INTRODUCTION

The practice of total confinement of beef cattle as an alternative to the open feedlot has generated a considerable volume of literature on the subject over the past decade. An appreciable portion of this, however, is of a subjective nature. Earlier reports, as noted for example by McFarlane (8) and Turnbull (12), often were limited to discussions of techniques and management relating to different systems of total confinement.

In recent years, a more analytical approach to the subject has been apparent but comparisons based on animal performance between these alternative systems of housing and open feedlots are difficult to make. Maddex (6) suggests that this is due to the objectives of the projects and the background of the researchers involved. Furthermore, there are management, feeding, and climatic variables existing between countries and regions from which studies have been reported, and these differences require careful interpretation if valid comparisons are to be made.

At present, there are three total-confinement housing systems for beef cattle that might be recognized as possible alternatives to the feedlot, namely straw-bedded, fully slatted-floor, and free-stall. Results of comparative studies between the first two systems have been reported (2, 5, 6, 7) and reviewed (4, 5, 8, 12). Experimental conditions in these studies varied, with some being conducted in a single building and others involving a separate building for each system.

The free-stall system for beef cattle has received little attention except in the British Isles where it appears to be finding some acceptance in commercial practice. Some experiences with free stalls for beef have been reported (2, 4, 9, 11) but these have been limited and comparative studies appear to be lacking.

In view of the difficulties in interpreting previous work in the context of Alberta conditions and because of the added interest in total confinement as a possible means of reducing environmental contamination by animal wastes, a study was carried out to compare the performance of beef cattle in straw-bedded, fully slatted-floor, and free-stall housing systems under similar conditions of thermal environment and feed. The study also compared the performances of the housed animals with those of animals in an open feedlot.

EXPERIMENTAL FACILITIES

The housing trials were carried out in the Livestock Environmental Engineering Laboratory on the research farm of the Department of Agricultural Engineering, University of Alberta, near Edmonton. This 100 X 40-ft wide (30.5 X 12.2-m) facility is an insulated structure with an animal weigh room and a feed room located at opposite ends. The building is oriented north-south about its long axis. Between these two rooms is the 80 X 40-ft (24.4 X 12.2-m) livestock area.

This area is fully slatted with 4-1/2-inch (11.4-cm) wide individual precast concrete slats, approximately 10 ft (3.05 m) in length. The slats are carried on the pit walls, the pits running across the building. An 8-ft (2.44-m) pit depth below the slats provides adequate storage capacity for the needs of the building. Agitation and emptying of each pit are accomplished through a 4 ft (122 cm) long, 12 inch (30.5 cm) OD steel pipe set centrally into each end wall at a 45 degree angle. These pipes extend a few inches above grade along the outside of the building and are covered with close-fitting steel caps to prevent drafts.

The external walls of the building are 14 ft 4 inches (436.9 cm) from wall level to wall plate and are constructed of an 8-inch (20.3-cm) concrete-filled block consisting of 2-inch (5.1-cm) outer skins of cement-bonded wood fiber. The internal partition walls at either end of the livestock area are of frame construction with sheathing on each face.

The gable-type roof consists of a 3-inch (7.6-cm) rigid insulation on a polyethylene vapor barrier over 20-gauge steel decking and finished externally with built-up roofing. Roof slope is 1:12 with shallow lattice steel trusses at 10 ft (3.05 m) o.c. giving a clearance of 11 ft 8 inches (3.56 m) above slat level to the horizontal lower members.

The pressurized ventilation system consists of rectangular galvanized steel ductwork running from either gable of the building along the centerline towards the midpoint of the livestock area and supported by the lower members of the trusses. Each half of the system is identical with the other and incorporates a centrifugal fan and an induced gas heater unit. Capacity per fan is 4000 ft3/min (6796 m3/h) with a manually controlled dampering arrangement to reduce flow to approximately half that rate. Each heater unit has a specified maximum output of 249,000 BTU/h (72.96 kw-h), with a maximum modulating turn-down ratio of 30:1. The heater fuel is natural gas.

Air is distributed into the livestock area from the ducts via diffusers fitted...
In Canada, 64.

Weighing was carried out on a 28-d.

Eighty steers were purchased in.

