing periods within each data collection cycle were distinguished by different colored flags. Within one or two days after the cows had grazed the paddock and had been moved to another paddock, each manure and urine spot was surveyed using the Topcon Total Station Laser Transit System ®. For intact feces piles, the point was
surveyed from the center of the piles. For feces events that were scattered, the middle of the feces event was estimated and surveyed. The fence lines and the location of the water tank were also surveyed and mapped. Data were transformed using Tripod Data Systems Forsight Software® for mapping and analysis. Maps were developed using Arc View® software. To generate the maps, areas of coverage for each feces and urine event were estimated at .12 m² and .36 m², respectively. Analysis was performed using Arc View® software. A series of eleven arcs in 10 m increments that radiated out from the water tank location were drawn. Each arc was lettered A through K with section A being closest to the water tank. The area of the paddock within each arc was calculated and the number of feces and urine events were counted within each arc. For the feces, the total number of events from the warm season was greater than the cool season. (Table 2). For the urine the total number of events from the cool season was slightly greater than the warm season. To adjust for this effect for comparative analysis, numbers of feces and urine events in each season were standardized to equal the number of respective events in the other season. Adjustment factors (Table 2) were obtained by dividing the total number of feces and urine events in the one season by the respective numbers in the other season. The number of feces and urine observations within each 10-m arc for the cool season then multiplied by these factors. These numbers were then divided by the area of each arc to obtain a density (number of events/ per m²) for each 10-m arc. The location of the water tank was essentially the same for each observation period.

Hourly temperature and humidity information was obtained from the State Climate Office of North Carolina at NC State University. The weather information was obtained from a computer weather station located at the Lake Wheeler Road Dairy Educational Unit. Using a temperature-humidity index equation (Dougherty et al. 1991) temperature-humidity indexes were calculated for each hour for each observation period.

**Statistical Analyses**

Correlations between the total number of feces and urine events for the 8 cows and time spent in each area were determined within each observation period using Excel Software (1997). Those correlations were averaged across the five 24-h observation periods. The density of feces and urine events within each arc from the water tank was analyzed using
general linear models procedures in SAS (1995). Season, linear, quadratic and cubic effects of
distance from the water source, and the interactions with season were tested in the model.

Results

Summarized results from the individual cow data are shown in Table 1. Percentages of
the manure events were highly correlated with time spent in each area for each observation
period \( r = .99 \). Averages of 84.1\% of the urinations and 84.7\% of the feces events occurred in
the paddock area. There were no differences in distribution or number of feces and urine events
between Jerseys and Holsteins.

Maps generated from the total paddock observations with the 10-m arcs are shown in
figures 1-7. For the 20-h grazing periods, the front 54\% of the paddock was used exclusively for
60\% of the total grazing period and contained approximately 62\% of the urine and 69\% of the
feces.

Using area estimates of .12 m\(^2\) and .36 m\(^2\) for feces and urine respectively, the total
manure from the five 20-h observations and the one 13.5-h observation covered 10\% of the total
paddock.

When the densities in each 10-m arc for feces and urine events were analyzed for the
observation periods, season, and season×distance were significant \( P < .05 \) for both feces and
urine events. The interaction of season and distance was such that both feces and urine events
closer to the water tank were significantly higher during the warm season compared to the cool
season. Figures 8 and 9 show the densities of the events in relation to the distance from the
water tank.

