Milk Production and Economic Measures in Confinement or Pasture Systems Using Seasonally Calved Holstein and Jersey Cows

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ABSTRACT

This 4-yr study examined total lactation performance of dairy cows in two feeding systems: pasture-based and confinement. Spring and fall calving herds were used and each seasonal herd had 36 cows on pasture and 36 cows in confinement with 282 Holstein and 222 Jersey cows included over seven seasonal replicates. Pasture-fed cows received variable amounts of grain and baled haylage depending upon pasture availability. Confinement cows received a total mixed ration with corn silage as the primary forage. Data were collected on milk production, feed costs, and other costs. Pasture-fed cows produced 11.1% less milk than confinement cows. Across treatments, Jerseys produced 23.3% less milk than Holsteins, but calving season and various interactions were not significant. Feed costs averaged $0.95/cow per day lower for pastured cows than confinement cows. Feed costs were lower for Jerseys than Holsteins and for cows calving in spring. Income over feed costs averaged $7.05 ± 0.34 for confinement Holsteins, $6.89 ± 0.34 for pastured Holsteins, $5.68 ± 0.34 for confinement Jerseys, and $5.36 ± 0.34 for pastured Jerseys; effects of breed were significant but treatment, season, and interactions were not. Economic factors such as labor for animal care, manure handling, forage management, and cow culling rates favored pastured cows. Higher fertility and lower mastitis among Jerseys partially offsets lower income over feed cost compared with Holsteins. Milk production was lower in this study for pasture-based systems but lower feed costs, lower culling costs, and other economic factors indicate that pasture-based systems can be competitive with confinement systems.

(Key words: pasture, total mixed ration, production, economics)

INTRODUCTION

Economic conditions in the dairy industry challenge dairy farmers to find ways to increase farm profitability in order to stay competitive. Feed is the largest cost in producing milk. Interest has been shown in pasture-based systems in which grazed forage from fresh pastures can replace much of the stored forages in the ration. In addition to reduced feed costs, pasture-based systems can have lower capital costs for machinery, manure systems, and facilities (Ford, 1996).

In direct comparisons of pasture and confinement feeding systems, some authors (Rust et al., 1995; Kolver and Muller, 1998) have reported that confinement-fed cows produce more milk than do pasture-fed cattle. Despite the lower milk production, economic models and farm surveys have shown that pasture-based systems can have lower operating expenses and higher net incomes per cow than confinement systems (Dartt et al., 1999; Emmick and Toomer, 1991; Hanson et al., 1998; Parker et al., 1992, 1993). Conneman et al. (1997) and Knoblauch et al. (1999) compared grazing and confinement type farms using data included in the New York Dairy Farm Business Summary. Total cost of producing milk from grazing farms was lower than the confinement systems, net income per cow was higher, labor efficiency was similar, and the grazing farms had a smaller investment per cow. Nott (2000a, 2000b) reported comparable data for Michigan farms, also with lower costs of production for grazing herds. However, net income per cow was only slightly higher for the grazing farms, and there was no advantage in terms of labor efficiency nor in level of investment on those farms. In contrast, Dartt et al. (1999) reported advantages in profitability, labor efficiency, asset efficiency and operating efficiency for Michigan grazing farms compared with confinement farms based on on-farm
data collection in 1994. Empirical analyses of dairy farms in Pennsylvania and New York revealed that moderate intensive grazing was associated with lower milk per cow, but that dairy profits were enhanced because of lower feed costs associated with pasture enterprises than for production of corn silage or hay (Hanson et al., 1998). However, grazing farms in that study did not generate large residual earnings that would allow for much debt reduction or capital expansion. One difficulty in interpreting grazing studies is that the term “grazing dairy” is seldom defined precisely. Dartt et al. (1999) did define grazing herds as getting at least 25% of annual forage as pasture versus comparison herds, where greater than 95% of forage was mechanically harvested and stored before feeding. Also, Ostrom and Jackson-Smith (2000) compared low capital grazing farms, high capital grazing farms, and confinement farms over a 4-yr period. They reported lower costs of production, higher net income per cow, and lower investment per cow. All the studies cited relate to northeastern states, and there are no comparable economic studies in the Southeast, which has a longer growing season and different forage options.

Most US production research on grazing has involved short-term comparisons over several weeks (Hoffman et al., 1993; Kolver and Muller, 1998). The replicated farmlet study of Fales et al. (1995) examined the economics of three pasture stocking rates for 25-wk grazing periods over 2 yr, but new cows were assigned each year and year-round system effects were not examined. Also, Rust et al. (1995) compared the economics of grazing versus confinement just during two grazing seasons and found net economic advantages for grazing during the 137 or 144 d in consecutive summers but did not examine year-round economics of the two systems. Although potentially well controlled and replicated, short-term trials are limited in scope. Longer-term effects of different feeding regimens on important herd performance and economic factors such as labor efficiency, investment cost, reproductive performance, herd health, and cow longevity cannot be captured or inferred. Furthermore, the applicability of the results in a farm setting may be compromised by these other factors or interactions because the total system drives the economic costs and returns. To more completely evaluate the economic effects of various systems of dairy management, there is a need for long-term, system-wide comparison trials. Long-term trials on a large scale allow researchers to examine systems as a whole across time and face situations that more closely resemble farming practice. This provides an opportunity to study production, reproduction, and other economically important effects in a context often missing in short-term component studies. Even though systems-oriented trials may sacrifice some control over individual variables, evaluation of overall systems across time provides results that should be valid and applicable in a farm setting.

