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THE EFFECTS OF VARIED FEED BUNK SPACE ON
ANIMAL PRODUCTION AND BEHAVIOR,
MANAGEMENT STRATEGY,
AND BUILDING DESIGN

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THE EFFECTS OF VARIED FEED BUNK SPACE ON ANIMAL PRODUCTION AND BEHAVIOR, MANAGEMENT STRATEGY, AND BUILDING DESIGN

By

Mark William Stephenson

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ABSTRACT

THE EFFECTS OF VARIED FEED BUNK SPACE ON
ANIMAL PRODUCTION AND BEHAVIOR,
MANAGEMENT STRATEGY,
AND BUILDING DESIGN

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The effects of varied feed bunk space on lactating dairy cows was studied on a large Michigan dairy farm. Animal behavior and production response were evaluated.

The highest producing one hundred cows were paired according to their stage of lactation and current level of production. These fifty pairs were separated and placed into one of two groups. The cows remained in these groups until their production level dropped below the top one hundred animals at which time replacement pairs were introduced and the lower production pairs removed. Feed was monitored so that on a per animal basis, an equivalent amount of complete ration was made available at all times to both groups. The only intended difference between the two lots was that one had two feet of bunk space per animal and the other had one and one half feet per animal.

Analysis of the mean difference of the production between animals of a pair for four two-month periods

showed no significant difference between the two groups. Lower strata animals (as determined by quantity of aggressive encounters) had difficulty gaining access to feed at prime feeding times, but ate their fill later when less disturbed.

Within these two groups, no detectable differences in the management of feeding time, heat observation, clean up time, and herd health could be noted.

Barns designed around the length of feed bunk can save construction costs. However, only a very small loss in milk production over the depreciated life of a building could be tolerated in recompense for initial savings.

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Finally, inadequate as it may be, a written thanks to my parents for all of their support, and to my wife and daughter whose spirits raised mine when they needed it the most.

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CHAPTER I

INTRODUCTION

Between 1960 and 1971, the numbers of dairymen selling milk in Michigan declined from 41,500 to 13,500. By 1985 only 3,500 to 4,500 dairy herds will probably be selling milk. This 90% decrease in herd numbers is predicted to be accompanied by a 500% increase in the number of cows per farm (38).

The management of the expansion on these enlarged farms will be critical. In one study (44), two-thirds of all expanded farms experienced a cash flow problem lasting for approximately two years. Ten percent of the cash flow problems were considered very serious. Any reduction in the building costs of an expansion may help ease these cash flow problems. Barns that have been designed to accomodate current recommendations for two lineal feet of feed bunk per animal, with resulting alley area, may have inflated construction costs.

Animal behavior studies have been conducted that indicate the feasibility of feeding a lactating dairy cow with as little as eight inches of lineal bunk space per animal (19). In addition, data from Duby (18) suggest that a total allotment of forty square feet of floor space per cow is sufficient. Professor Robert G. Light writes that "If it is possible . . . (to reduce) feed space per cow from two feet to perhaps 1.25 to 1.5 feet . . . smaller buildings can be constructed keeping the cost of construction within reason during this period of inflation (33)."

This study will look at the production response under two levels of competition for feed resources. Further, the study examines potential savings in building costs for several facilities designed around reduced feed bunk space.

The objectives of the study are as follows:

1. To determine the difference in production response under two levels of competition for feed resources.
2. To observe behavioral effects of lactating dairy cows within the two levels of competition for feed resources.
3. To note managerial differences (feeding time, heat observation, clean up time, herd health problems) between the two groups of cows.
4. To design and project differences in cost and feasibility of facilities built around the feed bunk area.
5. To make recommendations for future facilities based on conclusions drawn from this study.

CHAPTER II

REVIEW OF LITERATURE

> "Let us never forget that the cultivation of the earth is the most important labor of man. When tillage begins, other arts follow. The farmers, therefore, are the founders of human civilization." --Daniel Webster

Following this tillage of the earth, came the domestication of animals. Cattle, domesticated 6,000 - 6,500 years ago from the Auroch, were selected for meat, milk, and draft and later were bred for specialization in these areas (10).

We have continued to breed, specialize, and place constraints on dairy cattle in an ongoing effort to achieve an optimum balance between our inputs and animal output. It therefore becomes necessary to look at our constraints and assess their impacts individually before we can assess the effects as a whole.

Friend (20) studied the behavior of dairy cattle in confinement and catagorized behavioral affects from the four areas of free stall, feed trough, exercise lot, and inter-group movement of cows. The first three of his catagories, free stall, feed trough, and exercise lot are to be considered the primary areas of constraint in dairy cattle housing. Of the many scientific probes in these areas that have been indagated, Duby (18) feels that the question of "How much bunk space is required?" has not yet been answered.

Dairy cattle are grazing animals. In their natural environment, they do not typically get much feed at any one time nor for any one small cycle of behavior when compared to a carnivore (8). This natural ingestive pattern has been changed in management systems where a cow's total daily nutritional requirements are placed before her in a feed bunk.

Factors controlling intake in ruminants can be broken down into: 1) physical-rate of disappearance of digesta in the gastrointestinal tract; 2) chemostatic or physiological mechanisms; 3) sensory stimuli such as taste, smell, and; 4) possible psychological factors. The first three are discussed in a review by Jones (27). Possible psychological factors are based on the theory of social facilitation or the presence of other con-specifics causing an increase in feeding activity (24). Group fed dairy cattle will consume more total feed than when fed individually in stanchions (12), (26), (34). One investigator (26) attributed the feed increase to competition while others favored increased maintenance requirements due to the general increased activity of freedom of movement as the cause.

The amount of time individuals average at the feed trough fluctuates within a narrow range even with different types of forage. The average time a cow spent eating in four studies was 5.2 (32), 4.9 (9), 4 (41) and 3.7 hours per day (19). A sizeable portion of this variation is probably due to different criteria used by investigators as to what constitutes eating.

Schein and Fohrman (39) commented that, "There is little doubt that lower order animals would suffer markedly if they were wholly dependent on trough feeding." Apparently animals higher in the social order ate more under group feeding conditions by chasing lower rank animals away from the feed. Less dominant cows expend more effort getting feed from a trough (31). McPhee, McBride, and James (35) found that high social strata steers spent more time feeding (611 $\pm$ 19.5 vs. 546 $\pm$ 1.6 min) during a 60-hour period. Lower strata animals ate proportionately more at night when they were less disturbed. Friend and Polan (19) found dominant cows eating when hay, fresh silage, and supplemental concentrate were fed, r = .40, .55, and .57 respectively. The above studies indicate that social rank is important in determining how much access a cow will have to feed. They failed however, to measure individual intakes to determine how efficiently cattle use their time at the feed area.

A view of dominance is that there is one basic social order through which all of a group's resources are regulated (45). Since production in the lactating dairy cow is greatly influenced by nutritional status, a high correlation with milk production would be expected if the social order influenced feed intake. Social orders, derived from measures of agonistic behavior, have been correlated with body weight and/or age but not milk production (2), (5), (11), (16), (17), (19), (22), (39). A possible reason for this lack of association is that access was not limited enough for social dominance to have an effect on intake. Data from Lamb (29), however, indicate a negative correlation of milk production with less dominant heifers raised in isolation.

Recommendations for the amount of feed bunk space vary greatly, ranging from 15 to 30 inches per cow when feed is continuously available (4), (36). These recommendations apparently have not been based on experimental data, but on custom and successful experience with cows (2). Scientific information on behavior could be of great economic value to the industry (7), especially in determining optimum stocking rates and minimizing stresses.

In order to examine the effects of varied bunk space on lactating animals, the attempt must be made to limit other external variables such as number of free stalls per animal, exercise lot space per animal, intergroup movement of cows, individual feed preference, and inaccuracy in diet formulation.

The average amount of time cows spend resting in free stalls appears to be relatively constant, 10.7 hours for 15 cows in 20 stalls (41) and 11.1 hours per day for 21 cows in 20 stalls (19). Cows make maximum use of free stalls between 3:00 A.M. and 7:00 A.M. (41), and 1:00 A.M. to 5:00 A.M. (32). There is a preference to use certain stalls (19), (23), (41) and social rank appears to affect which stall a cow occupies (19). A cow's successor at a given free stall as well as cows occupying adjacent stalls tended to be of similar social rank, $r = .42$ and $.53$ respectively (19).