The steers, all commercial-type Here-

To investigate whether any inter-

The trial was terminated after 126

to full feed over a 2-week period, by

concentrate consisted of barley only,

predominately alfalfa with some brome.

whereas the good quality hay lagged

(50:50) ration of concentrate and hay

nutrition and the main treatments

Talent no. 3 lasted for three 28-d peri-

Animals in this group had 24-h access

feeding area for animals using the stalls

Throughout the trial the space available was

An 8-ft (2.44-m) high windbreak, constructed of spaced vertical

tical boarding to give a porosity of

To negotiate whether any inter-

the same as for the experimental trials.

The animals were allowed to adjust

Animals were adjusted to full

The animals were weighed, handled

conditioning for the trial. The animals

horses were ranked from the lightest

to heaviest to provide a uniform

Wedge,
TABLE I COMPOSITION OF PELLETED PROTEIN SUPPLEMENT (lb)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Amount (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>719</td>
</tr>
<tr>
<td>Rapeseed meal</td>
<td>200</td>
</tr>
<tr>
<td>Soybean</td>
<td>200</td>
</tr>
<tr>
<td>Dehydrated alfalfa</td>
<td>200</td>
</tr>
<tr>
<td>Urea 28%</td>
<td>83</td>
</tr>
<tr>
<td>Sulfur</td>
<td>4</td>
</tr>
<tr>
<td>Molasses (beet)</td>
<td>100</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>100</td>
</tr>
<tr>
<td>Trace mineral salt</td>
<td>360</td>
</tr>
<tr>
<td>Vitamin premix†</td>
<td>10</td>
</tr>
<tr>
<td>Diethylstilbestrol premix‡</td>
<td>10</td>
</tr>
<tr>
<td>Antibiotic premix§</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2000</strong></td>
</tr>
</tbody>
</table>

† 10,000 I.U. of A, 1000 I.U. of D, and 100 I.U. of E per gram.
‡ 2 g Diethylstilbestrol per pound.
§ Aureofac 10 or TM-10.

RESULTS AND DISCUSSION

The results of trial no. 1 are summarized in Table II. These indicate that the liveweight gain over the 84-d trial of the animals on slatted floors was superior to that of the animals on straw bedding, which, in turn, was superior to that of the animals in the free stalls. These differences, however, were not statistically significant (P<0.05). The variations within pens were large compared with the differences between pens. No significant differences (P<0.05) were found to exist between feed intake or feed conversion for the three treatments, either on a 28-d or an overall-period basis.

Table III shows the summarized results, including the data obtained on carcass quality, for trial no. 2. Again, as in trial no. 1, average daily liveweight gains showed considerable variations between pens according to confinement treatment and ration fed. Statistical analysis, however, showed no significant differences (P<0.05) over the 126-d test period. Analysis on a 28-d weight period basis showed significant differences (P<0.05) in gain between the two rations fed. The animals that were started on the 50:50 ration lagged behind those that were started on the 75:25 ration but, when both groups were changed to the 85:15 ration, the former gained weight more rapidly than the latter. The analysis of variance showed no interaction between housing and ration fed.

The results of trial no. 3 are summarized in Table IV, including the data obtained on carcass quality. Because of incomplete liveweight data at the end of the first 28-d weigh period, due to a fault in the weigh scale, the statistical analysis was undertaken on a 56-d basis, rather than a 28-d as was used in the early trials, in addition to the analysis for the total 168-d test period. Again, the differences in liveweight gain between treatments were not significant (P<0.05). As in the earlier trials, this lack of significance in rate of gain between pens was largely accounted for by the variation within pens.

Differences in feed intake between the treatments in trial no. 3 were found to be significant (P<0.05) only for the first 56-d period. Feed intake was higher for feedlot animals. Over the 168-d period, differences in feed intake were not significant (P<0.05) between treatments. At the same time, differences in feed conversion, although not significant (P<0.05) on a 56-d basis, proved to be significant (P<0.05) over the 168-d period, with the animals in the open feedlot being least efficient in this respect than any of the housed treatments. Differences in feed intake and feed conversion between housed treatments were not significant (P>0.05) when analyzed on both the 56- and 168-d basis.

