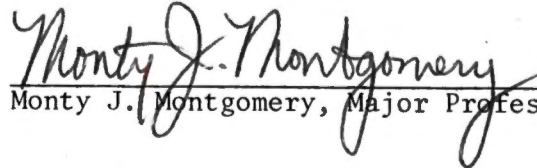
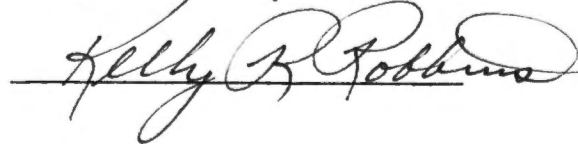


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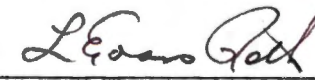
I am submitting herewith a thesis written by Pedro Chaverri-Oller entitled "Comparison of Corn Silage and Cottonseed Hulls in Complete Rations for Calves in Confinement Housing and Outdoor Calf Hutches." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.


Monty J. Montgomery, Major Professor

We have read this thesis and
recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

COMPARISON OF CORN SILAGE AND COTTONSEED HULLS IN COMPLETE
RATIONS FOR CALVES IN CONFINEMENT HOUSING AND
OUTDOOR CALF HUTCHES

A Thesis
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Pedro Chaverri-Oller

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ABSTRACT

In a 2×2 factorial experiment thirty-two Holstein calves were randomly allotted to two housing systems, (1) bedded pens in a closed barn and (2) outdoor calf hutches. Individual pens in a mechanically ventilated barn were utilized for the initial 18 weeks. At 19 weeks of age, calves were moved to group pens and remained there until 30 weeks old.

Housing system had no effect ($P > 0.05$) on body weight gains of calves for the first 18 weeks of age. However, significant differences ($P < 0.05$) were found when heifers were moved to group pens. Higher body weight gains were observed for heifers housed indoors than for those housed outdoors.

The method of housing did not affect height, heart girth, or length measurements.

Cottonseed hulls complete rations were compared to corn silage complete rations. The cottonseed hull ration consisted of two stages: stage A contained 20 percent cottonseed hulls, 60 percent corn and 20 percent soybean meal; stage B consisted of 43 percent cottonseed hulls, 43 percent corn, and 14 percent soybean meal. Stage A was fed ad libitum to calves from the first month of age up to approximately 300 pounds body weight. Stage B was fed ad libitum to heifers which achieved approximately 300 pounds, and continued to 30 weeks. Corn silage complete ration consisted of a 3:1 ratio of corn silage plus pelleted grain mix containing 18 percent crude protein, fed ad libitum.

Significant differences ($P < 0.05$) were detected for dry matter intake, body weight, and body measurements between rations 1 and 2. Greater body weight gains were observed from the use of ration 1. Ration 1 containing cottonseed hulls resulted in greater dry matter, crude protein, and acid detergent fiber intake.

Differences in ruminal volatile fatty acids, acetate, propionate, and valerate were significant. Molar percentages of propionate were higher in heifers fed ration 1.

The housing system did not affect the incidence of scours or pneumonia. Outdoor hutches required less bedding. Feeding calves housed in outdoor hutches was less comfortable for the operator during the winter.

Calves from 3 days to 18 weeks of age reared in outdoor calf hutches had growth rates comparable to those housed in a conventional barn.

When economically feasible, cottonseed hulls are recommended as a fiber source.

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CHAPTER I

INTRODUCTION

The future of any dairy operation depends upon a successful program for raising calves and heifers for replacements. However, despite the numerous advances in calf-rearing methods, a high proportion of calves die each year, even on farms where conditions appear to be favorable. Studies have reported that calf mortality ranges from approximately 6 to 30 percent (90).

Besides breeding and feeding, both housing and management of the environment are recognized as important factors related to survival rate, growth rate, and cost (106, 15). Until recent years, the trend has been toward environmentally controlled calf barns in colder climates. However, this type of calf barn represents quite an investment. Individual calf hutches, a type of cold calf housing, have been used successfully in cold environments as a low cost and high survival type of housing for calves (81).

Complete rations represent an alternative feeding system that can be used by dairymen in order to meet the nutrient requirement and obtain maximum economic return in dairy operations. Use of cottonseed hulls, a by-product from cotton industry, has been shown to be an efficient fiber source for raising dairy calves (78). Corn is the predominant silage crop in the United States because of its high nutritional quality for ruminants and its favorable yields. Limited data are available on its use in complete rations for dairy calves.

The objectives of this study were: (1) to compare intake, rate of growth, and body measurements of calves fed either a corn silage or cottonseed hull based complete ration, and (2) to compare the effects of confinement housing and calf hutches on weight gain and health.

CHAPTER II

LITERATURE REVIEW

Calf Starters

The use of calf starters in dairy calves has been associated with utilization of nutrients from less expensive sources. The National Research Council (86) recommends 16 percent protein, 80 percent TDN, 0.6 percent calcium, and 0.42 percent phosphorus for calf starters. However, there is a lack of agreement on protein requirements for young calves.

Crude protein levels on calf starters. Brown and Lassiter (21) reported very little differences in the growth rate of calves fed 14, 16, or 18 percent crude protein calf starters. Furthermore, they found that as the protein to energy ratio increased, the body weight gain of calves decreased. Gardner (40) suggested that limiting the amount of starter confounded protein and energy requirements. Feeding high energy starters ad libitum, he observed that calves fed starters containing 11.9 percent protein grew as well as those fed 14.7 or 16.9 percent protein. However, Brown et al. (20) reported that calves receiving starters containing approximately 16 percent crude protein gained slightly more weight than calves receiving either higher or lower protein starters. Jones et al. (58) compared diets of 9.3, 17.8 and 22.2 CP to a 21 percent CP highfat replacer. He found that increasing dietary crude protein content increased gains and feed efficiency. In

addition, Veira et al. (113) reported that 8 percent and 12 percent crude protein were inadequate to support normal growth.

Physical form of calf starters. The physical form of the ration appears to affect calf performance. Borland (16), and Bartley (8) indicated that feed intake increased with pelleting; whereas, Gardner (39), and Gardner and Akbar (41) reported no change.