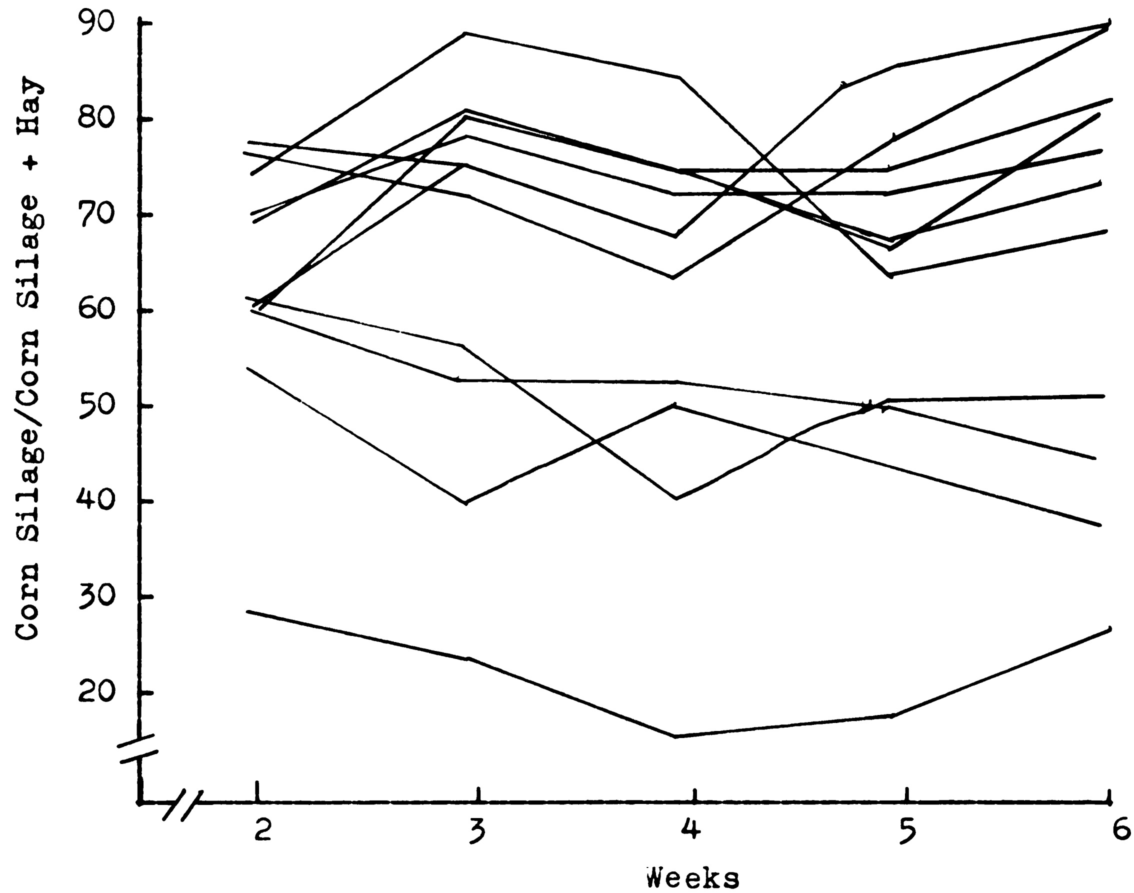
Recommendations for number of free stalls vary. There also appears to be discrepancy between current spatial recommendations and practice in the field. One free stall per cow plus up to 10% additional is now recommended (4), (36) while some dairymen are exceeding recommendation by 30% without apparent adverse effect.

The amount of space in which animals have to interact can be extremely important. Southwick (43) defines density as the number of individuals per unit space, while Friend (20), contrastingly, defines crowding as a product of density, communication, contact and activity. Although the amount of lot space required per cow is not known, one researcher (3) noted that restricting cows to a lot size of 25 ft^2 per cow may be beneficial. There was less activity, fewer encounters with herd mates, no discernible effect on milk yield, and significantly lower leucocytes than the same cows in a 100 ft^2 per cow sized lot.

Many dairymen are grouping their cows by production or stage of lactation if compatable with their physical facilities. A separate ration is then formulated for each group based on production. Most grouping schemes require the shifting of individuals from one group to the next as production, breeding status, etc. change. Farmers and researchers (2), (6), (40) have reported a decrease in milk production after regrouping cows. Shifting cows along with dietary changes has caused sharp but temporary reductions in milk production (1), (37). Researchers in two studies (2), (6) however, have observed a 5% decrease in milk production the day after shifting using the same ration indicating the cause of the decrease was behavioral rather than nutritional. Brakel and Leis (6) observed that aggressive encounters increased almost three fold during day 1 after four new individuals were introduced to a group of 13. Numbers of encounters as well as production returned to normal levels from day 2 on.

There is a large and consistent variation among Holstein cows in their preference for excellent forages whenever they are given a two-choice option (13). This was true either with a simultaneous choice or even though the choice was limited to one forage in the A.M. and the other in the P.M. An example of this variation is shown in Figure 1 in which thirty cows had a simultaneous choice of corn silage and hay.

Figure 1.--Expression of Forage Preference by Eleven Cows Offered Corn Silage and Hay Simultaneously.



The range in choice of corn silage dry matter was from 23.6 to 77% with the lowest cow nearly twenty percentage units below the nearest individual. The freedom to select a preferred forage is most serious when two forages such as corn silage and alfalfa are offered because of the great difference in their protein and mineral content which seriously limits the precision of concentrate formulation to match some "average" forage base (14).

Coppock suggests that similar feed selection occurs in early lactation cows between forages and concentrate mixtures as well as between energy fortified forage blends and protein supplements. From intensive studies of taste in cattle, Kudryavzev (28) concluded "the sense of taste in cattle is also very well developed. A cow distinguishes very well between the main gustatory flavours - bitter, sweet, sour, salty and between different concentrations of each other."

The use of a feed mixing unit can eliminate the problems of feed preference in cattle. It can further be used to formulate a quantitive blend of all dietary ingredients to specific nutrient concentrations. Several recent experiments (1), (15), (30), (42) have demonstrated the advantages of these complete rations not only in reduced costs but also in higher more stable production when fed to grouped animals.

CHAPTER III

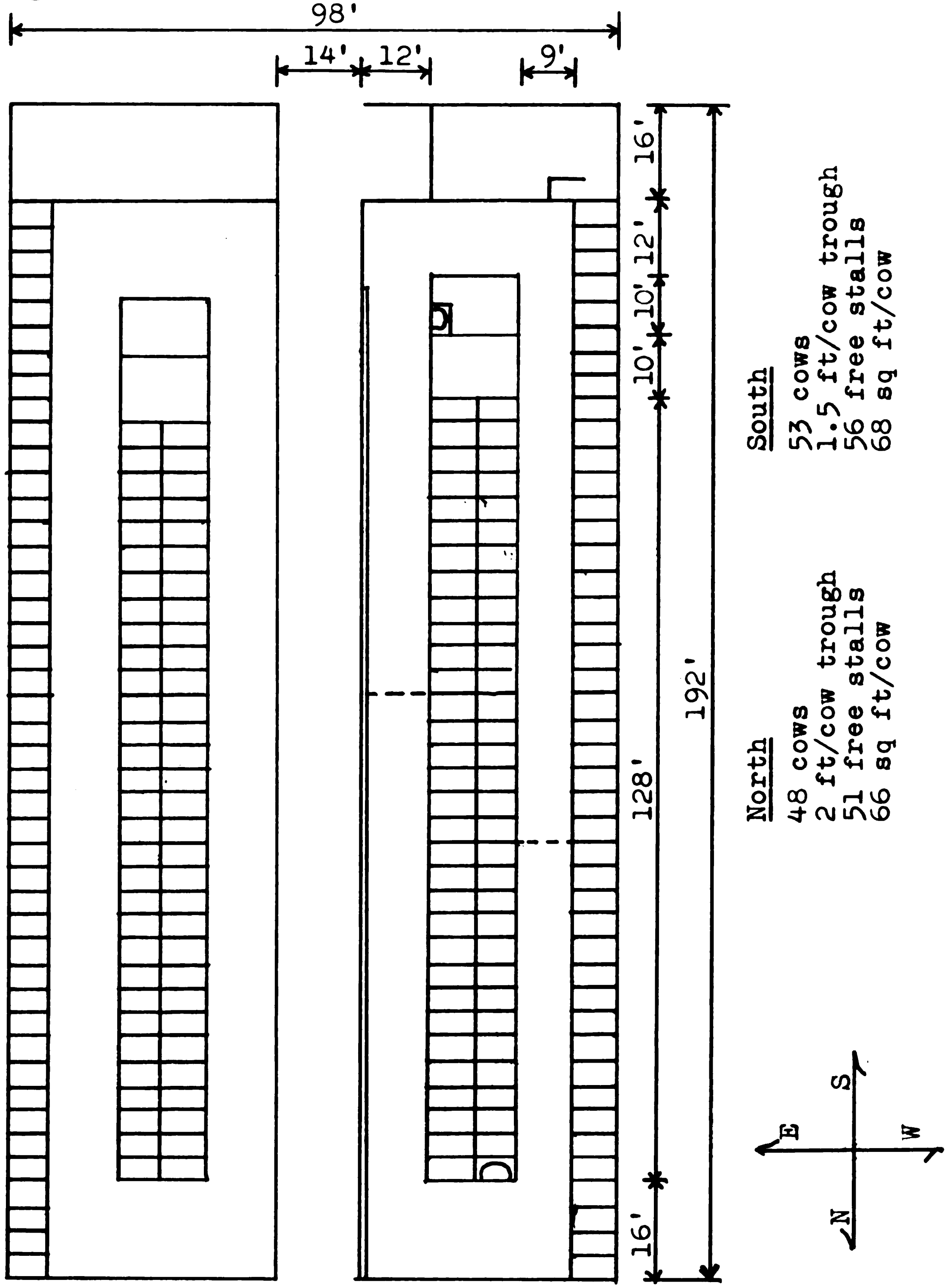
METHODS AND PROCEDURES

Research was conducted at the Halbert Dairy Farm of Battle Creek, Michigan, under commercial dairy farm conditions. It was felt that a field trial of this nature was an appropriate means of gaining information on the relationship between feed bunk space and animal response. The herd consists of approximately 600 cows, divided into five production groups and a dry cow lot. The rolling herd average at this time was 15,429 pounds of milk, 558 pounds of butterfat, and a 3.62 percent test per cow.

The highest production group of approximately 100 animals averaging 78.8 pounds of milk with a 3.1 percent test per day was used. The researchers felt that a stressful situation due to increased competition for resources would be more readily observed.