Trial no. 2, originally intended to start at the end of October 1969, did not commence until January 1970, due to time lost through correction of problems that arose through excessive deformation and failure in a number of concrete slats (10). By the time the

TABLE II SUMMARY OF RESULTS OF TRAIL NO. 1: 84-d TEST PERIOD (31 JULY - 23 OCTOBER 1969)

<table>
<thead>
<tr>
<th>Item (lb)</th>
<th>Straw-baed pens 1 2</th>
<th>Free-stall pens 3 4</th>
<th>Slatted-floor pens 5 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. initial wt</td>
<td>759.0 757.5</td>
<td>770.5 783.0</td>
<td>789.0 769.0</td>
</tr>
<tr>
<td>Avg. final wt</td>
<td>906.0 906.0</td>
<td>930.0 902.0</td>
<td>952.0 944.0</td>
</tr>
<tr>
<td>Avg. daily gain</td>
<td>1.75 1.76</td>
<td>1.90 1.42</td>
<td>1.94 2.08</td>
</tr>
<tr>
<td>Avg. daily gain intake</td>
<td>13.3 13.8</td>
<td>13.5 14.1</td>
<td>14.0 14.0</td>
</tr>
<tr>
<td>Grain/lb gain</td>
<td>7.6 7.8</td>
<td>7.1 9.9</td>
<td>7.2 6.7</td>
</tr>
<tr>
<td>Avg. daily haylage 4 intake</td>
<td>5.7 5.8</td>
<td>5.8 6.0</td>
<td>6.0 6.0</td>
</tr>
<tr>
<td>Haylage/lb gain</td>
<td>3.3 3.3</td>
<td>3.1 4.2</td>
<td>3.1 2.9</td>
</tr>
<tr>
<td>Feed/lb gain</td>
<td>10.8 11.1</td>
<td>10.2 14.2</td>
<td>10.3 9.6</td>
</tr>
</tbody>
</table>

† Ten steer per pen.
‡ Average haylage moisture content = 46.0%.
### TABLE III SUMMARY OF RESULTS OF TRIAL NO. 2: 126-d TEST PERIOD (29 JANUARY-5 JUNE 1970)

<table>
<thead>
<tr>
<th>Item</th>
<th>Straw-bedded pens</th>
<th>Free-stall pens</th>
<th>Slatted-floor pens</th>
<th>Feedlot pens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1† 2§</td>
<td>3† 4§</td>
<td>5‡ 6‡</td>
<td>7‡ 8‡</td>
</tr>
<tr>
<td>Avg. initial wt, lb</td>
<td>518 511</td>
<td>502 502</td>
<td>503 519</td>
<td>524 518</td>
</tr>
<tr>
<td>Avg. final wt, lb</td>
<td>870 890</td>
<td>918 872</td>
<td>880 876</td>
<td>928 895</td>
</tr>
<tr>
<td>Avg. daily gain, lb</td>
<td>2.79 3.00</td>
<td>3.30 2.93</td>
<td>2.99 2.76</td>
<td>3.20 2.99</td>
</tr>
<tr>
<td>Avg. daily grain intake, lb</td>
<td>13.6 13.0</td>
<td>14.9 12.7</td>
<td>14.3 12.5</td>
<td>14.8 13.4</td>
</tr>
<tr>
<td>Grain/lb gain, lb</td>
<td>4.9 4.3</td>
<td>4.5 4.3</td>
<td>4.8 4.5</td>
<td>4.6 4.5</td>
</tr>
<tr>
<td>Avg. daily haylage intake, lb</td>
<td>4.1 8.9</td>
<td>4.4 8.9</td>
<td>4.2 8.6</td>
<td>4.3 9.1</td>
</tr>
<tr>
<td>Haylage/lb gain, lb</td>
<td>1.4 2.9</td>
<td>1.3 3.0</td>
<td>1.4 3.1</td>
<td>1.4 3.0</td>
</tr>
<tr>
<td>Feed/lb gain, lb</td>
<td>6.3 7.2</td>
<td>5.8 7.3</td>
<td>6.2 7.6</td>
<td>6.0 7.5</td>
</tr>
</tbody>
</table>

Number grading:
- Canada Choice: 8 6 8 9
- Canada Good: 2 4 2 1
- Canada Commercial 3: - - - -
- Canada Commercial 3: 8 9 2 1