This experiment was designed to investigate and compare the production and economic performance of two production systems: one based on optimizing year-round use of pasture as the forage source (PASTURE); the other based on a confinement feeding system using a TMR (CONFINE). The experiment included both Holstein and Jersey cows for entire lactations and was replicated across time including four spring-calving and three fall-calving replicates of each breed and feeding system.

**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. To establish the pasture system, 29 ha of cropland were converted into 37 paddocks of approximately 0.8 ha each. Waterlines, fencing, and lanes were constructed, and pastures were seeded in the fall of 1994. Water was available in each paddock, but no shade was provided in any of them. More details of the pasture design are available (White, 2000). An existing free-stall barn was used to house and feed the confinement group, while pastured cows were maintained outside on paddocks summer and winter except when being fed concentrate supplements (group fed) and at milking. An existing feeding area in the free-stall barn was used to provide concentrate supplement to pastured cows, and both treatment groups were milked in the same double-6 herringbone parlor.

Within the pasture system, the intent was to supply as much of the cows’ nutritional needs from pasture as possible. Several combinations of cool- and warm-season grasses and legumes were used to provide grazing throughout the year. Perennial species included orchardgrass (*Dactylis glomerata*) and endophyte-free fescue (*Festuca arundinacea*), both in mixtures with white clover (*Trifolium repens*), as well as alfalfa (*Medicago sativa*), matua prairiegrass (*Bromus wildenowii*), caucasian bluestem (*Bothriochloa caucasica*), and hybrid bermuda grass (*Cynodon dactylon*). Annuals included rye (*Secale cereale*) and ryegrass (*Lolium multiflorum*) for winter and early spring grazing, while crabgrass (*Digitaria sanguinalis*) and sorghum-sudan hybrid (*Sorghum bicolor*) were used for summer grazing. Areas of each species changed somewhat from year to year but, on 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. These add up to more than 29 ha because of
double cropping or overseeding in some paddocks. On
paddocks with low percentages of legumes, nitrogen
fertilizer was applied at the rate of 22 to 40 kg of N/
ha two to three times during the growing seasons of
respective grass species. No irrigation was used, but
up to 3 cm/ha of dairy lagoon effluent was applied once
or twice yearly on 12 of the paddocks as a source of
nutrients. Excess growth from the pastures was har-
vested as round bale hay or individually wrapped round
bales of silage (haylage). This hay or haylage was fed
to the pastured cows during periods of low pasture
availability.

Typical grazing rotations for spring-calving groups
would start with annual rye and ryegrass at calving in
January and February, followed by orchardgrass-clover
with alfalfa and matua prairiegrass paddocks added
through spring and early summer. During summer,
spring-calving cows would rotate through alfalfa and
summer annuals such as crabgrass and sorghum-sudan
hybrids. As they neared the end of lactation in the fall,
cool-season perennial grasses such as orchardgrass and
fescue would again provide most of the pasture. Fall-
calving groups would start grazing on summer annuals
in August and September and gradually switch to cool-
season perennials in the fall. Winter annuals such as
rye and ryegrass were used for some late fall and winter
grazing as well as matua prairiegrass. Fall-calving cows
were also allocated strips of stockpiled fescue through
the winter. In the spring, fall-calving cows continued
grazing fescue-clover paddocks as well as orchardgrass-
clover. As late lactation approached in early summer,
fall-calving cows grazed hybrid bermudagrass, caucas-
sian bluestem, and crabgrass paddocks.

Fresh pasture was offered after each milking to both
spring- and fall-calving groups in the PASTURE treat-
ment. Paddocks were examined weekly to determine
grazing rotations. Weekly meetings were held to discuss
management issues of both systems. The pasture man-
gagement goal was to start to graze a paddock when it
had an estimated pasture mass of 2600 kg of DM/ha
and to leave 1400 to 1700 kg of DM/ha after grazing.
Paddocks that exceeded a pasture mass of 2600 kg of
DM/ha were closed off from grazing and harvested as
dry hay or haylage. Annual pasture species were re-
seeded each year and perennial pastures were over-
seeded as needed to maintain productivity. Average
fertilizer and reseeding costs are included in the pas-
ture budgets for various pasture species.

To study the feasibility of seasonal milk production,
separate groups of cows were bred to calve either from
January through early March (spring) or from August
through early October (fall). Breeding periods were for
75 d each (April 1 until June 14 for spring calving
groups and from November 1 until January 14 for fall
calving groups). Estrus detection was facilitated with
use of tail-head paint and androgenized teaser heifers
that were rotated weekly between CONFINE and PAS-
TURE groups. Cows not observed in estrus early in the
breeding season were examined via rectal palpation
every 2 wk and received prostaglandin F2α (25 mg, i.m.)
if a corpus luteum was present.

For the initial groups at the start of the experiment,
cows were selected from the existing dairy herd based
on their expected calving dates. Holstein and Jersey
cows were included in all groups. In the first year, cows
were paired based on breed, milk production, age, and
parity. Paired cows were assigned at random to the two
treatments: CONFINE or PASTURE. In subsequent
years, cows that rebred for the same calving season
remained in their respective treatment groups and new
cows (usually first lactation) were used to replace cows
that left the group for various reasons. Each treatment
group started with 36 cows each season. Cow numbers
within breed and average parity varied across the four
spring and three fall calving groups (Table 1). 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 Jer-
seys assigned to each feeding system.