Level of fiber in calf starter. The introduction of high roughage into the calf's ration at an early age results in early and proper development of reticulo-rumen function and takes advantage of the ruminant's ability to utilize low-cost fibrous feeds. McCandlish (75) indicated that the bulk of alfalfa hay has a great value for a normal digestion of the calves. Bulky feeds are necessary for digestion in the rumen and other sections of the digestive tract. Whitaker et al. (119), Murley et al. (84), and Wing (121) have indicated that the concentrate feed for young calves may be both simple and high in fiber. Miller et al. (78) found that additional fiber in either simplified or complex starters resulted in increased feed intake and weight gains. Johnson et al. (57) concluded that maximum food consumption occurred with a diet containing 15 percent roughage, as compared to none and 30 percent. However, Lucci (70) found no significant differences among diets in live weight gains or increases in heart and paunch girths from 15 to 92 days of age, by comparing 3.8, 6.7, or 9.3 percent crude fiber in starters fed to early weaned dairy calves. Whitaker et al. (119) using calf starters containing 5, 9, or 13 percent crude fiber, from corn cobs and

shucks or alfalfa meal, found no important differences among calves due to the level or source of crude fiber on weight gain, starter consumption or hay consumption at either 8 or 16 weeks of age. When John et al. (56) fed dairy calves various concentrations of fiber (straw) observed that fill contents of the rumen, reticulum, omasum and abomasum increased linearly with dietary fiber, resulting in a smaller proportion of live weight gain. Strozinski and Chandler (107) using rations containing 0, 22.5, 45, 67.5, and 90 percent of hay indicated that hay substitution for concentrate resulted in a linear increase on stomach fill. Corrected body weight gains did not begin to decline measurably until the amount of hay substituted exceeded 45 percent. On the other hand, Hardison et al. (49) reported that restricting the grain intake decreased height at the withers but did not affect roughage intake, weight gains or barrel circumference.

Use of Silage in Calf Rations

Interest in silage as a forage for dairy cattle has been related to the advantage of mechanization and storage. However, the extent to which silage can be used successfully with calves is not clear. Poster and Kesler (92) reported that good grass silage can be used as the sole source of roughage for young Holstein calves from birth to 16 weeks of age. Klosterman et al. (64) compared gains by steers fed an ensiled complete ration of chopped corn, corn grain, urea, and minerals with a similar ration formulated at feeding. Average daily gains on the ensiled complete ration were significantly higher. Besides the advantages previously mentioned, silage has been shown to be less

desirable for calves than hay in terms of dry matter intake and growth rates (61, 79, 26). Miller (79), and Kawasaki et al. (61) reported that calves fed grass silage have a lower digestibility of organic matter and lower N-retention than those given hay. In addition, Conrad (26) compared grass silage, ladino clover pasture with hay in the barn at 2:1 ratio of hay to grain. Calves fed the grass silage ration grew less and consumed less TDN and made less efficient gains than those fed hay.

Consumption of silage has been shown to be related to the dry matter content. Thomas et al. (109), in a study of factors affecting rate of intake of heifers fed silage, observed that alfalfa silage consumption was linearly and positively related to dry matter content of silage. Forbes and Irwin (37) reported reduced liveweight gains associated with low dry matter intake; 1.4 percent of body weight on grass silage alone compared with 1.95 percent on barn dried hay alone. Forbes and Jackson (38) compared grass silage containing 18.7, 35.2, and 51.0 percent dry matter in young beef cattle. The dry matter intake increased curvilinearly with the dry matter content of silage.

Waldern (115) reported that corn silage of low dry matter content (24 percent) decreased feed intake and milk production. Variation from no change to a decline of six units of digestible energy have been reported when comparing mature 60 percent dry matter silage with silage at dry matter content below 33 percent (22, 91).

Griffiths and Spellane (46) studied the effects of low dry matter grass silage offered ad libitum, supplemented with various levels of

barley and/or groundnut meal or urea. Results indicated that voluntary intake of the silage was low although apparent digestibility of dry matter was high (66-75 percent). Barley supplementation increased nitrogen retention.

Use of corn silage in calf rations. The popularity of corn silage in feeding programs has been related to its high nutritional quality, favorable yields under normal climatic and soil conditions, and ease of mechanization and storage.

Satisfactory results have been reported from feeding corn silage to growing animals (12, 62). Gardner (39) reported average gains of 154, 146, and 148 pounds in calves fed alfalfa hay, alfalfa silage or corn silage respectively for the first 16 weeks of age. When the effect of birth-weight differences was considered, the differences in gains were not significant. Grieve et al. (44) found no differences in forage intake, total dry matter intake and growth measurements when he compared corn silage and hay crop silage 60:40 DM or blended corn silage and chopped hay 60:40 DM, fed ad libitum to Holstein heifers.

Grieve et al. (45) fed roughage to heifer calves consisting of corn silage (60:40 DM) from birth through completion of three lactations. They concluded that corn silage can be fed satisfactorily to dairy cattle as the sole roughage without adversely affecting health and reproduction.

Nease (85) fed Holstein and Jersey heifers for the first six months of age with isonitrogenous rations of 1:1 hay and 16 percent CP grain mix; 2:1 corn silage and grain mix plus soybean meal. Average daily gains of Holsteins for the first trial were 1.73, 1.82, and 1.74 pounds

respectively. No significant differences in height at withers, length, or paunch circumference were found.

Borland and Kesler (16) compared four complete rations differing in composition, roughage, and form. Ration 1, control, contained chopped hay as roughage source; ration 2 was identical to control but was reground and pelleted; ration 3 was based on corn silage; and ration 4 was a commercial pellet. Intake of dry matter was least on corn silage. Weight gains were 0.93, 0.99, 0.89, and 1.10 kg/day with gains by animals fed the commercial product exceeding those on rations 1 and 3. Sudweeks (102) indicated a maximum utilization of concentrates fed to calves at 40 percent of dietary dry matter as corn silage.

Use of Cottonseed Hulls in Calf Rations

Cottonseed hulls have been shown to be an alternative source of fiber for ruminants in areas where cotton is grown. Lee et al. (68) reported higher daily intake and body weight gain in young dairy calves fed 25 percent cottonseed hulls (CSH) in starter rations than calves fed 25 percent rice hulls. In addition, no differences were reported between calves receiving 25 percent CSH or alfalfa pellets. Miller et al. (78) observed that the addition of 10 percent CSH as a fiber source to either simplified or complex calf starter rations resulted in increased intake and weight gains.

Murdock and Wallenius (82) using three different sources of fiber—alfalfa hay, CSH, or alfalfa-beet pulp—found that calves fed the CSH ration consumed more starter ration and gained more body weight.

Van Horn (110) evaluated a basic soybean meal plus supplement ration with similar rations differing in roughage source. Results indicated that the addition of 30 percent CSH resulted in greater weight gains than citrus pulp. Clifton and Fowler (25) reported that good quality coastal bermudagrass hay showed no advantage over CSH or pelleted corn cobs, when the source of roughage was used at 10 or 20 percent of a simplified ground corn and soybean meal ration.

Rakes and Davenport (94) studied the feasibility of incorporating by-product ingredients in complete, self-fed rations for Holstein heifers from 6 months of age until just before calving. Daily gain for the heifers fed a ration containing 62.5 percent of CSH, 17.1 percent ground corn, and 19 percent soybean oil meal was 0.98 kg. When the ration contained 72.5 percent CSH, 4.6 percent ground corn and 21.4 percent soybean oil, average body weight gain was 0.91 kg per day.

Greene et al. (43) evaluated the effects of including hydrolized feather meal in liquid supplements with corn stover or cotton seed hulls for Angus steers. Average daily gain, roughage intake and feed efficiency were improved ($P < 0.05$) when CSH was fed in place of corn stover.