Avg. livewt, lb | 1004 989 | 985 965 | 979 976 | 981 985 |
Avg. carcass wt, lb | 578 572 | 579 572 | 571 568 | 578 572 |
Avg. dressing, % | 57.6 57.8 | 58.8 59.3 | 58.3 58.2 | 58.9 58.1 |
Avg. loin eye area, in\(^2\) | 10.3 10.0 | 10.4 10.6 | 10.4 10.4 | 10.7 10.6 |
Avg. backfat, in | 0.67 0.67 | 0.90 0.64 | 0.73 0.68 | 0.72 0.73 |
Avg. marbling score | 6.8 6.4 | 6.6 6.6 | 6.8 6.6 | 6.4 6.4 |

† Ten steers per pen.
‡ 75% grain, 25% haylage ration from 29 January to 29 April; 85% grain, 15% haylage thereafter.
§ 50% grain, 50% haylage ration from 29 January to 29 April; 85% grain, 15% haylage thereafter.

### TABLE IV SUMMARY OF RESULTS OF TRIAL NO. 3: 168-d TEST PERIOD (29 OCTOBER 1970-15 APRIL 1971)

<table>
<thead>
<tr>
<th>Item</th>
<th>Straw-bedded pens</th>
<th>Slatted-floor pens (25 ft(^2))</th>
<th>Slatted-floor pens (22 ft(^2))</th>
<th>Feedlot pens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1(12) 2(12)</td>
<td>3(9) 4(9)</td>
<td>5(10) 6(10)</td>
<td>7(9) 8(9)</td>
</tr>
<tr>
<td>Avg. initial wt, lb</td>
<td>458 459</td>
<td>461 464</td>
<td>452 463</td>
<td>459 457</td>
</tr>
<tr>
<td>Avg. final wt, lb</td>
<td>856 888</td>
<td>877 881</td>
<td>878 886</td>
<td>869 834</td>
</tr>
<tr>
<td>Avg. daily gain, lb</td>
<td>2.37 2.55</td>
<td>2.48 2.48</td>
<td>2.54 2.34</td>
<td>2.45 2.24</td>
</tr>
<tr>
<td>Avg. daily grain intake, lb</td>
<td>11.0 11.8</td>
<td>12.1 12.0</td>
<td>11.8 11.3</td>
<td>12.5 12.1</td>
</tr>
<tr>
<td>Grain/lb gain, lb</td>
<td>4.6 4.6</td>
<td>4.9 4.8</td>
<td>4.6 4.8</td>
<td>5.1 5.4</td>
</tr>
<tr>
<td>Avg. daily haylage intake, lb</td>
<td>8.4 9.1</td>
<td>9.2 9.2</td>
<td>9.1 8.7</td>
<td>9.8 9.4</td>
</tr>
<tr>
<td>Haylage/lb gain, lb</td>
<td>3.6 3.6</td>
<td>3.7 3.7</td>
<td>3.6 3.7</td>
<td>4.0 4.2</td>
</tr>
<tr>
<td>Feed/lb gain, lb</td>
<td>3.2 3.2</td>
<td>8.6 8.5</td>
<td>8.2 8.6</td>
<td>9.1 9.6</td>
</tr>
</tbody>
</table>

Number grading:
- Canada Choice: 8 9 8 9
- Canada Good: 3 3 2 1
- Canada Standard: - - - -
- Canada Commercial 1: - - - -
- Canada Commercial 3: 1 - - -
- Canada Commercial 3: - - - -
- Canada Commercial 3: - - - -

Avg. livewt, lb | 966 982 | 1003 978 | 969 974 | 1015 961 |
Avg. carcass wt, lb | 563 571 | 583 569 | 564 562 | 578 554 |
Avg. dressing, % | 58.3 58.2 | 58.1 58.2 | 58.2 57.7 | 57.0 57.6 |
Avg. loin eye area, in\(^2\) | 9.4 9.4 | 9.7 9.4 | 9.3 9.4 | 9.4 9.3 |
Avg. backfat, in | 0.74 0.77 | 0.82 0.82 | 0.69 0.72 | 0.64 0.62 |
Avg. marbling score | 6.8 6.8 | 6.5 6.6 | 6.9 7.1 | 9.6 9.6 |

† No. in parentheses is the no. of steers per pen.
‡ Average haylage moisture content = 56.2%.
§ One carcass condemned due to stomach infection.
‖ One steer died on 3 April 1971 due to bloat.