Cows in the two treatments and two seasonal groups
were managed as four separate herds each year but all
were managed by the same workers and milked in the
same parlor. The two breeds of cows were managed
together within seasonal subgroups for all groups ex-
cept for CONFINE fall 1995 and spring 1996, when
Holsteins and Jerseys were in separate groups because
of other studies in the confinement facility. Cows from
both breeds and treatments were managed together
during the nonlactating period at a separate facility.

The cows in CONFINE were housed in a free-stall
barn with access to a dirt exercise lot. These cows were
fed a TMR (see Table 2 for a representative TMR) that
consisted of corn silage, alfalfa silage, ground corn, soy-
bean meal, whole cottonseed, minerals, and vitamins
and sometimes included cottonseed hulls. Silages were
the major source of forage for the CONFINE cows, and
they did not have access to pasture. Rations were bal-
anced with the DART ration program (Smith et al.,
1994) and adjusted throughout the year as season and
stage of lactation changed. Rations using that ration
program are similar to NRC guidelines but are not
based precisely on them. Rations were calculated to
challenge production to 10% beyond expected levels and
balanced for DMI, CP, ADF, NE_{li}, Ca, P, Na, Mg, and
K and for trace minerals and vitamins.

Table 1. Dates, number of days, number of cows assigned, and average parities for seasonal calving groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Experimental period</th>
<th>No. of days</th>
<th>Holsteins CONFINE1</th>
<th>PASTURE2</th>
<th>Jerseys CONFINE1</th>
<th>PASTURE2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number of cows</td>
<td>Average parity</td>
<td>Number 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>24</td>
<td>2.3</td>
<td>24</td>
<td>1.9</td>
</tr>
<tr>
<td>Fall 1995</td>
<td>9/27/95–7/16/96</td>
<td>305</td>
<td>21</td>
<td>2.2</td>
<td>21</td>
<td>2.2</td>
</tr>
<tr>
<td>Spring 1996</td>
<td>8/24/96–7/22/97</td>
<td>338</td>
<td>21</td>
<td>2.6</td>
<td>21</td>
<td>2.4</td>
</tr>
<tr>
<td>Fall 1996</td>
<td>8/24/96–7/22/97</td>
<td>338</td>
<td>21</td>
<td>2.6</td>
<td>21</td>
<td>2.4</td>
</tr>
<tr>
<td>Spring 1997</td>
<td>1/25/97–11/30/97</td>
<td>304</td>
<td>18</td>
<td>2.3</td>
<td>18</td>
<td>2.4</td>
</tr>
<tr>
<td>Fall 1997</td>
<td>8/26/97–7/21/98</td>
<td>326</td>
<td>18</td>
<td>2.6</td>
<td>18</td>
<td>2.4</td>
</tr>
<tr>
<td>Spring 1998</td>
<td>1/14/98–11/1/98</td>
<td>291</td>
<td>18</td>
<td>1.7</td>
<td>18</td>
<td>2.6</td>
</tr>
</tbody>
</table>

1Treatment group of cows fed a TMR.
2Treatment group of cows with pasture as the primary forage source.

Cows in the PASTURE system were kept on pasture summer and winter and were brought into the dairy facility only to be fed a supplement and milked. The supplemental grain ration consisted of ground corn, soybean meal, whole cottonseed, cottonseed hulls, minerals, and vitamins and was allocated to the PASTURE cows as a group and fed in a covered feeding area before each milking. Supplemental rations were balanced using the DART ration program (Smith et al., 1994) and adjusted in amount and formulation as pasture availability and stages of lactation changed. Rations were balanced for DMI, CP, ADF, NE_L, Ca, P, Na, Mg, and K and for trace minerals and vitamins. Concentrate consumption levels averaged 6.9 kg/cow per day for spring-calving PASTURE cows and 8.1 kg/cow per day for fall-calving PASTURE cows but varied throughout

Table 2. Formulation and nutrient content of typical TMR fed to CONFINE1 group and concentrate supplement fed to PASTURE2 group.

<table>
<thead>
<tr>
<th>Formulation, % of total ration DM</th>
<th>CONFINE1 TMR</th>
<th>Spring PASTURE2 Supplement</th>
<th>Winter PASTURE2 Supplement</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>44.5</td>
<td>87.3</td>
<td>87.1</td>
</tr>
<tr>
<td>CP, %</td>
<td>16.0</td>
<td>9.9</td>
<td>18.8</td>
</tr>
<tr>
<td>ADF, %</td>
<td>23.2</td>
<td>7.9</td>
<td>14.0</td>
</tr>
<tr>
<td>NE_L Mcal/kg</td>
<td>1.54</td>
<td>1.78</td>
<td>1.72</td>
</tr>
</tbody>
</table>