Sargent et al. (101) compared nutrient digestibilities in Holstein cows fed either a 30 percent CSH complete feed or a 50 percent corn silage complete feed. Digestibility of the corn silage ration was greater, even though average daily milk production during the digestion trial was greater for the CSH ration.

Migioia (77) using Holstein calves compared complete rations utilizing 20 and 43 percent CSH, from three weeks to approximately 300 pounds of body weight and from 300 pounds until 30 weeks of age

respectively, with long alfalfa hay plus 18 percent grain concentrate fed separately ad libitum. Calves fed long alfalfa hay showed lower response than those fed CSH for daily dry matter intake, body weight gain and heart girth. However, no significant differences were found between daily dry matter intake per hundred pounds body weight, body length and height due to treatment. He concluded that heifer calves can be raised successfully using a two-stage complete ration with CSH hulls as the fiber source. Van Horn et al. (111) compared complete starters containing sugarcane bagasse pellets with CSH for calves from 0 to 84 days and young heifers from 80 to 180 days. The results indicated that complete rations with 40 to 55 percent CSH gave excellent and equal gains from 80 to 180 days of age at either 10 or 12.5 percent protein (air-dry ration) and with or without 0.89 percent urea.

Murdock and Wallenius (82) found no difference between molar ratios of volatile fatty acids or pH of calves fed starters containing either CSH, alfalfa hay or alfalfa-beet pulp as sources of fiber. In contrast, Miglogia (77) reported a significant difference ($P < 0.05$) between volatile fatty acids, acetate and propionate in calves from three to 21 weeks of age fed rations containing 20 percent CSH or alfalfa hay. Briggs et al. (18) found higher pH values in roughage diets than in concentrate diets.

Complete Rations

Coppock (27) defines a complete ration as "quantitative blend of all diet ingredients mixed thoroughly enough to prevent separation and sorting, formulated in specific nutrient levels and offered ad libitum."

Feeding complete rations may simplify management for many dairymen. The diet consumed by all animals may be defined exactly and a better balance of nutrient intake can be achieved by avoiding individual preferences for forage or concentrate. Ease of handling and enhanced labor utilization may be possible. Complete feeds have been used in studies involving feasibility of different roughages such as silage, CSH, corn cobs, Hay, bagasse pellets, and rice hulls. Successful results were obtained when mixing roughage and concentrates together into a complete ration (24, 53, 59, 77, 89, 99).

The extent to which protein:energy ratio in complete rations affect rate of growth, has been studied by Schurman and Kesler (104). They suggested lower values than 1:41.1 grams digestible protein per kilocalorie of digestible energy for calves from 8 to 18 weeks of age. In addition Chandler and Walker (23) found that a ratio of 1:16.7 percent is optimum for calves 8 to 18 weeks of age fed complete rations.

Growth

The growth of calves consists of an increase in body size and weight as well as physiological and digestive changes. The optimum growth of a dairy calf is that which allows an animal to develop its full lactation potential at a desired age and at minimum cost (108). Factors such as sex, breed, inbreeding, climate, and ration have been shown to affect calf growth.

Effect of sex, breed and inbreeding on calf growth. Rathore (95) found sex and breed differences in growth rate of dairy calves. Heifers

of different breeds cannot be bound to the same standards, and even individuals within breeds may differ as much as 20 to 25 percent from an average growth pattern. Each animal has an inherent mature body size to which it grows at a genetically controlled rate (108). Martin et al. (74) reported that sex and breed influence birth weight of the calf; however, correlations of birth weight and weight gains are consistently small. In addition, they noted that inbreeding appeared to have little effect on weight change of young calves until the coefficient of inbreeding apparently depressed growth rate. Baker et al. (7) observed that growth rate decreased as inbreeding increased. Voelker and Tucker (114) found that wither height and heart girth were negatively correlated with inbreeding at a lower magnitude than body weight. Inbreeding and calfhood scouring were found to delay age at puberty and to significantly retard calf growth (52).

Effect of plane of nutrition on calf growth. Early surveys on the effect of nutrition plane on cattle growth rate indicate that a lower level of feeding retards growth as measured by daily weight gain. Savage (100) reported that calves and sheep were retarded in growth as a result of rations inferior in quality and amount. Waters (117) observed that a constancy in calf body weight could mean that the skeleton continues to grow while other tissues such as muscle decline. Eckles and Swelt (31) found compensation in the form of increased growth after periods of retardation; however, heifers restricted in diet never became as large as others which were not restricted.

Marshall and Smith (72) reported different rates of weight gain in Jersey calves given four different diets of milk: (1) whole milk, (2) skim milk ad libitum, (3) colostrum ad libitum, and (4) whole milk fed twice a day at 4-5 percent body weight per feeding. Body weight gains were 45, 32, 29, and 12 pounds respectively. In contrast, Khovry et al. (63) found no differences in weight gains of either late or early weaned calves. Decreases in milk consumption were compensated by increased intakes of concentrate and roughage. From analysis of diverse information, Schultz (103) concluded that (1) heifers within a breed tend to reach puberty at about the same size regardless of feeding level, (2) conception rate is not markedly affected by feeding level or breeding age, (3) underfeeding results in calves only slightly smaller than normal at first calving and increases calving difficulties, (4) sequence feeding with high, then low, levels of nutrition during rearing has an undesirable effect on mature production.

Effect of climate on calf growth. The effects of climate on daily weight gain have been reported by Roy et al. (98) and Muller and Owens (81). Daily weight gains of calves are lower during very low or very high temperatures. Lower gains during winter months are expected, since more nutrients are needed to maintain body temperature. Eckles and Swett (30) showed that environmental conditions had a greater effect on weight than on skeletal growth. Bianca and Blaxter (9), in a report on environmental influences on animal production and health under differing housing conditions, indicated that exposure of newborn calves to cold in open sheds did not adversely affect their later development.

They noted that cold seemed to have a stimulatory effect on the development of the chests of calves. Olbrich et al. (88) showed that intake in Highland and Zebu cattle decreased as temperature increased.

Relationship between Climate, Housing, and Animal Performance

The type of housing selected by a dairyman may be influenced by the climate. A primary reduction of productivity measured in terms of mortality rate, growth, and animal comfort has been negatively correlated with effects of temperature, humidity, and ventilation (9, 10, 11, 42, 71, 96, 106).