Discussion

Data from the eight cows showed that time spent in a certain location was highly
correlated to the number of events that occurred in that location. This can be affected by the
manner in which cows are handled. For example, our data showed that only 3.1\% of the total
number of urinations and 2.1\% of the feces events occurred while in the holding area near the
milking parlor and in the milking parlor. Only 2 feces events and 1 urine event occurred in the
parlor itself over all observation periods. This number would likely be higher if the cattle were
handled by a strange or “rough” milker. The number of events in other areas could also be
different depending on how the cows were handled in each area. Cows should always be handled as gently as possible to reduce stress and minimize the amount of manure events. The majority of the manure (84.1% urine and 84.7% feces) occurred in the paddock, which has implications on the storage capacity and cost of manure handling facilities in pasture systems. It should be noted that it was standard protocol for the farm crew that when cows were retrieved from the paddock they were given time to stand up and void themselves before they were driven into the lanes. By giving the cows time to empty themselves on the paddock the amount of manure on the lanes was reduced. Only 4% of the feces were recorded on the lanes while only .5% of the urinations occurred on the lanes.

Because time spent in an area and the number of events is highly correlated, the deposition of manure can be affected by the management of the cow herd. The time spent on pasture is often maximized for grazing cows to maximize pasture intake. In addition the amount of manure deposited on the pasture can be maximized. Ways to maximize the time spent on pasture include efficient feeding systems and especially high-through-put milking parlors. If a system is used where 85% of the manure is distributed on the pasture by the cattle, the manure storage and handling facilities required would only have to handle about 15% of the total manure produced. Minimal parlor clean up and manure handling systems would be needed, and such systems would not require large, expensive and controversial lagoons.

Our data and previous work with beef cattle (Peterson and Gerrish, 1996) showed that cattle tend to camp around the water source during heat stress. The average air temperature was 27 °C (80.6 °F) for the July observation, 22.5 °C (72.6 °F) for the August observation, and 23.2 °C (73.7°F) for the observation period in September. Maximum temperatures were 31.7 °C (89.1 °F) for July and 30.2 °C (86.3 °F) for August. In September, the maximum air temperature was 32.9°C (91.1 °F), which occurred at the very beginning of the observation period (15:30 h). The temperature-humidity index (THI) was above 22 °C (72 °F) for the entire 24-h observation period in July, above 22°C (72 °F) for eight hours during the August observation, and above 22 °C (72 °F) for the first seven hours of the September observation. The lowest air temperature recorded during the July observation was 24.8 °C (76.6°F) at 5:00h, which indicated there was very little night cooling. THI values that are above 22 °C (72°F) are considered a mild stress on lactating dairy cattle (Armstrong, 1994). Therefore it can be said
that the cattle were under some heat stress during those observation periods. The average air
temperature was 6.5 °C (43.8 °F), 10.6 °C (51.1 °F), and 13 °C (55.5 °F) for the December,
February and April observation periods, respectively. Maximum air temperatures for each cool
observation period were: December, 10.8 °C (51.4 °F); February, 20.2 °C (68.3 °F); and April
19.1 °C (66.4°F). The THI for these days did not approach 22 °C (72°F).

During the three observation periods (July, August and September) when cattle were
under mild heat stress, the density of both feces and urine events around the water tank were
significantly ($P < .05$) higher than from the months where there was no heat stress (December,
February and April) (Figures 8 and 9). This effect was especially seen within 30 m of the water
tank (sections A through C). While this can result in a problem for permanent water tanks,
portable water tanks could be used to help distribute the manure nutrients more evenly. For
example, a longer hose connection to the water tank could have been used to allow the water
tank to be moved several feet down the fence line for the subsequent grazing period. Another
option is to provide a second water source in the paddock. Shade was not a factor in our
experiment but has been shown to affect manure distribution (Wilkinson et al. 1989; Gerrish et
al. 1993). If shade is used in grazing systems, the use of portable shade structures that are
moved frequently can be used to help distribute manure. Despite the effect of the water tank,
distributions of feces and urine were relatively evenly distributed throughout the rest of the
paddock (Figures 1-7).