1Treatment group of cows fed a TMR.
2Treatment group of cows with pasture as the primary forage source.
3Winter pastured cows also received 2 to 5 kg/cow per day of haylage when pasture was limited.
4Volclay (American Colloid, Co., Arlington Heights, IL).
5Contains 14,400 mg/kg of Zn; 11,064 mg/kg of Mn; 26 mg/kg of Fe; 206 mg/kg of Cu; 425 mg/kg of I; 75 mg/kg of Se; and 111 mg/kg of Co.
6Contains 9,056,000 IU/kg of vitamin A, 22,048 IU/kg of vitamin E, and 1,963,000 IU/kg of vitamin D.
7Contains 22% S, 18% K, and 11% Mg (Pitman-Moore, Mundelein, IL).
samples were analyzed for CP by Dumas combustion sieve (Arthur Thomas Co, Philadelphia, PA). Ground after drying using a Wiley mill with a 1-mm °C for a minimum of 15 h. The samples were at 80 the following techniques: Samples were dried in an oven at the North Carolina Forage Testing Laboratory using 30 cm of stubble. Forage samples were analyzed 30 to 50 cm for sorghum-sudangrass hybrid, leaving a 5- to 10-cm stubble, to the top varied from the top few centimeters for bermudagrass were consuming on the day of sampling. Such samples the sample would be representative of what the cows a manner to mimic the selection of the grazing cow so periodically (Table 3). The grab samples were collected in Fresh pasture grab samples were submitted to the North Carolina Forage Testing Laboratory for analyses peri- basic cows were allowed to stay in the covered feeding area for shade for about an hour after the afternoon milking. This was done for about 10 to 20 d each sum- mer just for spring-calving cows because fall-calving cows were either in late lactation or nonlactating dur- ing summer.

Data Collection

The milking parlor was equipped with an electronic milk-recording device (Westfalia Dairy Plan, Westfalia-Surge, Inc. Naperville, IL). Milk production data for each cow was recorded at each milking. Milk yield data were processed in two ways: 1) As total yields across entire lactations for each cow, and 2) as daily averages within each treatment and breed within seasonal sub- groups. Concentrations of fat and protein in milk were obtained from monthly DHI herd records. Mastitis and other health problems were routinely recorded and are presented, along with reproductive data, BCS, and BW, in a separate report (Washburn et al., 2002).

Average daily milk income was calculated for each treatment by breed by seasonal subgroup of cows based

Table 3. Means ± SE for percentage DM, CP as a percent of DM, ADF as a percent of DM, and NE\textsubscript{L} in Mcal/kg for forage samples of pasture, hay, and haylage used for pastured cows and of haylage and corn silage used for confinement cow rations.\textsuperscript{1}

<table>
<thead>
<tr>
<th>Pasture species</th>
<th>Samples n</th>
<th>Percent DM (%) Mean ± SE</th>
<th>CP (%) of DM Mean ± SE</th>
<th>ADF (%) of DM Mean ± SE</th>
<th>NE\textsubscript{L} (Mcal/kg) Mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>11</td>
<td>23.0 ± 1.6</td>
<td>25.6 ± 1.1</td>
<td>23.7 ± 1.5</td>
<td>1.61 ± 0.05</td>
</tr>
<tr>
<td>Bermudagrass</td>
<td>6</td>
<td>28.9 ± 1.7</td>
<td>18.2 ± 1.0</td>
<td>29.3 ± 0.3</td>
<td>1.46 ± 0.01</td>
</tr>
<tr>
<td>Caucasion bluestem</td>
<td>9</td>
<td>26.8 ± 2.9</td>
<td>16.3 ± 0.4</td>
<td>31.7 ± 1.1</td>
<td>1.34 ± 0.04</td>
</tr>
<tr>
<td>Crabgrass (annual)</td>
<td>4</td>
<td>19.8 ± 2.6</td>
<td>19.3 ± 1.0</td>
<td>27.1 ± 0.9</td>
<td>1.50 ± 0.03</td>
</tr>
<tr>
<td>Fescue</td>
<td>12</td>
<td>22.9 ± 0.7</td>
<td>22.8 ± 0.6</td>
<td>23.8 ± 0.6</td>
<td>1.60 ± 0.02</td>
</tr>
<tr>
<td>Matua prairie grass</td>
<td>4</td>
<td>19.6 ± 3.2</td>
<td>26.5 ± 2.8</td>
<td>22.0 ± 3.1</td>
<td>1.66 ± 0.10</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>14</td>
<td>22.1 ± 0.7</td>
<td>23.9 ± 0.5</td>
<td>24.4 ± 0.6</td>
<td>1.57 ± 0.02</td>
</tr>
<tr>
<td>Rye (cereal)</td>
<td>6</td>
<td>20.6 ± 1.2</td>
<td>24.4 ± 1.6</td>
<td>19.0 ± 1.4</td>
<td>1.76 ± 0.04</td>
</tr>
<tr>
<td>Ryegrass (annual)</td>
<td>8</td>
<td>18.5 ± 0.4</td>
<td>29.2 ± 1.5</td>
<td>19.9 ± 1.5</td>
<td>1.73 ± 0.05</td>
</tr>
<tr>
<td>Sorghum-Sudan grass (annual)</td>
<td>5</td>
<td>23.0 ± 1.6</td>
<td>19.2 ± 1.9</td>
<td>29.8 ± 1.4</td>
<td>1.40 ± 0.03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stored forages</th>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa haylage (round bales)</td>
<td>10</td>
<td>50.5 ± 3.9</td>
<td>19.6 ± 1.4</td>
<td>30.5 ± 1.2</td>
<td>1.47 ± 0.03</td>
</tr>
<tr>
<td>Alfalfa haylage (silo)\textsuperscript{1}</td>
<td>11</td>
<td>34.7 ± 1.7</td>
<td>20.9 ± 0.6</td>
<td>36.6 ± 1.6</td>
<td>1.31 ± 0.04</td>
</tr>
<tr>
<td>Corn silage\textsuperscript{1}</td>
<td>19</td>
<td>30.4 ± 1.2</td>
<td>7.1 ± 0.4</td>
<td>25.9 ± 1.1</td>
<td>1.59 ± 0.03</td>
</tr>
<tr>
<td>Fescue haylage (round bales)</td>
<td>9</td>
<td>58.9 ± 4.0</td>
<td>18.1 ± 0.6</td>
<td>31.8 ± 1.1</td>
<td>1.34 ± 0.04</td>
</tr>
<tr>
<td>Fescue hay (round bales)</td>
<td>4</td>
<td>85.8 ± 1.9</td>
<td>15.7 ± 2.0</td>
<td>39.6 ± 1.7</td>
<td>1.08 ± 0.06</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Alfalfa haylage and corn silage stored in silos were used in formulating TMR for cows fed in the confinement group. Samples of pasture and other stored forages are representative of forages consumed by pastured cows.