Effect of temperature on animal performance. Cold is recognized as a stress factor which may reduce livestock performance. Whenever ambient temperature drops below a critical point, there is a direct effect on performance. The animal must produce extra metabolic heat to maintain its body temperature. The extent to which temperature affects calf performance is variable. Appleman and Owen (4), in a review of research on the engineering aspects of raising young calves, reported that an air temperature between freezing and 21° C was satisfactory. Webster et al. (118) reported that the critical temperatures of sheep and cattle were substantially reduced by prolonged exposure to cold. Martin et al. (73), using calf mortality data from the California Central Valley over a 5.5 year period, found that calf losses were more related to weather phenomena in winter than in summer. Bourne (17) stated that calf-housed temperature should not fall below 13° C during the first three weeks, but afterward the animal could grow satisfactorily

in temperatures as low as 8° C. Brody et al. (19) reported that Shorthorn calves maintained at a constant temperature performed better at 10° C than at 27° C. Baker (7) pointed out that food conversion was slightly less below 16° C. Gonzalez-Jimenez and Blaxter (42) found that minimal critical temperature for calves showed a gradual decrease with age, from 14° C at three days to 8° C at 20 days. These results related with the design of calfhouses, suggest that calfhouse temperature should not be allowed to fall below 13° C. Thus the young calf is considerably more sensitive to cold than the adult cow or the steer (9, 17, 42).

Several workers have studied the effect of temperature on animal efficiency. Young and Christopherson (124), and Knox and Handley (65), reported that cold reduced efficiency in ruminants. The primary reduction in productivity arises from the prolonged effect of cold, which reduces the efficiency of digestion and increases the animal's maintenance requirements. Studies conducted in Missouri (123) clearly indicate that high temperature could have an adverse effect on growth. Even a relatively mild temperature (-3° C) reduced daily gain of Shorthorn calves by 0.25 kg/day, compared to the gain in control calves at 13° C. Muller and Owen (81) found that daily weight gains of hutch-housed calves were lower at either very cold or very hot temperatures. Fast growth resulted at temperatures of -1° C to 16° C. Knox and Handley (65) reported significant reductions in weight gains and efficiency during winter months, even though the effective ambient temperature never fell below the critical temperature of the animals. McKnight (76) reported that hutch temperature varied directly with the outdoor

temperature, and that both calves in a barn in a winter trial and calves in hutches in a summer trial grew significantly faster ($P < 0.05$) than calves in any other housing-season combination. Autrey et al. (6) found that to maintain the same growth rate in calves, those reared in outdoor pens had to consume more food than those reared indoors.

Blaxter and Waiman (14) estimated the critical temperature of fasted steers kept indoors to be approximately 18°C ; the critical temperatures of steers fed at maintenance or at a 0.5 kg/day gain level were 6 and -1°C , respectively. However, Roy et al. (98) found no advantage in maintaining a calfhousing above 14.5°C , except for veal calf production in which high fat deposition may be required. Their results also suggested that calves weaned early were predisposed to a higher incidence and greater severity of pneumonic lung lesions when compared to calves receiving a plentiful amount of milk. The effects of temperature on health were reported by Erb et al. (33), who found that calves kept in open sheds where the temperature had fallen to -7°C suffered from a lower death rate (2 percent) than those found in conventional barns.

Effect of humidity on animal health. High humidity is detrimental to calf health. Effects of relative humidity and temperature on calf health and productivity have been reported by Jorgenson et al. (60), Manton (71), and Bickert (11). Cold temperature with high relative humidity causes dampness of the coat, bedding, floor, and walls. Evaporation of moisture from these surfaces may be expected to increase the unfavorable effects of cold. Loosemore, Anderson and Edgson (69)

referred to the effects of excess humidity plus poor ventilation, which caused condensation and lower drying rates of bedding, and thus influenced the resistance of stock to infection and the survival of infectious organisms. Roy et al. (98) reported that in calves raised in a 15° C environment, lung lesion incidence increased with increasing relative humidity. In a 23° C environment, lung lesions decreased with increasing relative humidity. They concluded that extremes in relative humidity had a minimal effect on predisposition of lung lesions at 17° C or higher.

Hellickson et al. (54) observed that heat and moisture produced from a slotted floor, closed-environment beef building were significantly affected by ambient temperature and relative humidity. Bianca and Blaxter (9) stated that high humidity itself caused discomfort to stock only at temperatures greater than 25 to 30° C. Hastings (51) believed that in winter conditions, relative humidity was more important to calf health than was temperature. Wisniewski (122) indicated that both temperature and humidity in enclosed barns were higher than in open sheds and hutches. Apparently calves are better able to tolerate cold temperature than high humidity. Norman (87) reported that veal producers noticed a rapid drop of weight gain and feed conversion when relative humidity decreased to 40 percent. Other researchers have indicated that the ideal relative humidity is between 60 and 80 percent (11, 17, 69, 87).

Effect of air movement on animal health. Reduction of natural indoor air movement and restriction of the air space allotted to each animal produce new problems because CO₂, CH₄, NH₃, H₂S, and water vapor

accumulate. Efficient ventilation brings oxygen to the calf and carries away CO_2 and NH_3 , which cause distress to stock and may predispose them to respiratory problems. In summer, ventilation is needed to remove heat and moisture produced by calves. Ammonia is said to have an irritating effect on mucous membranes in concentrations higher than 0.005 percent to 0.009 percent (9). Hastings (51) and Appleman and Owen (4) emphasized the need for proper ventilation. Hastings also stressed the need for positive ventilation with only tempered fresh air. Brody (19) recommended $0.0063 \text{ m}^3/\text{minute}/\text{kg}$ of animal for winter ventilation and $0.125 \text{ m}^3/\text{minute}/\text{kg}$ of calf. Smith (105) concluded that the air flow rate in barns for 45-136 kg calves should be $0.40 \text{ m}^3/\text{minute}$ per calf in winter conditions (-7°C), $0.91 \text{ m}^3/\text{minute}$ in mild climates (-7 to 10°C), and $3.40 \text{ m}^3/\text{minute}$ in warm weather (10°C). Ventilation rates recommended by both researchers were for calves raised in enclosed insulated structures, apparently artificially heated.

Relationship between Housing Type and Animal Performance

A successful calf raising program has been associated with a correct choice in the type of housing (15). Over the years, researchers have produced evidence that housing is important in a reduction of mortality and an increase in growth. Several building types are used, with variable results, to raise calves in cold environments. These include two common types: (1) warm, insulated or mechanically ventilated housing, and (2) cold, naturally ventilated housing (outdoor calf hutches or open sheds).

Effect of housing on rate of growth and feed intake. The effect of housing on calf growth and development has been extensively investigated (5, 60, 67, 83). Kurtz (66) reported that calves reared in outdoor hutches had better rates of gain than those housed in a conventional type of housing system. Autrey et al. (6) found that calves reared outdoors made greater weight gains than those reared indoors. McKnight (76) reported that calves in hutches grew slightly but not significantly ($P > 0.05$) faster than barn calves. Starter intake was greater for hutch calves from birth to 28 days ($P < 0.05$), and from birth to 49 days ($P < 0.10$). He suggested that hutches have potential as housing for new calves, regardless of season. Jorgenson et al. (60) found that outdoor hutches supported gains comparable to those of calves maintained in pens in an insulated, heated barn. Hay consumption was not affected by housing system.