Literature surveyed reported that the range of area covered is 0.05 to .14m$^2$ for feces and
.14 to .36m$^2$ for urine (Petersen et al., 1956; Wilkinson and Lowery, 1973; Dalrymple et al.,
1994). Using .12 m$^2$ and .36 m$^2$, for feces and urine respectively, the total area covered from the
six observational periods (a period of 10 months) was only about 10%. During and Weeda
(1994) reported that the area affected by nutrients from a feces or urine spot can be as much as
five times the area of the actual manure spot. From our data this means that about half of the
total paddock was being covered by nutrients over the 10 month period. This calculation relates
to nutrients applied and does not take into account the uptake of nutrients by plants during the
growing season. Other factors affecting the nutrient movement include the action of rain,
earthworm and insect activity, and the traffic of the cattle.
Conclusions

Our findings show that the distribution of manure in a pasture system can be influenced by the amount of time cattle spend in certain areas. By maximizing the time spent on pasture the amount of manure distributed on the pasture can also be maximized. This can reduce the cost associated with expensive manure storage and handling equipment. In addition, the manure deposited on pasture is relatively evenly distributed over multiple grazing periods. Although concentrations of nutrients were greater near the waterer under summer conditions, use of portable water sources and shade might help distribute manure more evenly during hot weather.
TABLE 1. Average percentages of daily total of urine and feces events for eight dairy cows from five 24-h observation periods.¹

<table>
<thead>
<tr>
<th>Location</th>
<th>Percentage of time spent in each area</th>
<th>Feces ± S. E.</th>
<th>Urine ± S. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Area</td>
<td>7.3</td>
<td>9.1 ± .01</td>
<td>12.3 ± .01</td>
</tr>
<tr>
<td>Parlor Holding</td>
<td>2.8</td>
<td>1.7 ± .006</td>
<td>2.9 ± .008</td>
</tr>
<tr>
<td>Parlor</td>
<td>5.5</td>
<td>.4 ± .003</td>
<td>.2 ± .002</td>
</tr>
<tr>
<td>Lanes</td>
<td>4.3</td>
<td>4 ± .02</td>
<td>.5 ± .003</td>
</tr>
<tr>
<td>Paddock</td>
<td>81.2</td>
<td>84.7 ± .15</td>
<td>84.1 ± .15</td>
</tr>
</tbody>
</table>

¹Average correlation of percentage of events with percentage of time spent = .99.

TABLE 2. Total number of events for each seasonal observational period¹ and adjustment factors.

<table>
<thead>
<tr>
<th></th>
<th>Warm Season</th>
<th>Cool Season</th>
<th>Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feces</td>
<td>1359</td>
<td>1160</td>
<td>no. cool season events/no. warm season events .85</td>
</tr>
<tr>
<td>Urine</td>
<td>668</td>
<td>691</td>
<td>no. warm season events/no. cool season events .97</td>
</tr>
</tbody>
</table>

¹Warm season = July, August, September; Cool season = December, February, April.
FIGURE 1. Feces and urine distribution, July 1997.

FIGURE 2. Feces and urine distribution, August 1997.
FIGURE 7. Feces and urine distribution, July, August, September, December 1997; February and April 1998.
Figure 8. Least squares means for total feces distribution.*

Significant ($P < .05$) Interaction of season X linear distance from water tank. (Section A is within 10 m and K is > 100m from water tank).

* Unadjusted LS Means used for graph.
Figure 9. Least squares means for total urine distribution.*

Significant \( P < .05 \) Interaction of seasonXlinear distance from water tank.
(Section A is within 10 m and K is > 100m from water tank).

* Unadjusted LS Means used for graph.
Literature Cited


Overall Conclusions

Confinement cows produced significantly more milk than pasture-fed cows, both for total lactation and average daily production. Reproductive performance of the two treatments did not differ with an overall 75-day pregnancy rate of 68%. Jerseys in both systems did have higher percentages of cows inseminated (96.5%), conception rate (59.6%), and 75-day pregnancy rate (78%) compared to Holsteins (86%, 49%, 57.9% respectively). The percentage of cows infected with at least one case of clinical mastitis was higher in the confinement herd than the pasture-fed herd (43% vs. 24%) with Holsteins higher than Jerseys (41% vs. 26%). Interactions of breed and feeding system and average somatic cell count scores were not significantly different. Pasture-fed cows had lower average body condition scores than confinement cows, ranging from 0.2 to 0.6 points lower on a 5-point scale.