the lactation periods depending on the availability and quality of pasture, stage of lactation, and body condition. Typical spring and winter PASTURE supplemental rations, which were group fed, are included in Table 2. There were times during late winter when both spring and fall-calving PASTURE cows were fed the winter ration and both groups usually received the spring ration when pastures were abundant. When pasturing was limiting, the cows were fed round-bale alfalfa or fescue haylage or hay (Table 3) that had been harvested from the pasture system. The round-bale haylage or hay was unrolled and fed on pasture paddocks using a looped electric wire to minimize trampling and spoilage of the forage.

Samples of corn and alfalfa silages, hay, haylage, and fresh pasture grab samples were submitted to the North Carolina Forage Testing Laboratory for analyses periodically (Table 3). The grab samples were collected in a manner to mimic the selection of the grazing cow so the sample would be representative of what the cows were consuming on the day of sampling. Such samples varied from the top few centimeters for bermudagrass and crabgrass, leaving a 5- to 10-cm stubble, to the top 30 to 50 cm for sorghum-sudangrass hybrid, leaving about 30 cm of stubble. Forage samples were analyzed at the North Carolina Forage Testing Laboratory using the following techniques: Samples were dried in an oven at 80°C for a minimum of 15 h. The samples were ground after drying using a Wiley mill with a 1-mm sieve (Arthur Thomas Co, Philadelphia, PA). Ground samples were analyzed for CP by Dumas combustion (LECO FP-428, LECO Corporation, St. Joseph, MI) and for ADF by wet chemistry digestion (Ankom 200, Ankom Technology Corp, Fairport, NY); NE\textsubscript{L} was determined using the Cornell regression equations (Mertens, 1973).

In periods of extreme heat and humidity when the temperature-humidity index was at or above 86 (based on degrees Fahrenheit; Armstrong, 1994), pasture-based cows were allowed to stay in the covered feeding area for shade for about an hour after the afternoon milking. This was done for about 10 to 20 d each summer just for spring-calving cows because fall-calving cows were either in late lactation or nonlactating during summer.

Data Collection

The milking parlor was equipped with an electronic milk-recording device (Westfalia Dairy Plan, Westfalia-Surge, Inc. Naperville, IL). Milk production data for each cow was recorded at each milking. Milk yield data were processed in two ways: 1) As total yields across entire lactations for each cow, and 2) as daily averages within each treatment and breed within seasonal subgroups. Concentrations of fat and protein in milk were obtained from monthly DHI herd records. Mastitis and other health problems were routinely recorded and are presented, along with reproductive data, BCS, and BW, in a separate report (Washburn et al., 2002).

Average daily milk income was calculated for each treatment by breed by seasonal subgroup of cows based
on daily average milk production. The raw milk production data were adjusted for mastitis treatments to calculate the yield of salable milk. Daily salable milk was valued at the prevailing North Carolina average milk price as reported by USDA (USDA, b) with an adjustment for differences in butterfat test at the reported butterfat differential (USDA, a).

Feed costs were estimated from the ration formulations developed from the DART ration-balancing program (Smith et al., 1994), using ingredient prices comparable to those paid by farmers at the time the ration was formulated. Forage costs were based on the NCSU forage Enterprise Budget Guidelines (Department of Agricultural and Resource Economics, 1992). Corn silage was charged at $27.50 per metric tonne (1000 kg), alfalfa haylage at $38.50 per metric tonne, and hays at $74.80 to $94.60 per metric tonne depending on type. Cost estimates are on an as-fed basis and were considered adequate to cover the full cost of production and harvesting these crops, including operating expenses, labor, and annual charges on capital investments in machinery and equipment. Production costs for pasture were estimated at $44 per metric tonne of DM consumed, averaged across the various species grown. For the PASTURE groups, pasture intake was estimated based on the difference between the predicted DMI and the DM contained in the nonforage portion of the ration. Predicted DMI was calculated using the DART ration-balancing program (Smith et al., 1994). Feed cost estimates do not include a labor charge for mixing and feeding the various grain and TMR rations, the cost of moving cows to and from the pastures, or any charge for land used in crop production.

Statistical Analyses

Cows were considered as measurement units, and each treatment and breed group within the seven seasonal replicates (n = 28) was considered the experimental unit for principal statistical analyses.