The facilities, illustrated on the following page in Figure 2, show a 212 free stall barn with a drive through feed alley. The high production group was housed in the west side which had 107 free stalls and 186 lineal feet of bunk space. To suitably separate the high producers into two groups, gates were placed across the alleys as

Figure 2.--Facilities Used During Trial.



indicated by the dotted lines. The separation into two groups attempted to minimize any environmental differences with the exception of feed trough space. The group housed on the north end was to incorporate forty-eight cows in fifty-one stalls with ninety-six lineal feet of bunk space. The south end was to accommodate fifty-three cows in fifty-six stalls with eighty lineal feet of bunk space. On a per animal basis, this allotted 1.06 free stalls for both groups: 66.08 square feet of exercise space on the south end. On the north end there were two feet of bunk space compared to one and a half feet on the south end. This arrangement would accommodate up to forty-eight pairs of animals plus five individual cows.

A complete ration was prepared using a truck-mounted mixer so that on a per animal basis, all cows received an equivalent amount of feed. The corn silage/grain supplement mixture was fed morning, noon, and evening in the quantities shown in Table 1.

Table 1.--Quantities of Ration as Fed in Pounds.

	Control			Treatment		
	Silage	Grain	Total	Silage	Grain	Total
Morning	1127	423	1550	1273	477	1750
Afternoon	1186	214	1400	1356	244	1600
Evening	1176	424	1600	1324	476	1800
Group Total	3490	1060	4550	3952	1198	5150
Per Animal Total	72.7	22.1	94.8	73.2	22.2	95.4

Twice during the feeding trial a feed sample was taken and sent to the Ohio Agricultural Research and Development Center for ration evaluation. Results of the evaluations can be found in Appendix A. A brief summary may be found in Table 2.

Table 2.--Ration Analysis Based on a 100 Percent Dry Matter

	Silage	Grain Mix	Blended Ration
Dry Matter	29.9	92.4	41.1
Crude Protein	13.7	17.9	19.4
Crude Protein (as fed)	4.1	16.6	8.0
T D N	58.7	80.0	71.0
M Cal Energy/Cwt D M	46.8	79.1	63.8

In his book, Design and Analysis of Experiments in the Animal and Medical Sciences, Gill (21) states that "If pairs of experimental units considerably more alike than random subjects . . . can be obtained . . . this feature can be designed into the experiment to reduce experimental error." In order to eliminate the experimental bias of genotypic expression of lactation, this statistical tool of paired data or simple blocking was used.

The decision as per which animals were to enter the high production group was left for farm management. However, the cows entering this group were then subject to pairing and separation into either the control or treatment lot. Individuals were assigned a pair mate on the basis of current and/or past production, and their stage of lactation. If pair mates could not be identified whose daily production level was within eight pounds and whose freshening dates were within eight days of each other, then the animals were considered as individuals and data relating to them were not collected. Once cows were paired, the pair was split and one cow entered the treatment group and the other entered the control group for the duration of their stay.

With the facilities available, up to forty-eight pairs and five individuals could be accommodated. At times there were less than forty-eight pairs but always a total of one hundred one cows separated into a group of forty-eight control and a group of fifty-three treatment animals.

Again, it was left as a farm management decision as to when an animal left the high production group. At that point data collection on the pair stopped and a new pair was introduced.

The trial spanned an eight month period of time. During this time, milk production was monitored on a monthly basis from DHIA reports and behavioral observations were noted. The trial was divided into four two-month periods and the production data were combined and analyzed as suggested by J. Gill (21). For the four two-month periods, t-tests were used with the hypothesis that the population mean difference was zero. Furthermore, a Bonferroni t-test was utilized to detect any seasonal or period progression of the sample means.

CHAPTER IV

RESULTS AND DISCUSSION

The data collection for the production trial spanned an eight month portion of the year from January 18 to September 25, 1979. During this time 210 animals were involved, and of these 210 animals, 28 had no pair mates. The remaining 182 cows were paired and their milk weights were monitored monthly. Of these 91 pairs, 84 pairs stayed in the high production group for one consecutive two-month period to be included in the analysis of results. Table 3 depicts this information as well as the average duration of stay and average production when entering and leaving.

Analysis of Production Data

The milk weight data recorded in Appendix B were combined for two-month intervals as shown. These two-month averages were then calculated for pair mates so that the treatment average was subtracted from the control average leaving mean differences ($\bar{y}_D$) between pairs. The test statistic for a Student-t with paired data is as follows:

Table 3.--Quantity of Animals Used in Trial, Average Length of Stay, and Production Averages when Entering and Leaving.

	Control	Treatment	Total or Combined
Number of Animals*	101	109	210
Number Without Pair Mates	11	17	28
Average Time in Group*	113	119	(days)
Average Production When Entering	79.6	81.6	80.6 lbs
Average Production When Leaving	65.4	67.1	66.3 lbs

*Total of 84 pairs with adequate data that averaged 116 days on trial.

$t = (\bar{y}_D - \mu_0) / (s_D/\sqrt{r})$, where s_D is simply the standard deviation of the sample differences, r is the number of replications and μ_0 in these cases is equal to zero.

Test statistics for period one:

$$t = (-1.032 - 0) / (6.848 / \sqrt{28})$$

$$t = (-1.032) / (1.294)$$

$$t = -.797$$

The hypothesis that there is no difference between the treatment and control is quantified by comparing this t value with the critical value $\pm t_{\alpha/2, r-1}$ in the upper percentage points of Student's-t distribution. The hypotheses may not be rejected with even 80% confidence.

Table 4 outlines these values for all four of the two-month periods.

Table 4.--Student's-t Statistics for Period Production Data

Period	Mean[a]	Standard Deviations	Replications	t	80% Critical Values
1	-1.032	6.848	28	-.798	1.703
2	-3.531	13.520	35	-1.545	1.691
3	.468	9.816	28	.252	1.703
4	3.538	12.783	29	1.490	1.701

[a]Mean differences between treatment and control pair mates in pounds of milk.

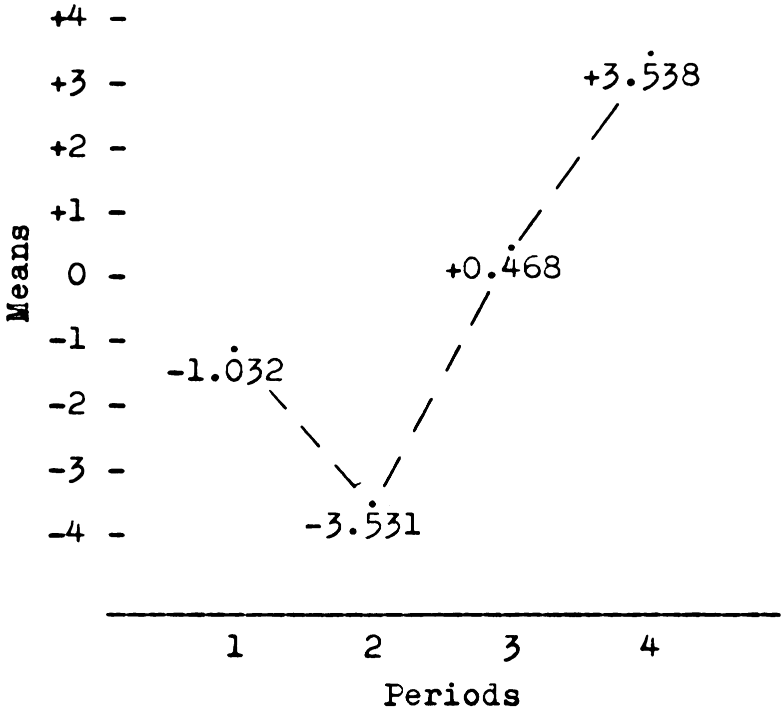
The hypothesis of no difference between groups must be accepted in all of the periods and for the overall trial. However, when the mean differences are plotted on a graph (Figure 3) for sequential two-month periods, the visual assessment suggests the possibility of period or seasonal trends.

To make comparisons among the means of nonorthogonal contrasts, Bonferroni-t statistics may be used. The only contrasts that may show seasonal trends and need to be evaluated are the comparisons of period one versus period two, and period two versus period four.

The test statistic for a Bonferroni-t is:

$$t_B = \frac{\bar{y}_1 - \bar{y}_2}{\sqrt{\frac{(s_1)^2}{r} + \frac{(s_2)^2}{r}}}$$

Figure 3.--Plot of Period Means[a]



[a]Mean differences between treatment and control pair mates in pounds of milk.

When solved for period one versus period two:

$$t_B = \frac{(-1.032) - (3.531)}{\sqrt{\frac{(6.848)^2}{28} + \frac{(13.520)^2}{35}}}$$

$$t_B = \frac{2.499}{\sqrt{1.675 + 5.223}}$$

$$t_B = \frac{2.499}{2.626}$$

$$t_B = .952$$

And when solved for period two versus period four:

$$t_B = \frac{(-3.531) - (3.538)}{\sqrt{\frac{(13.520)^2}{35} + \frac{(12.783)^2}{29}}}$$

$$t_B = \frac{-7.069}{\sqrt{5.223 + 5.635}}$$

$$t_B = -2.15$$

Again if our hypothesis is that there are no differences between the means of two periods, the comparison of t_B with the critical value $\pm t_{B,\alpha/2,m}$, would not let us be 95% sure that there was a change. Thus, the null hypothesis is accepted.

As noted earlier in Table 3, the average period of time that animals spent in the high production herd was greater for the treatment group than for the control group. Again a Student-t analysis of the mean difference between animals of a pair for duration of stay was used. The results in Table 5 indicate that we may have 99% confidence that this difference was real.