It was determined that Jerseys could consume as much as Holsteins at three different feeding levels (6.8, 4.5, and 2.3 kg/cow per feeding). This experiment showed that in certain time frames, Jersey cattle can consume equal amounts of supplements compared to Holsteins. Therefore in mixed groups Jerseys can consume relatively more supplemental energy relative to body size and milk production compared the Holsteins.

When fatty acids were examined, concentrations conjugated linoleic acid were 80% higher in pasture-fed cattle compared to the confinement-fed cattle. In addition concentrations of CLA were higher in Holsteins compared to Jerseys.

When the distribution of manure in the pasture was studied, percentages of the manure events in each area were highly correlated with time spent in each area (r=.99). Feces and urine (estimated at .12 m² and .36 m², respectively) from six observational periods covered 10% of the total paddock. Within 30 m² of the portable waterer and gate, concentrations of feces and urine from the warm season observations were significantly greater than concentrations during the cool season observations. Manure on pasture was relatively evenly distributed over multiple grazing periods with the exception of the area around the water tank during summer grazings.

These experiments showed that when compared to confinement-fed cattle, pasture-fed cattle produced less milk, produced more conjugated linoleic acid, had less mastitis and had lower body condition scores, while reproductive performance did not differ between the two groups. Jerseys had less mastitis, produced less conjugated linoleic acid, and performed better
reproductively when compared to Holstein cattle. In addition, pasture-fed Jersey cattle can consume as much supplemental grain in certain time frames as pasture-fed Holstein cattle. Manure distribution on a pasture-based system is highly correlated with time spent in an area and is fairly evenly distributed over the paddock area over multiple grazing periods except for the area around the water tank during heat stress temperatures.

**Overall Discussion**

Our study found that while pasture-fed cattle produced less milk than confinement-fed cattle, the pastured cattle had significantly less mastitis than the confinement cattle. Mastitis can be a very serious and costly herd health problem. Income is lost due to mastitis from lost milk, cost of medications and nursing sick cows, and the cost of replacement cows. The difference in mastitis cases represents a clear advantage to the pasture system. In addition, very few pasture-fed cows had to be culled in contrast to the high number of confinement cows that were culled. This represents another economic savings that a pasture-based system can provide.

Although there were no significant differences in reproductive performance, the pasture-fed cows had the numerically higher conception and pregnancy rates. If such rates are achieved in larger herds this higher rate could prove to be a considerable advantage to pasture systems. The improved footing that pasture offers can also aid in estrus display and detection.

Jersey cows from both treatments achieved relatively high conception and pregnancy rates, and although Holstein conception rates were better than might be expected 76-day pregnancy rates were lower than desired for both treatments. A seasonal calving system can be very labor efficient for many types of dairy farms, although not usually considered for confinement farms. By concentrating the tasks associated with fresh cow care, calf rearing and cow breeding to a few months of the year, additional labor is needed for a short time. The seasonal dry period offers not only the dairy cow a rest but allows families to take vacations away from the farm. In addition, seasonal calving matches cow nutrient requirements with the spring or fall flush in forage growth.

In our experiment as well as others, the BCS of pasture-fed cattle are lower compared to confinement cattle. BCS is an indication of energy balance and overall health of a lactating dairy cow. Low BCS scores are most likely due to the fact that with pasture-fed cattle the
consumption of energy is the limiting factor for both body condition and milk production. In addition, pasture-fed cattle expend extra energy walking to and from grazing paddocks. Body condition and energy balance did not seem to affect reproduction or overall health, but can be a concern if BCS remains low throughout the lactation and dry period. Grain supplementation for pasture systems should be carefully managed and balanced to support milk production and body condition. Pasture-fed cattle should also be carefully managed during the dry period to slightly gain or maintain body condition for optimal performance for the next lactation.