However, preliminary statistical analyses were performed to evaluate the milk production data using general linear models procedures in SAS (1997). Due to reproductive and general culling, some cows were only used once during the study, while other cows repeated from year to year. The first statistical model for milk production compared the response of the cows used once and the repeated cows. That model showed that both groups of cows responded similarly, and so data were combined.

A second preliminary analysis within each seasonal replicate adjusted for effects of parity where parity groups were defined as 1 = first parity; 2 = second and third parities; and 3 = fourth or greater parities. In those models within each seasonal replicate, treatment, breed, and treatment × breed interactions along with linear and quadratic effects of parity group were used as independent variables. The second preliminary analysis generated adjusted least squares means for total lactation milk production for each breed and treatment within seasonal subgroup (n = 28), which were then subjected to an analysis of variance using treatment, breed, season (spring vs. fall), treatment × breed, treatment × season, breed × season, and treatment × breed × season included in the model as independent variables.

Calculated feed costs per cow per day were averaged for each treatment and breed within seasonal subgroup to generate 28 means. Similarly, 28 subgroup means were generated for milk income over feed costs. Those means for feed costs and income over feed costs were also subjected to an analysis of variance using treatment, breed, season (spring vs. fall), treatment × breed, treatment × season, breed × season, and treatment × breed × season included in each model as independent variables (SAS, 1997).

Data for percentages of milk fat and milk protein were also analyzed by general linear models procedures in SAS (1997). Treatment, breed, and treatment × breed interactions were included in the model as independent variables in the main plot using cow within breed and treatment as the error term with effects of time (sampling date), and interactions with time considered in the subplot for each analysis within seasonal replicate.

Other economically important observations are included from other papers (White et al., 2001a, 2001b; Washburn et al., 2002) as well as other relevant observations related to the economic discussion.

RESULTS AND DISCUSSION

Milk Production

Treatment and breed were significant (P < 0.01) effects for total lactation production (Table 4). The effects of season (fall vs. spring) were not significant, nor were any of the interactions. CONFINE cows produced more milk than the PASTURE cows for each season and year. Overall, the PASTURE cows produced 11.1% less milk compared with CONFINE. A difference of similar magnitude has been shown in other pasture-based experiments (Rust et al., 1995; Kolver and Muller, 1998). In the current experiment, Jerseys produced 23.3% less milk compared with Holstein cows.

There were no significant differences between treatments for monthly fat or protein percentages (data not shown) within seasonal replicates with the exception of protein in fall 1997, when PASTURE cows did have a higher protein percentage than the CONFINE cows (3.5 vs. 3.4 ± 0.04%, P < 0.05). Jerseys had significantly
(P < 0.05) higher values for fat (4.67 vs. 3.81 ± 0.04%) and protein (3.73 vs. 3.21 ± 0.04%) than Holsteins across all seasonal replicates.

**Economics**

Income over feed cost is a commonly used indicator of financial performance because it captures both the primary source of income on a dairy farm and the major cost of production. Differences in milk production due to treatment and breed were discussed previously. The income associated with milk production is directly associated with amounts produced but was adjusted for losses of mastitic milk and for fat composition. Feed costs per cow per day differed by treatment (P < 0.01), breed (P < 0.01), and season (P < 0.05), but interactions were not significant (Table 4). Daily feed costs were lower for PASTURE compared with CONFINE ($2.08 vs. $3.03 ± 0.09), for Jerseys compared with Holsteins ($2.28 vs. $2.82 ± 0.09), and for spring compared with fall-calving cows ($2.41 vs. $2.69 ± 0.09).

Holsteins had significantly higher income over feed cost than Jerseys ($6.97 vs. $5.52 ± 0.24/cow per day; P < 0.05), but feeding system, season, and interactions were not significant (Table 4). Holsteins had greater income over feed cost within both feeding systems, as the lower feed costs for Jerseys did not completely offset the lower value of milk produced. In contrast, estimated feed costs were enough lower for PASTURE groups compared with CONFINE groups to offset the lower value of milk production, resulting in similar incomes over feed costs. However, differences in income over feed costs were quite variable, ranging from $0.85 per cow per day advantage to the spring 1997 PASTURE group to a $0.74 per cow per day advantage to the CONFINE fed group for the spring 1996 calving cows. Feed ingredient costs and weather also varied considerably during the 4 yr of the experiment, which affected the income over feed costs for the individual groups. Proportions of pasture and supplementary feed varied markedly between the spring and fall PASTURE cows because of limited pasture in winter months.

Income over feed cost is an important economic measure but does not tell the whole story. Several other factors affect the relative profitability of grazing and confinement systems.

**Herd health and longevity.** There was a lower incidence of mastitis in the PASTURE cows (Washburn et al., 2002). One major cost of mastitis is lost milk income, and this was factored into the income over feed cost calculations. Losses ranged from zero for the spring 1996 PASTURE Jerseys to 3.0% of milk produced by the fall 1996 CONFINE Holsteins. Significantly more of the CONFINE Holsteins than the PASTURE Holsteins were culled for mastitis—12 cows compared to just one over the seven seasonal lactation groups.

**Table 4.** Least-squares means ± SE for: total lactation milk production (kg/cow per lactation); feed costs ($/cow per day); and income over feed costs ($/cow per day) by treatment system (CONFINE vs. PASTURE)1, calving season, and breed.