The same analysis was used to determine production difference between pair mates as they left the trial. If the treatment animals stayed for a longer period of time, then one might expect their average production to be higher than control animals at the time the first pair mate left the experiment. This was not found to be true (see Table 5) and the hypothesis that there was no difference in production between animals of a pair has to be accepted.

Table 5.--Student's-t Statistics for Duration of Stay and Production Exit Data.

	Mean	Standard Deviations	Replications	t	Critical Values
Duration of Stay	-17.45[a]	50.68	49	-2.41	2.68 (99%)
Exit Production	- 1.22[b]	15.30	49	- .56	.68 (75%)

[a]Mean difference in days between pair members.

[b]Mean difference in pounds production between pair members at the time the first animal was removed.

This analysis of the milk production data indicates that at this level of competition for feed resources, milk yield was not impaired and that during this trial management decisions for the regrouping of animals was not solely dependent on production data.

Observed Behavioral Affects

As noted earlier, Syme's (45) view of dominance is that there is one basic social order through which all of a group's resources are regulated. The administration of a group's feed resource appears to lend credence to this idea.

At the current recommendation of two lineal feet of bunk space per animal, all or nearly all cows can eat simultaneously. However, at one and one half feet per cow many animals are forced to wait for less congested opportunities. Less dominant animals, as determined by the number of aggressive encounters, were not able to eat at prime feeding times.

During this trial, the animals were fed a complete ration three times a day. On a per head basis an equivalent amount was continuously available. Cows were most active at the feed trough when the ration was being deposited and upon return from the milking parlor. During these times the social order of the treatment group was more readily observed than was the social order of the control animals. Because of limited time resources, complete herd ranking for dominance could not be accomplished. However, visual assessment was used to determine the few most aggressive and least aggressive animals at any given time. The lower strata animals would often retire to a free stall or resting area during these prime feeding times and later ate proportionately more when less disturbed.

An interesting observation was noted early in the trial. The more crowded group appeared to consume their feed more rapidly than the less crowded group. At times the ration for one feeding would be cleaned up as much as thirty minutes faster on the treatment side. It was later found that any speculation as to the possibility of increased consumption may be confounded. When the cows were milked in separate groups, animals from the treatment group were shut away from the feed alley and individuals from the control lot had access to their feed while returning from the parlor.

It appears that although some animals from the more crowded group could not consume feed at preferred times, their production was not impeded as they ate their fill later.

Managerial Differences

Managerial differences between these two groups may have been of importance. Thus, one of the objectives of this trial was to note any variation in the labor involved with the feeding, heat observation, cleanup, and herd health problems.

Having made use of existing and slightly modified facilities for this trial, many observations were difficult to quantify. For example, the feed mixture for both treatment and control groups was blended as one batch on the truck and was dispensed for both groups in a single pass. The load cells on the mixer indicated when the proper amount had been given to each group. Because the animals were fed off the floor along a fenceline and not in a trough, the only labor difference to look for was that of pushing the spilled feed back within a cow's reach. Since the same quantity of feed was delivered in less feeding space for the treatment group, this disparity seemed likely. However, no feed had to be returned to either group of cows as this feed was always within reach. A possible explanation for this is that animals were fed three times a day in small enough quantities.

Conception differences were to be monitored between the animal pairs inasmuch as nearly all of the cows were fresh when they entered. Presumably, an animal distressed by competition for resources would require more impregnations per conception or take longer to cycle. It was not possible to tabulate this data as results would be inaccurate. The cows were often replaced by higher producing pairs before they could be checked pregnant or even before they were bred. As a result, the time between parturition and the first observed estrus was noted. Hafez (25) writes that "Adverse environment such as poor nutrition or inclement weather may cause estrual hiatus" and therefore nutritional competition to the point of deprivation should influence detectable heat in the lower strata animals.

Results in Table 6 indicate no significant differences between the control and treatment groups.

Table 6.*--Student's-t Statistics for Heat Detection Data.

Mean	Standard Deviation	Replications	t	80% Critical Value
-1.56[a]	7.79	18	-.85	.863

*Data found in Appendix B.

[a]Mean differences in days between animals of a pair to first observed estrus.

Another of the managerial differences that was difficult to assess within these facilities was the labor involved in the clean-up and waste disposal. Previous work in the area of high density housing found that the increased activity required more intensive care of the free stalls and alleys (18). However, Duby's (18) trial assessed the combined effects of decreased free stall, exercise and bunk space so that those results might differ significantly from this trial.

The facilities shown in Figure 2 were cleaned by an automatic alley scraper. And although it was cycled differently for different periods of the year, it was not cycled more or less frequently as a result of the activity of either group. Any differences in clean-up time could not be identified.

Finally, herd health measurements within both groups did not reveal any trends. Previous considerations in high density studies by Duby (18) and Light (33) suggested that animals in a weakened condition due to diseases and those with serious weaknesses of the feet and legs were not able to withstand the stress of high density housing. Again the dissimilarity of the experimental designs may have been the reason that those results were not duplicated. A given cow averaged less than four months on this trial which probably was not enough time to aggravate foot and leg problems. Nor was wet bedding a disease factor in this experiment as it was in Duby's.

All in all, only two cases of displaced abomasum and a few cases of mastitus were spread among the 210 animals in both groups for the eight month experiment.

In the areas of feeding, heat observation, clean-up time, and herd health, no detectable differences in management schemes were noted for these facilities.

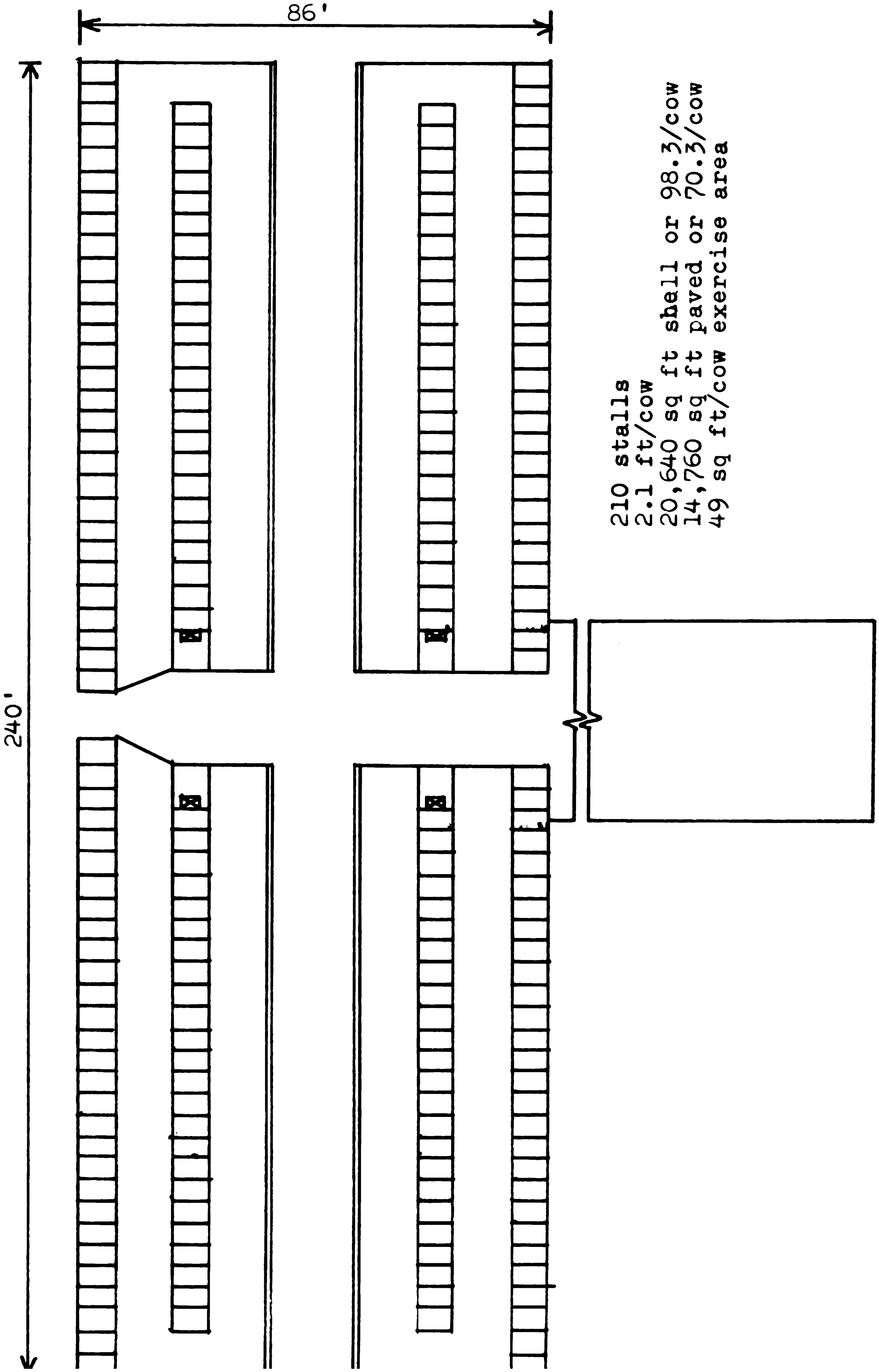
Barn Designs Built Around the Feed Bunk

At the present time, recommendations of the Midwest Plan Service provide for free stall alley width of eight to ten feet between adjacent stall rows, nine to ten feet between a feed bunk and a wall, and ten to twelve feet between a feed bunk and a stall row. Commonly, free stalls are seven feet in length while a drive through alley is fifteen to eighteen feet in width, allowing two feet per cow in length.