Murley et al. (83) studied the effects of management and housing upon growth and health of dairy calves. Their results showed mean body weight gains of 0.88 and 0.85 pounds daily during the first eight weeks for calves in the closed barn and open shed, respectively. In contrast, Albright (2) found that housing type was not an important factor influencing growth of calves. Willet et al. (120) evaluated a conventional concrete calf barn, outdoor portable pens, and pens built in a free-stall barn. The results showed that gains in body weight and hay intake of portable pen calves were not significantly greater than those from calves raised in the barn. No differences in height at the withers ($P > 0.05$), heart girth, or barrel ($P > 0.01$) were found. Roy et al (97) found that

the weights of six-month-old calves reared outdoors reached similar figures to those reared indoors and that their later growth was also satisfactory. However, Preston (93), working under similar conditions, found a less satisfactory response in calves raised outdoors. Significantly greater gains in body weight of calves raised in portable pens, compared with those of calves raised under barn conditions, have been reported (28, 29). Van Horn et al. (110) compared bedded pens in a closed barn, outdoor movable pens, and elevated slatted floor pens with a semiautomated manure flushing system. No differences were found in growth due to housing system or interactions with rations or milk feeding system.

Effect of housing on disease incidence. The effect of house design on animal health has been previously investigated (3, 28, 71). Two major groups of diseases, respiratory and enteric, are frequently shown by researchers and dairy farmers to be the most common problems related to animal housing and health (28, 47, 48, 80). It has also been demonstrated that disease problems are much greater during the rearing stages than in adulthood, and that herd size plays an important role in calf morbidity and mortality (32). Oxender et al. (90) reported average total mortality of 17.7 percent in calves between birth and 60 days of age, with 64 percent of those born dead or dying, and 8.5 percent dying before 14 days. Mortality was higher in herds with over fifty cows. Fewer deaths occurred in stanchion housing than in free stalls, but these results were related to some extent to the size of the herd. In addition, Speicher and Hepp (106) reported that under the same conditions

calf mortality was 13.5 percent. Mortality increased as herd size increased, from 9.7 percent with less than 25 cows to 16.6 percent with 85 or more cows.

Calf hutches have been reported as examples of housing systems which may reduce health problems (29, 48, 50). Some important factors related to disease reduction in calf hutches are ease of cleaning, disinfection, and isolation. Open sheds and outside hutches are easily cleaned manually or with a tractor. Furthermore, hutches can be moved readily from place to place, and a buildup of bedding can be avoided.

Hartman (50) found that disease organisms do not multiply as fast in calf hutches as inside a barn. A six month survey (122) showed that the type of housing profoundly affected calf morbidity and mortality. Calf losses were substantially lower in herds that utilized outside hutches or open sheds rather than totally enclosed buildings. Mortality was intermediate in herds using a combination of enclosed and open housing. McKnight (76) reported that calves in hutches were somewhat healthier than barn calves. Warnick et al. (116) showed that calves in individual hutches tended to be free from diseases and also adjusted well to a group environment after weaning. Autrey et al. (6) indicated that calves reared outdoors were healthier than those reared indoors. Similar results were obtained by Davis (29) in a comparison of outdoor individual portable pens and conventional housing over a nine year period. In a study of portable pens versus other enclosures, Davis et al. (28) found that calves in barns suffered diarrhea more frequently than calves in the portable pens. In both years of the study, every calf in the barn

showed respiratory problems, chronic spasmodic coughing, abnormal respiration, and other symptoms of early pneumonia such as nasal discharges.

In contrast, Willet et al. (120) found no effect on incidence of scours or pneumonia between indoor and outdoor housing systems. Murley et al. (83) found no effect of housing in health on calves. Similar results were reported by Jorgenson et al. (60), who found no differences in the number of scours cases between calves in heated barns and those housed in outdoor hutches. However, Mitchell and Brodbent (80) suggested that the extra capital cost involved in a "controlled environment" type of calf house did not appear to be justifiable in terms of calf health or performance when compared with the performance of calves in a "climatic" house in Scotland.

Effect of housing on labor and other requirements. The extent to which calf housing affects labor requirements is not clear. Jorgenson et al. (60) evaluated labor requirements between indoor and outdoor housing. Their results indicated that outdoor hutches required less labor and bedding, and that the difference was related to the required time to clean and bed the pens. Davis et al. (29) also reported that calves in portable pens required less labor than calves in enclosed conventional housing. However, Muller and Owen (81) found that a disadvantage of hutches was the relatively high labor requirement. Extra labor was related to time for feed and care of calves when they were located away from the barn. These results have been supported by McKnight (76), Hartman (50), and Fehr (35).

The lack of comfort of the person feeding calves is another disadvantage of calf hutches. Warm buildings have been found to be more comfortable for the calfman, especially on stormy days when the feeding of calves outdoors becomes unpleasant.

CHAPTER III

EXPERIMENTAL PROCEDURE

Experimental Animals

Thirty-two Holstein calves from The University of Tennessee, Knoxville, dairy herd, were used in the experiment, conducted from October 1981 to June 1982. Sixteen animals per ration and housing treatment were used in a continuous six month trial. Female calves were randomly assigned to housing and ration treatments, based on birth order within breed. Sufficient replications were utilized to allow the detection of a 10 percent difference in means 80 percent of the time. Three animals were dropped from the experiment, because of sickness not related to ration or housing effect. Therefore, the statistical analysis data was performed with 29 animals.

Ration Treatments

Treatment 1 consisted of a two-stage complete ration. Stage A, consisted of a ration composed of 20 percent cottonseed hulls (CSH), 60 percent corn, 20 percent soybean meal (SBM) plus vitamins (A, D₃). Calves were fed from two weeks old, until they reached a body weight between 270 to 300 pounds. Stage B consisted of a ration composed of 43 percent CSH, 43 percent corn, and 14 percent SBM plus vitamins (A, D₃). Limestone was added to both rations at the rate of 7.5 pounds per 500 pounds of ration mix. Ration B was fed to calves from approximately 300 pounds of body weight until the animals reached 30 weeks of age.

Both complete rations A and B were formulated to contain, respectively, 17.3 percent CP, 18.6 percent ADF and 13.6 percent CP, 32.5 percent ADF, on a dry matter basis. They were mixed 455 kg at a time and stored for one week. Treatment 2 consisted of a complete ration composed of 3 parts of corn silage and 1 part of pelleted dairy concentrate (18 percent CP). This ration was formulated to contain approximately 14 percent CP and 23 percent ADF, and was mixed fresh just prior to feeding. All rations were offered ad libitum.

Housing Treatment

Housing consisted of (1) 1.22 m wide $\times$ 2.44 m long individual pens on a concrete floor bedded with sawdust, in a mechanically ventilated, closed barn; (2) portable outdoor 1.17 m $\times$ 2.42 m calf hutches made of plywood (55); (3) outdoor concrete pens. Hutches were equally spaced (3.89 m separation) and calves were held by a rope 1.78 m long. Calves were randomly assigned to the housing system in birth order. Both outdoor and indoor housing treatments consisted of two stages. Stage I calves were housed in individual barn pens or outdoor hutches from approximately 3 days after birth until they reached 270 to 300 pounds of body weight. Stage II animals were moved to group pens until they were 30 weeks old.