The possible breed and cow differences in rate of intake of grain supplements is an important issue for pasture-based farms where cattle are generally fed relatively small amounts of grain. The amount of grain consumed by pasture-fed lactating dairy cow can have an important impact on her milk production, body condition and overall health. It has been generally accepted that a Jersey cow will eat less dry matter compared to a Holstein cow due to body mass differences, but this may only apply to total dry matter intake. Our trial showed that pasture-fed Jerseys could consume the same amount of supplement as pasture-fed Holsteins, which means Jerseys can consume more energy dense supplement per unit of milk production compared to Holsteins. This ability for the Jersey to consume more supplemental energy may affect the relative performance (milk production, body condition score, reproduction) of Jersey cattle in pasture-based systems.

The potential health benefits associated with conjugated linoleic acid (CLA) offers the dairy industry an exciting potential to increase dairy product consumption. Our data as well as others has shown that the consumption of fresh pasture forages of various types increases the concentration of CLA in milkfat. Niche marketing of CLA-rich products offers a new way for pasture-based dairies to develop and promote unique products such as “farm-fresh” milk, cheese and yogurts. There are already a number of family-size farm businesses that offer products such as “grass-produced” or organic dairy products, and CLA offers another way to promote such businesses. The implementation of niche marketing has been one way some dairies have been able to remain competitive in the market today, and can offer both confinement and pasture systems an advantage.

Dairy farms today are faced with many environmental pressures, both from social and regulatory aspects. Pasture-based dairy farms can have less of an impact on the environment
compared to a confinement based operation. Because cattle are rotationally grazed around the
farm, manure is evenly deposited all across the farm and used by the growing pasture forages.
There is significantly less pollutant runoff from grazing paddocks compared to a conventional
drylot. Our data also showed that within a paddock, manure is evenly distributed except for the
area around the water source during the hot summer months. This problem may be alleviated
by moving the water source for each grazing period or providing another water source in
another location. If shade is used, a portable system should be used to prevent the camping of
cattle in one area. In addition, our data showed that the number of manure events is highly
correlated to the time spent in a respective area. Our data showed that 85% of the total manure
was deposited on the paddock. This implies that the manure handling system for a pasture-
based dairy needs only to be designed for less than 20% of the total manure produced. This
represents a substantial savings compared to the elaborate and expensive manure handling
systems that confinement type system require. A pasture-based system would require minimal
water use for manure collection, minimal storage facilities and could be an underground pit
system. Manure that is collected in the system can be irrigated every few days onto forage that
is recovering from harvest. Such systems would not require controversial lagoons that can
cause conflicts with neighbors due to appearance and odor problems.

Lower milk production of pasture-fed dairy cattle does pose a problem for the
profitability and competitiveness of a farm. The use of supplemental grain should be used to
maintain milk production and herd health in a pasture-based herd. The use of supplemental
grain should be carefully balanced to maximize the net income the grain produces. Even with
heavy supplemental feeding, a pasture-based system can be very profitable if pasture is
managed properly and costs of production are kept low. This usually can be accomplished with
the use of pasture due to the fact that the costs of production for pasture are much lower than for
stored forages.

Pasture-based dairy systems can also offer social and personal advantages to dairy
farmers. The social acceptability of a pasture-based farm is more than a confinement system.
People generally prefer to see clean cows on open fields of green grass rather than cows
confined in barns on concrete. In addition, pasture-based farms that offer on-farm marketing of
products can be an important part of the local economy. Some dairy farmers have found that
pasture-based dairying is much more enjoyable than confinement type of farming. Some farmers enjoy the challenge of trying a new flexible system while others may prefer the reduced labor that can be realized with a pasture system. Despite some disadvantages, pasture-based dairy systems offer today’s dairy farmer a potentially profitable way to continue to dairy.