Application of these design criteria by engineers has resulted in standard covered housing systems ranging in size from ninety to one hundred square feet of shell per cow (Figure 4). This standard design of a four-row barn with center feeding will allow the correct bunk space in direct proportion to the number of animals housed in accordance with current recommendations of two feet per cow. Thus, regardless of the length, the unit will be in balance for both feeding and resting.

However, only by constantly reassessing standards

Figure 4.--Standard Covered Housing System.



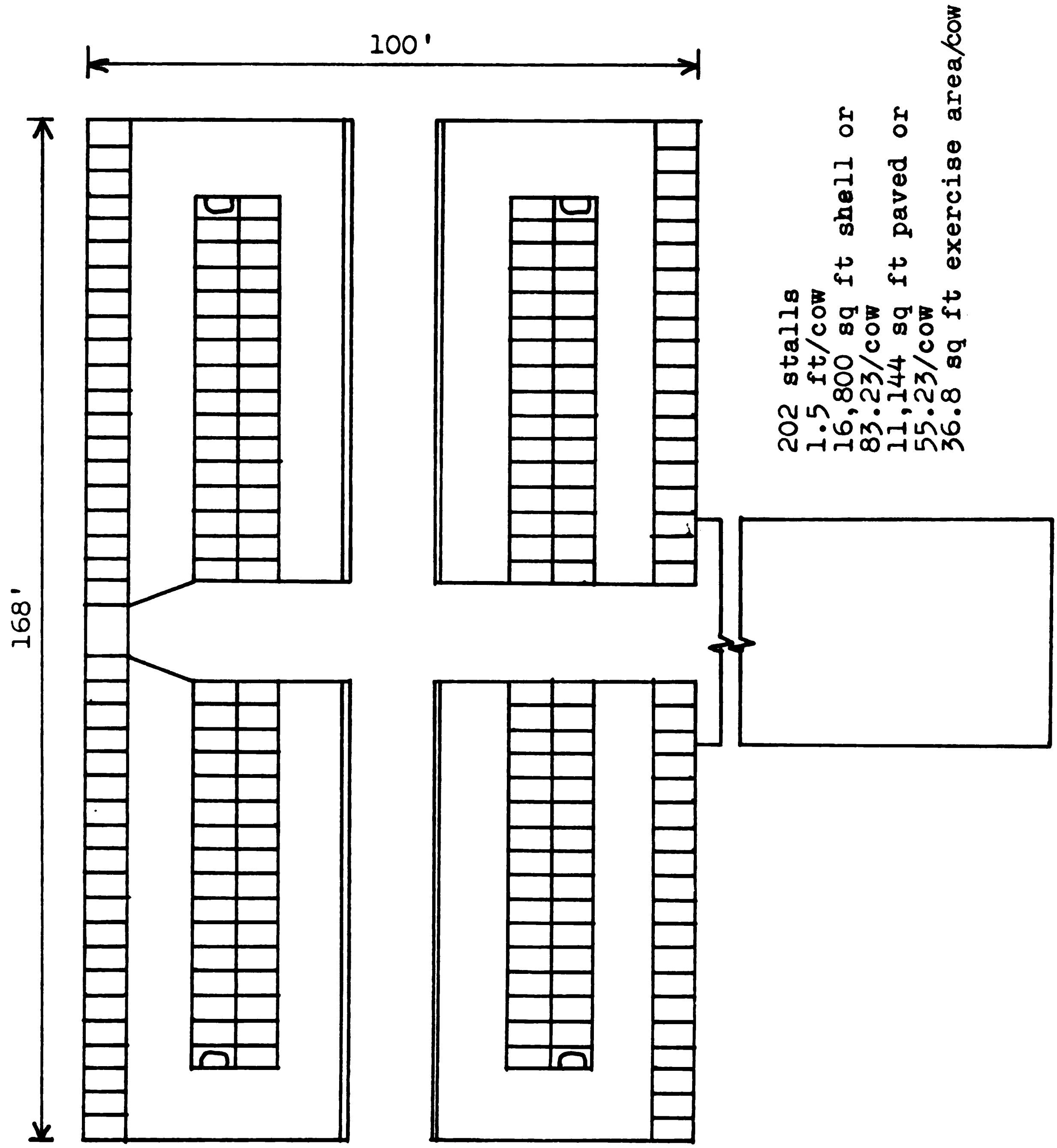
can the dairy industry balance between inputs and outputs. Arave (3) has shown that reducing lot size to twenty-five square feet per cow had no effect on milk yield while significantly lowering leucocytes. Other researchers (18, 33) have concluded from trials that thirty-five to forty square feet of exercise space per animal is sufficient.

Having determined from this experiment that the reduction of bunk space from two lineal feet to one and one-half lineal feet did not adversely affect milk yield, return to estrus, or herd health, it becomes credent to speculate on housing facilities of different standards. Following the assumption that production levels and other factors would remain within tolerable ranges, a look at the pros and cons of these new "high density" housing facilities is necessary.

Figure 5 shows a barn with the same basic floor plan as the conventional standard housing in Figure 4. The only difference is that the free stalls were arranged to utilize the reduction of feed bunk space to one and one-half feet per animal and the floor space to forty-nine square feet per animal. It contains approximately the same number of free stalls.

An obvious advantage of this high density housing is the reduction of building costs. The costs of construction for a barn shown in Figure 5 will be less than those for Figure 4 since the shell size was reduced by 15.1 square

Figure 5.--Standard Covered Housing With Reduced Feed Bunk.



feet per cow; the paved area was reduced by 15.1 square feet per cow; and the feed bunk was reduced by six inches per cow. Another dialectic advantage is the flexibility offered for waste handling. First the reduced paved area allowance in these units makes the use of automatic manure scrapers more feasible as less chain would be required and scraper travel would be reduced. If tractor scraping is used, less time would be required to scrape the smaller paved areas. The other possibility of slatted floors for waste removal has less drawbacks in high density housing than ever before. The smaller exercise area will result in a smaller manure storage tank and less alley area to be equipped with slats. The increased cow traffic on the slats will improve the functioning of these units in forcing manure through the slats to the storage tank below.

Of the possible drawbacks, most would be related to waste handling. The reduced paved area does result in more manure per square foot of surface requiring that these units be given more intensive attention. When scraped by tractor, the manure will accumulate to a greater depth in the course of a twenty-four hour period between scrapings, perhaps indicating that the stalls should be higher above the alley than with standard designs of ten inches. Further, because of the higher animal density scraping by tractor may be more difficult to accomplish thereby placing greater emphasis on the inclusion of automatic floor scrapers. Duby (18) also reports that management of high density stalls becomes more critical in the summer months when bedding stays damp and foot problems arise.

The use of a partial budget to evaluate costs that differ from one barn design to another in this analysis, is only effective when comparing similar systems. One should not compare a two foot per cow bunk space and automatic alley scraper with a one and one-half foot per cow bunk space and slatted floor. As a result, the partial budget in Table 7 only concerns the construction costs of the shell, poured concrete alley, and precast feed bunk for one hundred cow housing. Because this trial could not detect any differences in milk yields, there were no reduced or added returns to include. And, because all designs were compared with the standard facilities (Figure 4), only added or reduced costs are shown.

Figure 6 is a barn designed around one and one-half feet of bunk space as in Figure 5. However, Figure 6 has further reduced the alley area. Figures 7 and 8 are conjectures as to the reduced costs of facilities associated with one foot and six inches of bunk space respectively.

Although these reduced costs for building in Figures 5 and 6 would help to ease the cash flow problems encountered by management after an expansion, it is also necessary to evaluate these calculations in perspective.

Table 7.--Partial Budget of Barn Designs.*

	Fig. 4	Fig. 5	Fig. 6	Fig. 7	Fig. 8
Bunk Space (Ft.):	2	1.5	1.5	1.0	0.5
Exercise Space (Sq. Ft.):	49.0	36.8	34.0	32.7	28.6
Shell costs[a]	$393.20	$332.80	$282.80	$308.00	$240.80
Concrete costs[b]	46.06	36.17	33.74	31.71	20.70
Feed bunk costs[c]	32.00	24.00	24.00	16.00	8.00
Total cost	$471.26	$392.97	$340.58	$355.71	$269.50
Reduction in costs from Figure 4		$ 78.29	$130.68	$115.55	$201.76

*All barns are approximately two hundred stall size. All costs and information are given on a per cow basis.

[a]Shell costs calculated at four dollars per square foot.

[b]Concrete costs for five inch thick alleys. Five sack mix at forty-two dollars per cubic yard.

[c]Feed bunk costs calculated for precast bunks at sixteen dollars per lineal foot.

Table 8 depicts these reduced building costs annualized for a fifteen year straight-line depreciation.

The annual savings noted for buildings in Figures 5 and 6 are not substantial. When compared with the quantity of fluid milk of an equivalent value, the magnitude of this economic planning becomes apparent. Figures 7 and 8 further illustrate the relatively small monetary advantages

Figure 6.--High Density Housing With One and One Half Lineal Feet of Feed Trough Per Cow

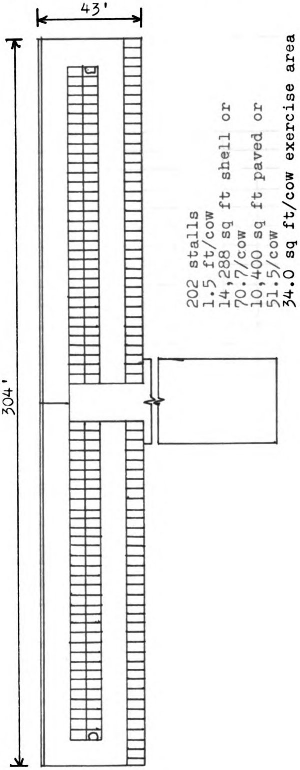


Figure 7.--High Density Housing With One Lineal Foot of Feed Trough Per Cow.