Calf Management

Each calf received ample colostrum during the first few hours postparturition. Milk replacer (1 pound per 9 pounds water), or whole milk from fresh cows or treated cows, were fed to each calf individually

at the rate of 10 percent of body weight for six weeks. The two experimental rations were offered to calves starting the second week of the experiment. Individual feed consumption data were collected starting the third week. Individual and group pens in the calf barn as well as in calf hutches were bedded with sawdust and straw, respectively, as needed.

Data Collection

Body weights were taken at birth and at biweekly intervals thereafter for the remainder of the experiment. Starting at one week of age and biweekly for 30 weeks, length, wither height, and heart girth were determined on each animal. Starting at eight weeks of age and every fourth week thereafter for 30 weeks, a sample of rumen fluid was collected from each animal via a stomach tube, approximately 2 hours after the morning feeding. Rumen fluid was aspirated via an esophageal tube and analyzed immediately for pH by use of a Fisher Model 600 pH meter equipped with an electrode standardized with pH 7.0 phosphate buffer solution. A portion of each sample was then acidified with 25 percent metaphosphoric acid and frozen until an analysis for volatile fatty acids could be performed. Individual feed consumption was recorded daily.

Chemical Analysis

Weekly samples of complete rations were collected and analyzed for dry matter content. The fresh samples were dried in a 60° C oven for 72 hours to obtain air-dry matter content. Samples were composited by

month and analyzed for crude protein, acid detergent fiber, and acid insoluble lignin, calcium, and phosphorus. Total dry matter was determined by placing the samples in a 100° C oven overnight. Composited samples were analyzed for crude protein content by the Kjeldahl method (1). Acid detergent fiber (ADF) and lignin were determined by the method of Van Soest (112). Calcium levels in the feed were determined by atomic absorption-atomic emission spectrophotometry. The method of Fiske and Subbarow (36) was used for the phosphorus determination. Ash was determined by ashing an air-dry sample for 3 hours at 500° C and overnight at 100° C in an ashing oven. Molar percentages of the volatile fatty acids were determined by use of a Bendix gas chromatograph model 2600 with procedures developed by Erwin et al. (34).

Statistical Analysis

The data were analyzed statistically with programs described by Blair et al. (13). Single and multivariate analysis techniques were used to determine if treatments affected growth curves and dry matter intake. Body weight, wither height, body length, heart girth, dry matter intake, crude protein intake, and acid detergent fiber intake were used as dependent variables in a multivariate regression analysis procedure. Similarly, volatile fatty acid data were tested for differences between treatments.

The preliminary analysis of variance was performed using the following model:

$$Y_{ijk} = u + h_i + r_j + w_k + (h + r)_{ij} + e_{ijk1}$$

where: Y_{ijk} = the dependent variable: body weight, body length, withers height, heart girth, dry matter intake, acid detergent fiber intake, or crude protein intake

u = theoretical population mean

h_i = housing, $i = 1, 2$

r_j = ration, $i = 1, 2$

w_k = week, $k = 1-29$

e_{ijk1} = random error

The dependent variables (body weight, length, heart girth, wither height, dry matter intake, crude protein intake, acid detergent fiber intake) were fitted to a nonlinear regression on age using biweekly observed values as a polynomial to describe the response curve for each calf. The following equation was used:

$$Y_1 = a + b_1 (\text{week}) + b_2 (\text{week}^2) + b_3 (\text{week}^3)$$

where: Y_1 = the estimated value of the dependent variable

a = the intercept value for each dependent variable at week 0

week = age of calf in weeks

Multivariate analysis of the regression coefficient, b values, (generated in the previous model for each dependent variable by calf) was performed using the following model:

$$Y_{ij} = u + h_i + r_j + e_{ijk}$$

Y_{ij} = the estimated intercept and the regression coefficient for each dependent variable on the independent variable week

u = theoretical population mean

h_i = housing, $i = 1, 2$

r_j = ration, $j = 1, 2$

e_{ijk} = random error

CHAPTER IV

RESULTS AND DISCUSSION

Chemical Composition of Feed Ingredients

Mean values for the chemical composition of feed ingredients fed to Holstein heifers are presented in Table 1. In ration 1, both A and B have a higher dry matter percentage (90.80 and 90.70 percent) than ration 2 (45.79 percent) where silage was included. The fact that cottonseed hulls (CSH) had 64.7 percent ADF while corn silage had 29.6 percent ADF accounts for the differences in ADF between rations 1 and 2.

Dry Matter Intake

Daily dry matter (DM) consumed at various ages is listed in Table 2. Heifers progressively consumed more dry matter as a function of age. Significant differences ($P < 0.05$) were observed for total dry matter intake between ration 1 (94.4 percent DM) and ration 2 (45.79 percent DM) in the two housing systems. Throughout the study, calves fed ration 1 consumed more dry matter than those fed ration 2. Increased dry matter percentage on ration 1, obviously accounted for the differences in dry matter intake between rations in this study. However, Nease (85) found very little difference within years and among rations containing hay and grain (89.0 percent DM) or corn silage and grain (44.8 percent DM).

A similar relationship between dry matter content of a silage ration and dry matter intake has been reported (37, 38, 109, 115). Thomas et al. (109) observed that alfalfa silage consumption was

TABLE 1

MEAN AND STANDARD DEVIATION OF CONSTITUENTS OF COMPLETE RATIONS
FED TO REPLACEMENT HEIFERS

Constituents	Ration 1 ^a		Ration 2 ^b
	A	B	
Dry matter (%)	90.08±0.82	90.77±0.69	45.79±2.47
Crude protein (%) DMB ^d	17.35±0.88 ^c	13.58±0.62	14.38±0.66
Acid detergent fiber (%) DMB	18.60±1.77	32.47±0.58	21.77±1.13
Acid insoluble lignin (%) DMB	4.70±0.44	9.27±0.45	3.28±0.73
Calcium (%) DMB	0.55±0.23	0.39±0.55	0.71±0.08
Phosphorus (%) DMB	0.39±0.03	0.28±0.01	0.57±0.06

^aRation 1 = (A and B): A = 20% cottonseed hulls, 60% corn, and 20% soybean meal plus minerals fed ad libitum up to 300 pounds body weight. B = 43% cottonseed hulls, 43% corn, and 14% soybean meal fed ad libitum from approximately 300 pounds of body weight.

^bRation 2 = 3 part corn silage: 1 part concentrate (18% CP) fed ad libitum up to 525 pounds of body weight.

^cStandard deviation.

^dDMB = dry matter basis.

TABLE 2
DAILY DRY MATTER INTAKE (POUNDS/DAY)
OF HOLSTEIN HEIFERS*

Ages (Weeks)	Housing Ia		Housing IIb	
	Ration 1 ^c	Ration 2 ^c	Ration 1	Ration 2
5	1.72	1.72	1.33	1.37
10	4.98	4.02	4.61	3.82
15	8.29	5.91	8.16	5.87
20	11.62	7.53	11.64	7.76
25	14.96	8.98	14.72	9.75
29	17.63	9.82	16.68	11.57

^aCalf barn

^bCalf hutches

^cRations 1 and 2 refers to Table 1, page 30, for description of ration composition.