The start of trial no. 3 in late October 1970, coincided with an unusually severe and sudden onset of winter conditions. Over most of the next 2 mo, the weather was characterized by rapid decreases in temperature followed by gradual moderation, culminating in strong winds and relatively heavy snowfalls. Temperatures, for example, ranged from a minimum of -40°F (-40° C) on 5 December to a maximum of 36°F (2° C) on 25 December, the mean for the month.
Ambient temperatures within the total confinement facility were maintained in the 50-60°F (10-15.5°C) range for the colder months. Under hot weather conditions, such as occurred briefly towards the end of trial no. 2 when the maximum recorded inside temperature was 89°F (32°C), the ambient temperature was not often above the outside shade temperature and indeed was usually a few degrees cooler. This was assumed to be due to an evaporative cooling effect. Air movement and temperature within the zone of occupancy in the facility were quite uniform.

On the basis of the results of trial no. 2 and 3, there does not appear to be justification for building a warm barn with the expectation of increased animal performance under Alberta winter conditions. The finding that the open feedlot animals were able to maintain performance at a level similar to the warm-housed groups is in keeping with the work of Webster (13) and Young (14) on cold-temperature acclimatization of steers. Even though there was some improvement in feed efficiency in favor of total confinement in trial no. 3, the actual difference in feed costs per steer over the 168-d period, based on typical costs in the area, was only $2.77. In these circumstances, any justification for such a barn, therefore, would have to be primarily on the basis of factors such as operator comfort, reduction of waste pollution potential, or feed handling considerations.

Within each trial, all animals in the housed treatments were exposed to an environment, which if not identical for each individual, was at least similar. The stocking densities within each group were in accordance with recommended practice (1), whereas the free-stall dimensions were selected from those that had been found satisfactory (4, 9). The lack of significant differences (P < 0.05) between the performances of animals in the three total-confinement treatments would indicate that considerations other than performance would dictate the choice of one of the systems used.

Animals on the slatted floors remained consistently cleaner than those on straw bedding, either inside or outside, even though bedding was used liberally. Animals in the free stalls were as clean or cleaner than those in the bedded groups. The free stalls were accepted by the majority of the steers within 1 or 2 d of being introduced to them but, inevitably, one or two individuals within each group refused to conform.

From a health standpoint, there were few serious problems. Instances of bloat occurred in all three trials and in both feedlot and housed groups. In trial no. 2, five feedlot steers developed pinkeye, and several developed foot rot in the straw-bedded housed groups in both trial no. 2 and 3.

**CONCLUSIONS**

The conclusions drawn from the investigation involving three trials as described are:

1. Considerations other than animal performance would be required to justify provision of warm barn facilities for beef cattle over an open feedlot under Alberta weather conditions.

2. Animal performance does not appear to be a factor in any decision-making process involving a choice between free-stall, slatted-floor, and straw-bedded systems of total confinement of beef cattle.

3. There does not appear to be any interaction between confinement housing system and plane of nutrition of beef cattle.

4. There are no apparent differences in carcass quality between animals kept in open feedlot and total confinement, or among animals housed in free-stall, slatted-floor, and straw-bedded systems.

**SUMMARY**

The performances of beef cattle kept under three different total-confinement housing systems, namely, straw-bedded, slatted floor, and free stall, were compared under similar conditions of thermal environment and feeding. These performances were also compared with those of animals confined in an open feedlot. The series of three trials involved comparisons of liveweight gain, feed efficiency, and feed intake. In two trials, all animals were followed through the packing plant to ascertain if treatments had affected carcass quality. The possible existence of interaction between plane of nutrition and the main treatments was investigated in one trial.

Results indicated that the performances of the animals housed under the three systems were not significantly different (P < 0.05), and no interaction was found between housing systems and plane of nutrition. Although a significant difference (P < 0.05) in feed conversion existed in one 168-day trial between housed steers and those in the open feedlot, the differences in feed intake and liveweight gain over the period were not significant. Considerations other than animal performance would be required to justify provision of warm barn facilities under Alberta weather conditions. Carcass quality appeared to be unaffected by any of the main treatments.

**REFERENCES**


9. McQuitty, J.B. 1966. Experimenting...