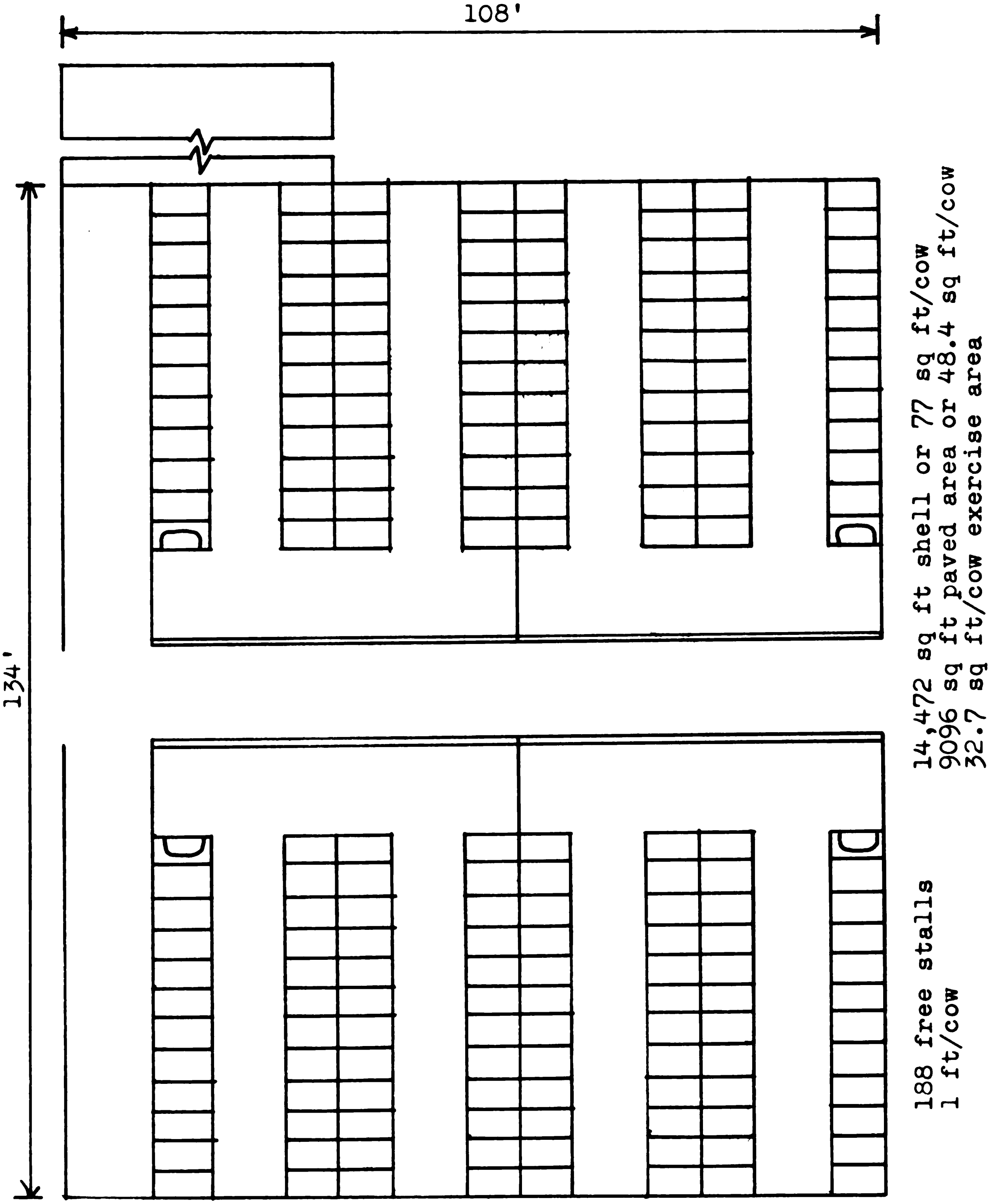
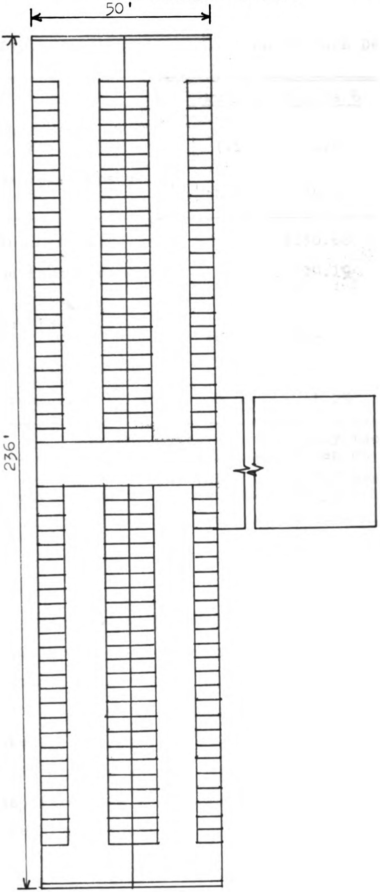


Figure 8.--High Density Housing With Six Lineal Inches of Feed Trough Per Cow.



196 stalls
6 in/cow
11,800 sq ft shell or 60.2 sq ft/cow
6200 sq ft paved or 31.6 sq ft/cow
28.6 sq ft exercise/cow

Table 8.--Annualized Savings of Barn Designs.

	Figure 5	Figure 6	Figure 7	Figure 8
Bunk Space (Ft.):	1.5	1.5	1.0	0.5
Exercise Space (Sq. Ft.):	36.8	34.0	32.7	28.6
Reduced Costs	$78.29	$130.68	$115.55	$201.76
Savings per Year[a]	11.49	19.19	16.97	29.62
Annual Milk Equivalent (in pounds)[b]	92	154	136	237
% Reduction in Production to Break Even Point[c]	0.6%	1.0%	0.9%	1.6%

*All barns are approximately two hundred stall size. All costs and information are given on a per cow basis.

[a]Net Present Value using fifteen year period and twelve percent interest rate per period.

[b]Calculated from current 3.5% milk price of $12.50/Cwt.

[c]Based on a 15,000 pound rolling herd average.

to be gained with facilities of designed reduction. The total reduced construction costs on a per annum basis amount to less than thirty dollars per cow per year for facilities with six inches of bunk space per animal and twenty-nine square feet per animal. This would indicate that at this extreme high density you could only afford approximately a 1.6% drop in production to break even with the higher costs of a standard covered housing unit.

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS, AND DISCUSSION

The analysis and observations of this study found no significant differences in the production response, animal behavior, and management strategies between cows fed at two levels of competition for food resources: one level being the current recommendation of two lineal feet of bunk space per cow and the other a reduction of six inches to one and one-half lineal feet per cow.

The implications of reduced construction costs of housing facilities designed around the shorter feed bunk lengths cannot be considered without caution. It appears possible to house and feed lactating dairy cows in less than current recommendations while maintaining state. However, only a very small loss in milk production over the depreciated life of a building could be tolerated in recompense for initial savings.

Seemingly, the risk of reduction to one and one-half feet of feed trough could be undertaken with the advantages of lower building costs and more feasible automated waste handling. Yet, further reduction of exercise and bunk space has not accumulated enough information to make the uncertainty worthwhile. The questions of production loss, herd health problems and intensified management have not been closely studied for these extreme high density situations.

The most useful application of these findings is probably the quantified information that high density housing can be successful with overcrowding existing facilities as well as by design. Farms that have standard covered housing systems may be able to increase herd size to a level of one and one-half lineal feet of feed space per cow without altering facilities.

Future studies in the area of high density housing should next be concerned with the allotment of exercise space. In this researcher's opinion, the most important question about feed bunk space has been answered. It was not "what are the effects of two feet versus one and one-half versus one versus six inches," but rather "is it necessary for all animals to be able to eat simultaneously." From this study and others one can conclude that it is not necessary for every cow to be fed at the same time as long as feed is continuously available. The only savings that can be realized in reduced bunk space are those associated with the consequential reduction of alley area. Documentation of the effects of much reduced exercise space has been done only on a small number of dairy cows and only on a few trials. Future studies effectuated under commercial dairy herd conditions and numbers could be of value to the industry. However, the potential for economic gains is probably not great enough to command the support of large amounts of research dollars.

As the availability of research funding becomes harder to acquire and the costs associated with conducting these trials escalates, there will probably be more emphasis placed on conducting such trials on privately owned farms. This trial, as an example, was carried out under such conditions and had its peculiar strengths and weaknesses.

The greatest strength of this type of research (aside from reduced costs), is the assimilation to current farm conditions. This lends more credence to the practicability of findings. Because these farms are in business to make a profit, their daily management decisions focus not on the success of the experiment, but on the overall success of the farm operation.

It is in this same light that the problems associated with these conditions surface. Farm owners and managers are reluctant to commit their resources to untried or new ideas. And, because they are participating of their own volition, researchers must work within management's constraints. It is sometimes difficult to gather the necessary data or to make sure that research specifications are maintained when the facilities are not manned with university help. The temptation and the right of farm management is to terminate any trial that may be causing a decrease in production or an increase in farm labor.

As the need to conduct research on commercial farms increases, the need to perpetrate goodwill and to provide directly applicable research information also increases. The universities must support personal contact with the farm sector through more than country cooperative ties. Furthermore, some means of assurance should be provided to compensate for any potential losses sustained by individuals. Perhaps if the losses can be documented, their value can be taken as a tax deductable donation to the university.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Akinyele, I. O., and S. L. Spahr. 1975. State of lactation as a criterion for switching cows from one complete feed to another during early lactation. J. Dairy Sci. 58:917.