*Values of this table are taken from regression equation developed for heifers by housing and ration. Rations were significantly different ($P < 0.05$). Neither housing nor housing * rations were significantly different ($P > 0.05$).

linearly and positively related to dry matter content of silage; whereas, Forbes and Jackson (38) found that dry matter intake increased curvilinearly with dry matter content of grass silage.

Regression curve plots of the effect of ration on dry matter intake are shown in Figure 1. Voluntary dry matter intake for calves fed ration 1 showed the effect of supplementation of CSH as a fiber source on dry matter intake. Van Horn (111) found an increase in feed intake when CSH were added to a basic corn-soybean meal ration. Migioia (77) reported higher dry matter intake with a complete ration containing CSH than with long alfalfa hay. Similar results have been also reported by Murdock and Wallenius (82) and Greene et al. (43).

No significant effect of housing ($P > 0.05$) on dry matter intake was observed in this experiment. Results from this research for housing effects are in accord with previous studies conducted by Jorgenson et al. (60) and Willet et al. (120).

Acid Detergent Fiber Intake

Daily acid detergent fiber (ADF) intake values taken from regression equation developed for heifers by housing and ration are shown in Table 3. The effect of ration on ADF intake approached significant difference. Average ADF intake (pounds) were 2.37 and 1.28 for ration 1 and 2, respectively. Our results agreed with those of Miller et al. (78). However, a wider range of cottonseed hulls was represented in this study.

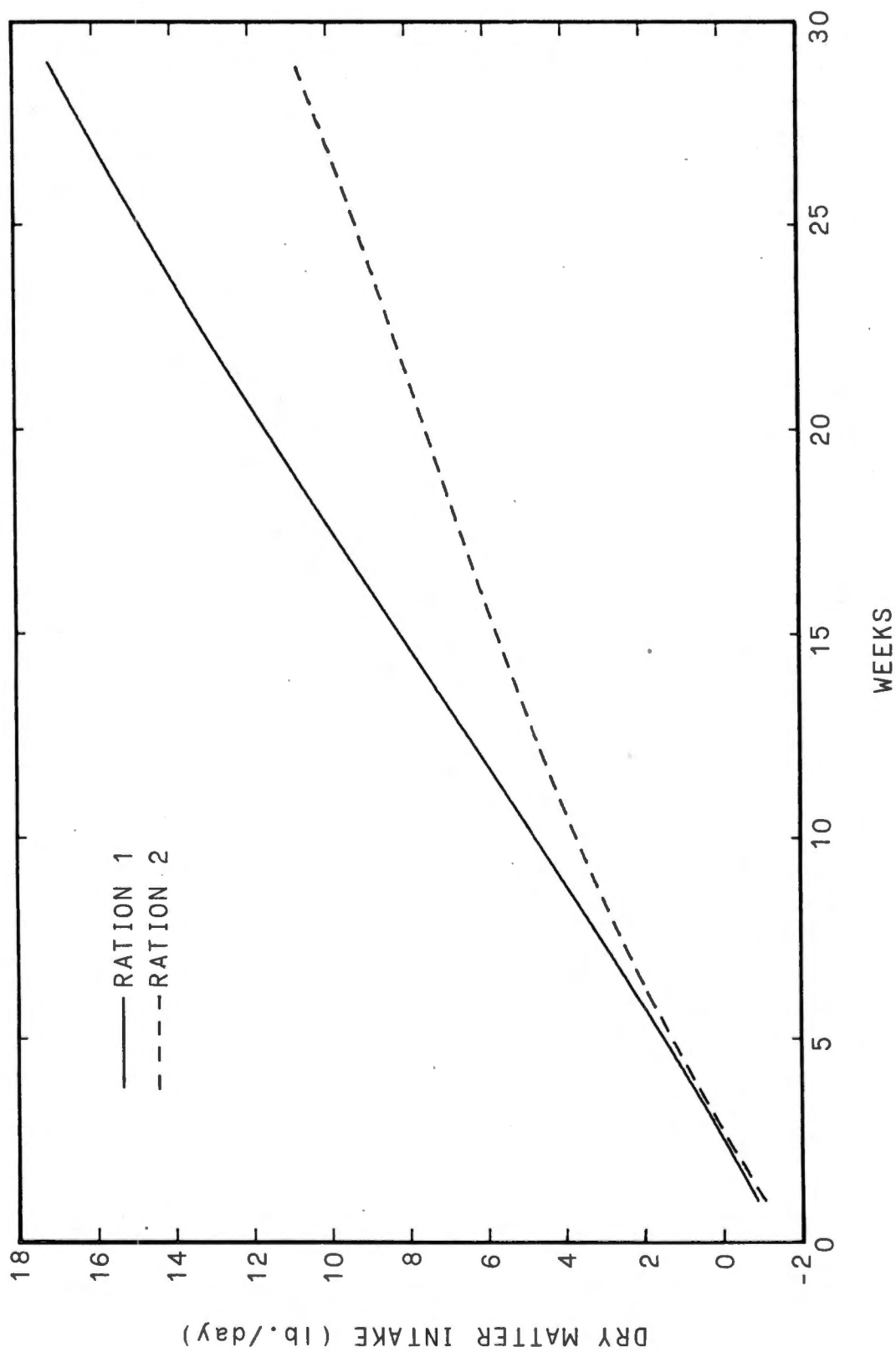


Figure 1. Trinomial Regression Curves of Dry Matter Intake of Holstein Heifers.

TABLE 3
DAILY ACID DETERGENT FIBER INTAKE (POUNDS/DAY)
OF HOLSTEIN HEIFERS*

Age (Weeks)	Housing I ^a		Housing II ^b	
	Ration 1 ^c	Ration 2 ^c	Ration 1	Ration 2
5	0.19	0.23	0.14	0.27
10	0.79	0.76	0.69	0.80
15	1.95	1.25	1.82	1.30
20	3.39	1.66	3.30	1.79
25	4.82	1.98	4.93	2.29
2 29	5.77	2.16	6.20	2.72

^aCalf barn

^bCalf hutches

^cRations 1 and 2 refers to Table 1, page 30, for description of ration composition.

*Values of this table are taken from regression equation developed for heifers by housing and ration. Rations were significantly different ($P < 0.05$). Neither housing nor housing * ration were significantly different ($P > 0.05$).

Crude Protein Intake

Regression curve plots of the effect of ration on crude protein intake are shown in Figure 2. Table 4 lists crude protein intake for ration 1 and 2. All heifers progressively increased crude protein intake with age. Rations 1 and 2 did not differ for crude protein intake due to housing effect. However, a higher significant crude protein intake ($P < 0.01$) was observed in calves fed ration 1 than those fed ration 2. Because rations were not equivalent in crude protein content, the greater crude protein intake by heifers fed ration 1 is related to a greater crude protein content and dry matter intake.