<table>
<thead>
<tr>
<th></th>
<th>Milk production2 (kg/cow/lact.)</th>
<th>Feed costs3 ($/cow/day)</th>
<th>Income over feed costs4 ($/cow/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONFINE Holsteins</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall calving</td>
<td>8560 ± 461 kg</td>
<td>$3.48 ± 0.18</td>
<td>$7.33 ± 0.52</td>
</tr>
<tr>
<td>Spring calving</td>
<td>7261 ± 400 kg</td>
<td>$3.24 ± 0.16</td>
<td>$6.78 ± 0.45</td>
</tr>
<tr>
<td><strong>PASTURE Holsteins</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall calving</td>
<td>7329 ± 460 kg</td>
<td>$2.54 ± 0.18</td>
<td>$6.98 ± 0.52</td>
</tr>
<tr>
<td>Spring calving</td>
<td>6901 ± 400 kg</td>
<td>$2.01 ± 0.16</td>
<td>$6.81 ± 0.45</td>
</tr>
<tr>
<td><strong>CONFINE Jerseys</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall calving</td>
<td>6164 ± 461 kg</td>
<td>$2.71 ± 0.18</td>
<td>$5.71 ± 0.52</td>
</tr>
<tr>
<td>Spring calving</td>
<td>6129 ± 400 kg</td>
<td>$2.66 ± 0.16</td>
<td>$5.64 ± 0.45</td>
</tr>
<tr>
<td><strong>PASTURE Jerseys</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall calving</td>
<td>5446 ± 461 kg</td>
<td>$2.02 ± 0.18</td>
<td>$4.97 ± 0.52</td>
</tr>
<tr>
<td>Spring calving</td>
<td>5315 ± 400 kg</td>
<td>$1.73 ± 0.16</td>
<td>$5.76 ± 0.45</td>
</tr>
</tbody>
</table>

1CONFINE cows housed in a free-stall barn and fed a TMR; PASTURE cows were housed outdoors using pasture as the primary forage. Supplemental concentrates were provided to PASTURE cows.
2Total lactation milk production (kg/cow per lactation) adjusted for parity and discarded mastitic milk. Significant effects included treatment and breed (P < 0.01). Season and various interactions were not significant.
3Feed costs for concentrates and purchased supplements were based on ingredient prices comparable to those paid by farmers during the time of the study. Forage costs were based on NCSU Forage Enterprise Budget Guidelines (Department of Agricultural and Resource Economics, 1992). Significant effects included treatment, breed (P < 0.01), and season (P < 0.05). Interactions were not significant.
4Income over feed costs was determined based on values of milk sold during the study (USDA a,b) minus the lower value of milk produced in contrast, estimated income over feed cost within both feeding systems, as the lower feed costs for Jerseys did not completely offset the lower value of milk produced. In contrast, estimated income over feed costs were enough lower for PASTURE groups compared with CONFINE groups to offset the lower value of milk production, resulting in similar incomes over feed costs. However, differences in income over feed costs were quite variable, ranging from $0.85 per cow per day advantage to the spring 1997 PASTURE group to a $0.74 per cow per day advantage to the CONFINE fed group for the spring 1996 calving cows. Feed ingredient costs and weather also varied considerably during the 4 yr of the experiment, which affected the income over feed costs for the individual groups. Proportions of pasture and supplementary feed varied markedly between the spring and fall PASTURE cows because of limited pasture in winter months.

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Cow turnover also represents a cost to the farm business. Based on USDA reports (USDA, b) during the period of this project, dairy replacements were valued at $1050 per head and culled cows were valued at $0.704 per kilogram, net after sales costs. Cull cows weighing 591 kg sold for beef had a salvage value of $416, which was $659 less than the cost of replacements. Therefore, the additional 11 cows culled from the CONFINE Holsteins across all replicates incurred a cost of $7249, which is equivalent to $0.07/kg of all the milk sold from CONFINE Holsteins, or $0.213/cow per day. There were no other statistically significant differences in the incidence of health events (Washburn et al., 2002).

Reproduction. Although reproductive performance did not differ due to feeding system (Washburn et al., 2002), differences between Jerseys and Holsteins in reproductive performance also has economic implications. Jerseys had an advantage of 20 percentage points over Holsteins (78 vs. 58%) in pregnancy rates over 75-d breeding seasons, which would mean a substantially higher turnover rate among Holsteins if seasonal breeding was a management objective. Had equal numbers of Jerseys and Holsteins been assigned across seven seasonal replicates, those percentages indicate that 50 more Holsteins than Jerseys would have failed to rebreed in the 75-d periods. The economic cost associated with this added turnover depends on the disposition of the cows that fail to rebreed within the window. At one extreme, the cost difference calculated above for culled animals and replacements ($659) on those 50 cows would have resulted in marginal reproductive culling costs of $32,950 compared with Jerseys, which would offset about 30% of the Holstein advantage in income over feed cost. Alternatively, if the cows rebred to calve outside the seasonal period and could be marketed for dairy purposes to nonseasonal herds the economic disadvantage would likely be reduced.

Labor. There is wide variation in labor efficiency on confinement dairies, based on many years of data from university farm business records programs (Department of Agricultural, Resource and Managerial Economics, annual). Part of this variation likely is caused by differences in facility design. The NCSU dairy unit is not representative of a commercial farming operation and, therefore, is not ideal for evaluating labor efficiency. However, the comparison of the labor used in various aspects of the grazing and confinement groups yields some insights.