2. Arave, C. W. and J. L. Albright. 1976. Social rank and physiological traits of dairy cows as influenced by changing group membership. J. Dairy Sci. 59:974.

3. Arave, C. W., J. L. Albright, and C. L. Sinclair. 1974. Behavior, milk yield, and leucocytes of dairy cows in reduced space and isolation. J. Dairy Sci. 57:1497.

4. Babson Bros. Dairy Research Service. 1970. The way cows will be milked on your dairy tomorrow. 7th ed. Babson Bros. Co., Oak Brook, Il.

5. Beilharz, R. G., D. F. Butcher, and A. E. Freeman. 1966. Social dominance and milk production in Holsteins. J. Dairy Sci. 49:887.

6. Brakel, W. J. and R. A. Leis. 1976. Impact of social disorganization on behavior, milk yield, and body weight of dairy cows. J. Dairy Sci. 59:716.

7. Brambell, F. W. R. 1965. Report of the technical committee to inquire into the welfare of animals kept under the intensive livestock husbandry system. Command paper 2836. London: H.M.S.O., p. 10.

8. Breland, K. and M. Breland. 1966. Animal behavior. Macmillian Company, N. Y.

9. Burghardt, W. G. and C. E. Coppock. 1974. Behavioral and feeding responses of lactating dairy cows fed a complete ration in free stalls. Unpublished mimeo. Cornell Univ., Ithaca, N. Y.

10. Campbell, J. R. and J. F. Lasley. 1969. The Science of Animals That Serve Mankind. McGraw-Hill Book Company, New York, N. Y.

11. Collis, K. A. 1976. An investigation of factors related to the dominance order of a herd of dairy cows of similar age and breed. App. Anim. Ethology 2:167.

12. Coppock, C. E., C. H. Noller, B. W. Crowl, C. D. McLellon and C. L. Rhykerd. 1972. Effect of group versus individual feeding of complete rations on feed intake of lactating cows. J. Dairy Sci. 55:325.

13. Coppock, C. E., R. W. Everett, N. E. Smith, S. T. Slack, and J. P. Harner. 1974. Variation in forage preference in dairy cattle. J. Animal Sci. 39:1170.

14. Coppock, C. E. 1976. Feeding methods and grouping systems. Presented at 71st. annual meeting ADSA, North Carolina State Univer., Raleigh.

15. Coppock, C. E., C. H. Noller, and S. A. Wolfe. 1974. Effect of forage-concentrate ratio in complete feeds fed ad libitum on energy intake in relation to requirements by dairy cows. J. Dairy Sci. 57:1371.

16. Dickson, D. P., G. R. Barr, L. P. Johnson and D. A. Wieckert. 1970. Social dominance and temperament of Holstein cows. J. Dairy Sci. 53:904.

17. Dickson, D. P., G. R. Barr and D. A. Wieckert. 1967. Social relationships of dairy cows in a feed lot. Behav. 29:195.

18. Duby, Robert T. 1979. Reproductive Performance of Dairy Cattle in High and Low Density Housing. (Final report of unpublished paper, University of Massachusetts, Amherst, Ma.).

19. Friend, T. H. and C. E. Polan. 1974. Social rank, feeding behavior, and free stall utilization by dairy cattle. J. Dairy Sci. 57:1214.

20. Friend, Theodore H., and C. E. Polan. 1977. Cow Performance, Adrenal Function, and Milk Quality Under Varying Levels of Competition. (PhD thesis, Virginia Polytechnic Institute and State University).

21. Gill, John L. 1978. Design and Analysis of Experiments in the Animal and Medical Sciences. The Iowa State University Press, Ames, Iowa.

22. Guhl, A. M. and F. W. Atkeson. 1959. Social organization in a herd of dairy cows. Trans. Kansas Academy of Science 62:80.

23. Hacker, R. R., J. L. Albright, R. W. Taylor and D. L. Hill. 1969. Cow preferences for permanent bedding materials supported by different foundations in a free stall slotted floor barn. J. Dairy Sci. 52:918 (Abstr.).

24. Hafez, E. S. E. (Ed.). 1962. The Behavior of Domestic Animals. Williams and Wilkins Co., Baltimore.

25. Hafez, E. S. E. 1974. Reproduction in Farm Animals. Lea and Febiger, Philadelphia, Pennsylvania.

26. Hyppola, K. and O. Hasunen. 1970. Dry matter and energy standards for dairy cows. Acth Agralia Fennica, 116:1.

27. Jones, G. M. 1972. Chemical factors and their relation to feed intake regulation in ruminants: A review. Canadian J. of Anim. Sci. 52:207.

28. Kudryavtzev, A. A. 1962. Higher nervous activity and the physiology of the senses in lactating cows. 16th Int'l. Dairy Congress. Copenhagen, Denmark.

29. Lamb, R. C. 1978. Annual Progress Report North Central Regional Research Project NC-119.

30. Larkin, J. C., and O. T. Fosgate. 1970. Comparisons of two different systems of feeding dairy cows for three consecutive lactations. J. Dairy Sci. 53:561.

31. Larsen, J. J. 1963. Feeding habits of grazing and green feeding cows. J. Anim. Sci. 22:1134.

32. Lewis, R. C. and J. D. Johnson. 1954. Observations of dairy cow activities in loose-housing. J. Dairy Sci. 37:269.

33. Light, Robert G., 1975. Housing and Environment High Density Cuts Construction Costs. Dairy Herd Management Planner Issur.

34. McCullough, M. W. 1962. Use of digestible dry matter by dairy cows group-fed silage. J. Dairy Sci. 45:1107.

35. McPhee, C. P., F. McBride and J. W. James. 1964. Social behavior of domestic animals. II. Steers in small yards. Anim. Prod. 6:9.

36. Midwest Plan Service. 1971. Dairy Housing and Equipment Handbook. Iowa State Univ., Ames.

37. Moseley, J. E., C. E. Coppock and G. B. Lake. 1976. Abrupt changes in the forage-concentrate ratios of complete feed fed ad libitum to dairy cows. J. Dairy Sci. (In Press).

38. Rippen, A. L., Hoglund, C. R., Boyd, J. S., and McBride, G. 1972. The Michigan dairy industry of 1985. Farm Science Research Report 183. Agri. Expt. Station and Cooperative Extension Service, Michigan State University, East Lansing.

39. Schein, M. W. and M. H. Fohrman. 1955. Social dominance relationships in a herd of dairy cattle. Anim. Behav. 3:45.

40. Schein, M. W., C. E. Hyde and M. H. Fohrman. 1955. The effect of physiological disturbances on milk production in dairy cattle. Page 79 in Proc. Ass. Southern Agr. Workers 52nd. Convention, Louisville, K. Y. (Abstr.).

41. Schmisseur, W. E., J. L. Albright, W. M. Dillon, E. W. Kehrederg and W. H. M. Morris. 1966. Animal behavior responses to loose and free stall housing. J. Dairy Sci. 49:102.

42. Smith, N. E. 1971. Feed efficiency in intensive milk production. Proc. 10th Ann. Dairy Cattle Day, Univ. Calif.

43. Southwick, C. H. 1971. The biology and psychology of crowding in man and animals. The Ohio J. of Sci. 71:65.

44. Stoll, Thomas L., 1974. An Analysis of the Effect of Expansion on Cash Flow, Management Income, and Various Management Factors. (M.S. thesis, Michigan State University).

45. Syme, G. J. 1974. Competitive orders as measures of social dominance. Anim. Behav. 22:931.

APPENDIX A

Table 1.--Ration Evaluation. Analytical Results on a 100 Percent Dry Matter Basis, Except as Noted.

	Silage	Grain Mix	Blended Ration
Dry Matter (DM)	29.9	92.4	41.1
Crude Protein (CP)	13.7	17.9	19.4
Crude Protein, as Fed	4.1	16.6	8.0
Available Protein	--	--	18.1
ADF Fiber	--	--	23.0
TDN	58.7	82.0	71.0
Phosphorus (P)	.27	.51	.68
Potassium (K)	1.53	1.43	1.43
Calcium (Ca)	.59	1.39	.85
Magnesium (Mg)	.25	.45	.28
Sulfur (S)	.10	.21	.12
Nitrates	--	--	.17
Ph	--	--	5.41
MCal Energy/Cwt DM	46.8	79.1	63.8
Parts per Million:			
Manganese (Mn)	82	99	121
Iron (Fe)	122	302	219
Copper (Cu)	6	44	14
Zink (Zn)	41	48	63

Source: Ohio Agricultural Research and Development Center.

Table 2.--Ration Evaluation #1

Feed	Pounds Consumed				Grams Consumed			
	As Fed	DM	TDN	CP	Ca	P	Mg	S
Corn Silage No NPN	73.0	21.9	12.8	3.0	58.	26.	24.	10.
Grain Protein Mix	22.0	20.3	16.6	3.6	128.	47.	41.	19.
Total Consumed	95.0	42.2	29.5	6.6	186.	73.	66.	29.
Recommended		50.4	35.4	7.4	169.	84.	45.	41.
Difference		-8.2	-5.8	-0.7	17.	-10.	20	-11.
Percent of DM Consumed			69.9	15.8	0.97	0.38	0.34	0.15
Recommended			70.2	14.6	0.74	0.37	0.19	0.17
Ratios in Ration	Ca/P = 2.52			N/S = 16.25			K/Ca + Mg = 1.12	
Ratios Recommended	1.35 - 2.50			8.00 - 15.00			1.00 - 2.20	

Source: Ohio Agricultural Research and Development Center.

Table 3.--Ration Evaluation #2

Feed	Pounds Consumed				Grams Consumed			
	As Fed	DM	TDN	CP	Ca	P	Mg	S
Blended Ration	64.0	26.3	18.7	4.7	101.	81.	33.	15.
Total Consumed	64.0	26.3	18.7	4.7	101.	81.	33.	15.
Recommended		51.0	36.2	8.0	176.	88.	46.	41.
Difference		-24.7	-17.5	-3.2	-74.	-6.	-12.	-26.
Percent of DM Consumed			71.0	18.1	0.84	0.67	0.27	0.12
Recommended			70.9	15.6	0.76	0.38	0.19	0.17
Ratios in Ration	Ca/P = 1.25			N/S = 23.00			K/Ca + Mg = 1.26	
Ratios Recommended	1.35 - 2.50			8.00 - 15.00			1.00 - 2.20	

Source: Ohio Agricultural Research and Development Center.

APPENDIX B

Production and Estrus Data

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given							
			2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
180	C		85.	75.	69.					
145	T		79.	63.	---					
375	C		77.3	59.	---					
186	T		83.5	83.	70.					
544	C		71.	72.5	---					
234	T		72.	70.8	63.5					
239	C		78.8	63.5	---					
398	T		84.5	91.	86.					
297	C		72.5	72.5	58.					
348	T		76.	71.5	60.8					
113	C		81.5	64.						
660	T		81.5	60.						
620	C		90.5	85.	---					
466	T		86.	71.	67.					
457	C	32	77.	74.	70.	65				
211	T	35	80.	75.	65.5	52.3				
228	C	36	88.3	79.	76.	46.				
648	T	48	88.8	89.3	70.5	56.8				

Production and Estrus Data--Continued

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given							
			2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
281	C		79.5	84.	66.	53.5	---			
626	T		77.5	82.	68.5	64.	64.			
303	C	41	75.8	70.8	61.	59.				
321	T	44	73.5	71.3	71.5	43.5				
627	C		97.5	85.	85.	69.8				
304	T		99.5	94.	74.5	70.				
326	C		73.5	61.	70.5	37.8				
537	T		72.	68.5	61.5	57.3				
358	C		77.5	73.5	69.	57.8				
601	T		79.3	83.5	72.8	50.				
698	C		77.5	81.5	77.3	70.	66.5	---	---	
668	T		---	79.3	80.	79.	73.	69.	60.5	
520	C	38	85.5	68.	70.	74.5				
10	T	41	86.	69.5	69.	62.				
25	C		81.	72.5	73.5	65.5				
638	T		77.5	57.5	48.5	49.				
195	C		77.5	72.5	61.	34.6	---			
65	T		86.	83.	76.	55.	72.			
607	C		88.3	84.	74.5	43.8				
631	T		94.	82.	67.5	51.5				

Production and Estrus Data--Continued

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given 2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
575	C	28	101.	100.	91.	87.3	86.	78.3		
674	T	30	94.5	93.	87.	71.5	69.	---		
613	C		101.5	88.5	74.	50.				
515	T		102.5	85.5	79.	53.				
633	C	43	92.	88.5	70.	49.6	---	---		
431	T	41	96.8	91.	78.5	40.5	76.	68.5		
451	C	36	82.	75.	67.	57.3	---			
357	T	31	86.	83.	74.	55.	65.5			
414	C	48	96.5	97.	84.5	80.5	---	---		
325	T	38	98.	93.	88.	56.8	81.	60.		
538	C		113.	99.5	92.5	84.5	81.	63.5		
47	T		101.	87.8	91.	84.5	72.8	---		
440	C		105.	100.	85.5	49.5	71.	---	---	
418	T		115	93.5	80.	78.	81.	71.	50.	
70	C		96.3	73.	78.5	59.	69.5	---	---	
642	T		94.8	86.5	85.5	59.8	75.	66.5	55.6	
615	C	44	95.5	98.5	90.	64.	78.5	78.5	69.	
557	T	38	95.5	96.5	84.5	69.	64.8	---	---	
605	C	36	75.	88.	84.	84.	88.	80.5	70.	
8	T	30	75.5	87.5	81.5	80.5	75.	69.	54.8	

Production and Estrus Data--Continued

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given 2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
305	C	28	80.5	98.	92.5	58.	76.	56.	---	
374	T	36	81.	112.	102.	57.	95.5	79.5	72.3	
402	C	42	95.	90.	97.5	78.5	82.5	68.		
675	T	56	93.	86.	81.	80.	76.	55.		
273	C		---	101.5	86.5	49.5	53.	---	---	
530	T		74.5	108.5	110.	100.5	93.	82.	85.	
94	C	38		82.	91.5	89.3	85.	84.	64.5	30.
381	T	52		76.5	83.5	59.	76.5	69.5	---	---
216	C			94.5	92.5	81.	70.5	---	---	
565	T			96.	91.5	89.5	86.5	71.5	68.	
48	C			78.8	78.5	56.5	65.	---	---	
570	T			72.5	88.3	102.	78.8	69.8	75.5	
577	C	28		108.3	103.5	84.	96.5	77.5	66.5	46.
341	T	41		94.	104.	106.	90.5	91.5	84.5	76.1
417	C			92.	84.	52.5	75.8	---	---	
352	T			93.5	99.5	60.5	84.	72.	70.8	
696	C			41.	83.	84.5	88.5	83.		
535	T			67.5	72.	65.	---	---		
379	C				67.5	41.5	---			
224	T				71.3	47.8	76.			

Production and Estrus Data--Continued

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given 2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
369	C				99.	84.5	76.5	68.5		
246	T				113.5	85.3	99.3	71.5		
54	C				76.5	66.	66.	---	---	
629	T				95.	83.	88.	86.6	59.	
556	C	43			61.	72.	72.	64.		
81	T	44			85.8	74.5	79.5	57.3		
43	C				57.5	51.5	64.5	---	---	
19	T				94.	89.8	88.3	77.3	78.5	
661	C				79.	66.	65.5	---	---	
209	T				94.	84.	85.5	75.	59.3	
672	C				---	92.3	98.	82.3	75.5	63.
290	T				63.5	103.5	107.5	83.	83.	68.3
97	C				---	66.	74.	69.		
106	T				73.5	43.	68.	---		
582	C				99.	86.	95.	91.5	82.8	70.3
59	T				---	---	93.8	88.	89.5	62.5
126	C					58.	80.	73.	71.5	61.
62	T					57.	78.5	77.5	79.5	60.
201	C	38				49.5	87.	84.	77.3	69.5
44	T	36				69.5	94.8	91.	88.	82.

Production and Estrus Data--Continued

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given							
			2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
51	C					52.5	74.5	66.	---	
614	T					66.8	73.	60.5	54.	
652	C					56.3	82.5	68.5	66.	
63	T					73.5	74.	58.	---	
547	C					---	76.5	66.	---	
41	T					75.5	73.3	73.	72.5	
389	C					67.	81.5	83.	78.	
152	T					---	73.3	66.	---	
151	C					64.3	84.5	84.	80.3	63.5
122	T					---	93.	74.	72.3	54.
36	C	43				110.	112.3	100.	84.5	79.
232	T	31				---	108.	88.5	78.5	69.
73	C	44					50.	82.	89.	69.5
291	T	46					51.8	84.5	73.	66.3
146	C						81.	80.	63.	60.
58	T						89.	81.	89.3	62.5
170	C						81.3	81.	76.	68.
267	T						75.	61.	---	---
306	C						84.5	90.	74.5	64.
670	T						81.5	70.5	72.5	65.

Production and Estrus Data--Continued

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given							
			2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
14	C						71.	80.	---	
664	T						85.8	74.	65.	
89	C						77.	71.5		
108	T						63.	52.5		
667	C						74.5	98.5	87.	78.
28	T						76.5	85.	74.5	63.5
690	C						99.5	92.5	80.8	
673	T						91.5	107.	---	
105	C						80.5	47.	---	
83	T						83.3	77.	73.	
210	C						115.	62.	81.5	71.5
6	T						107.5	98.5	80.	73.8
214	C						93.	83.5	63.3	62.
133	T						91.5	93.5	78.8	66.5
7	C							75.3	83.	67.5
289	T							78.	86.	76.
46	C							89.	91.5	---
112	T							84.	82.	66.5
257	C							71.5	82.5	73.5
5	T							71.	62.	43.5

Production and Estrus Data--Continued

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given							
			2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
262	C							89.5	93.5	81.8
503	T							86.5	61.8	68.5
270	C							62.	85.	77.
562	T							51.5	52.5	53.8
349	C							68.5	83.	---
264	T							68.5	63.5	48.5
435	C							73.5	107.5	85.5
598	T							76.	73.3	68.5
253	C							42.	55.	54.8
685	T							---	55.	46.8
223	C								48.8	64.
161	T								49.5	74.
313	C								53.	41.5
243	T								50.3	50.3
683	C								62.3	75.5
571	T								58.	63.5
377	C								63.	50.
279	T								63.5	68.
80	C								72.	95.3
323	T								65.8	68.

Production and Estrus Data--Continued

Pairs	Control or Treatment	Days to First Estrus	Daily Production in Pounds on Date Given							
			2/20	3/18	4/22	5/23	6/29	7/25	8/22	9/25
181	C								89.	68.8
248	T								85.5	76.5
95	C								87.	88.5
587	T								84.	61.
139	C								77.5	64.5
190	T								76.	66.8
33	C								80.	81.
311	T								75.5	66.
249	C								75.5	70.
288	T								74.5	66.