The various groups were milked consecutively, but it was judged that those times were broadly similar for both groups. It took slightly less time, approximately 15 min per day, to bring the grazing cows in from the pasture for feeding and milking, move temporary fences, and feed grain than it did to move confinement cows and prepare and feed a TMR twice daily.

The groups had access to the same facility, and no measurable differences were noted in the time spent on heat detection or breeding. However, time spent in maintaining free stalls or in treating mastitic cows was not recorded. With those omissions, the labor advantage to the PASTURE groups was estimated to be 100 h over a 10-mo lactation.

There are a number of different forage production and management activities under the two systems that were evaluated using the labor assumptions contained in the NCSU forage enterprise budget guidelines. The estimated time required to produce forage crops for the confinement cows was 236 h. The estimated annual labor requirement for pasture establishment and maintenance, hay or haylage harvest and feeding, pasture walks, and setting up paddocks for the following day during a 10-mo lactation is approximately 420 h.

One area that should yield significant labor savings for the PASTURE system is manure management. Most (−85%) of daily defections and urinations took place on pasture and, therefore, incurred no storage or handling costs (White et al., 2001b). The NCSU facility was designed for a confinement operation and has a flush system with lagoons, and the waste from both groups of cows was handled jointly because they used the same feeding and milking facilities. The estimated time spent operating the system for the entire university herd (200 cows) was 2.25 h/d, or 675 h for a 10-mo lactation, excluding the time spent irrigating the waste. It is likely that a waste system can be designed for a seasonal, pasture-based dairy that would require significantly less labor and investment per cow.

On balance, this assessment suggests that the overall difference in labor efficiency between the pasture-based and confinement groups would favor the pasture system. In a farm setting, labor efficiency differences are likely to depend on site-specific factors.

Other factors. Several factors of importance were beyond the scope of this study but should be noted. Higher content of the potentially beneficial conjugated linoleic acid in milk from pastured cows (White et al., 2001a) could lead to niche marketing opportunities. For new pasture-based dairy farms, lower investments would be expected for manure handling facilities and equipment, housing, and equipment associated with storage and feeding TMR compared with those required for confinement systems. However, confinement farms that convert to grazing may not fully realize these benefits because they have already made an investment in facilities. Also, some new investments may be needed when a grazing system is introduced (Ford, 1996). For example, in the current study, new investment of
$1152/ha was required for materials to establish the grazing system, including lanes, fencing, and water, based on prices in 1994.

The largest investments on a dairy farm are in land and cattle, and it is not clear a priori what happens to these under grazing systems vis-à-vis confinement systems. Typical estimates for perennial pasture DM production are in the 7 to 10 metric tonne/ha per year range, depending on species, type of harvesting, and intensity of pasture management. Comparable average corn silage production estimates are about 11 to 12 metric tonne per hectare, so less area may be needed to support a cow’s forage needs under row cropping as also indicated by Davenport et al. (1977), but lower feed costs associated with pasture enterprises compared with production of corn silage or hay have been reported (Hanson et al., 1998).

Profitability and performance of pasture-based dairy farms are affected by many factors, and much variation exists among farms regardless of the feeding system. King (1997) investigated the effects of stocking rate, feeding systems, and calving season on profitability using computer modeling. Increases in stocking rate were predicted to increase pasture utilization, milk production, and gross margin per hectare. In a 2-yr grazing trial, Fales et al. (1995) reported economic advantages per hectare as stocking rates increased from 2.47 to 3.95 cows/ha, but returns per cow were lower at the higher stocking rates. Therefore, overall economics were expected to favor higher stocking rates when higher per hectare operating and land costs prevail. Under good pasture growth conditions, higher stocking rates also improved pasture productivity, quality, and efficiency of use (Fales et al., 1995). The current study had a stocking rate at only 2.48 cows/ha for entire lactations, so the optimal economic efficiency may be at a higher stocking rate. Such concepts need to be examined further within actual pasture systems across multiple years, taking into account effects of stocking rates on nutrient loading and animal health.

The farm business management studies discussed above all show a wide variation in economic performance among farms of a similar type, whether managed as pasture or confinement systems. The level of management skill is a major determinant of farm performance.

CONCLUSIONS

In this 4-yr seasonal calving study, pasture-fed cows produced less milk, had lower feed costs, and lower culling costs compared with the confinement-fed cows. Jerseys produced less milk, had higher protein and fat percentages, and lower culling costs than the Holsteins. Overall there was not a significant difference for income over feed costs between the confinement-fed and pasture-fed cows. Holsteins consistently had higher milk income over feed costs than Jerseys. Other factors such as manure management, labor, and some investments are projected to favor the pasture-based feeding system, but land needed for forage production may be less in a confinement system. Although many factors contribute to the economic success of dairy farm businesses, results from the current study indicate that pasture-based dairy production can potentially be an economically competitive management system.

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REFERENCES

Department of Agricultural and Resource Economics. NCSU forage Enterprise Budget Guidelines, September, 1992. North Carolina State University, Raleigh NC.
Department of Agricultural, Resource and Managerial Economics. Dairy Farm Management: Business Summary for New York State, College of Agriculture and Life Sciences, Cornell University, Ithaca, NY. Published annually.
WHITE ET AL.


Nott, S. 2000b. Dairy Grazing Farms in Michigan. Staff Paper 2000-33, Department of Agricultural Economics, Michigan State University, East Lansing, MI.