When compared to National Research Council recommendations (86) for crude protein intake of large breed dairy heifers, the daily crude protein intake of heifers fed ration 2 (14.4 percent crude protein) were slightly deficient until 15 weeks of age; whereas, heifers fed ration 1 consumed quantities in excess of crude protein requirements as recommended by National Research Council. Average daily crude protein intake (pounds) for calves consuming ration 1 and 2 were 1.25 and 0.81 respectively.

Volatile Fatty Acids and pH

Rumen pH and volatile fatty acids (VFA) composition of rumen fluid obtained from heifers fed ration 1 and 2 are shown in Table 5. The lowest pH of rumen fluid was for ration 1-A containing 18.6 percent ADF and the highest was for ration 1-B containing 32.4 percent ADF. The results observed in this study were similar to those reported by Migioia (77) and Briggs et al. (18) who found higher pH values in roughage diets than in concentrate diets. Differences between molar

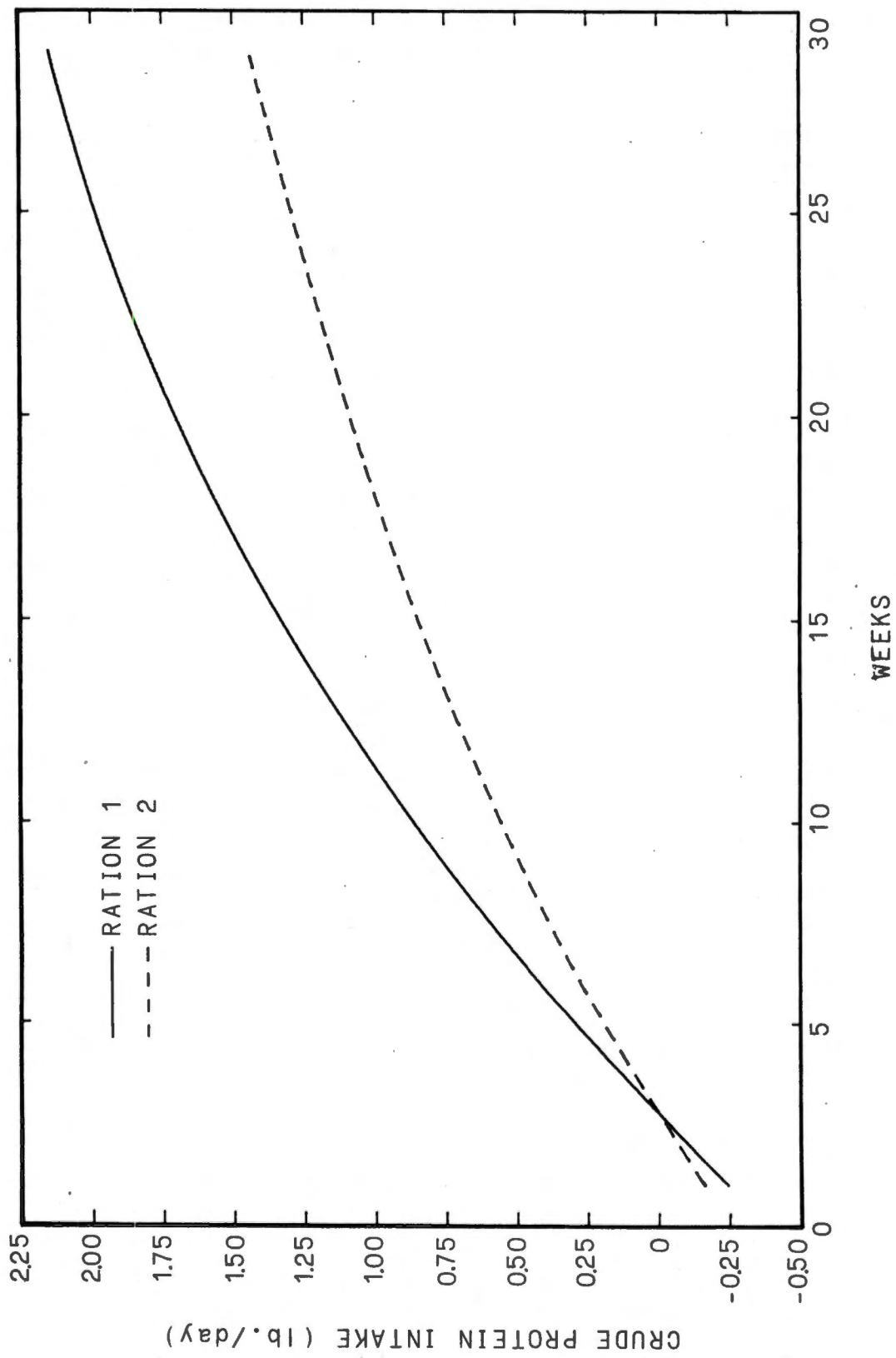


Figure 2. Trinomial Regression Curves for Crude Protein Intake of Holstein Heifers.

TABLE 4
DAILY CRUDE PROTEIN INTAKE (POUNDS/DAY)
OF HOLSTEIN HEIFERS*

Age (Weeks)	Housing Ia		Housing Ib	
	Ration 1 ^c	Ration 2 ^c	Ration 1	Ration 2
5	0.33	0.18	0.26	0.20
10	0.89	0.54	0.84	0.57
15	1.34	0.82	1.33	0.87
20	1.70	1.04	1.71	1.13
25	2.02	1.20	1.96	1.36
29	2.28	1.30	2.04	1.55

^aCalf barn

^bCalf hutches

^cRations 1 and 2 refers to Table 1, page 30, for description of ration composition.

*Values of this table are taken from regression equation developed for heifers by housing and ration. Rations were significantly different ($P < 0.05$). Neither housing nor housing * ration were significantly different ($P > 0.05$).

TABLE 5

RUMEN pH AND RUMEN VOLATILE FATTY ACIDS COMPOSITION OF HOLSTEIN HEIFERS

Variable $\bar{X}$	Housing Ia		Housing Iib	
	Ration 1c		Ration 1	
	A	B	A	B
pH	6.20±0.47	6.56±0.20	6.36±0.23	6.69±0.22
Acetate (molar %)	49.99±7.51	67.16±5.47	52.67±5.62	66.86±3.76
Propionate (molar %)	31.15±8.39	20.91±5.02	32.96±4.80	19.40±2.83
Butyrate (molar %)	12.80±9.72	7.98±0.94	9.69±2.13	8.68±2.63
Isobutyrate (molar %)	1.23±1.20	0.69±0.21	0.70±0.22	1.56±2.40
Valerate (molar %)	3.74±2.35	1.66±0.58	2.97±1.31	1.80±1.39
Isovalerate (molar %)	1.06±0.91	1.62±0.43	0.98±0.49	1.64±1.36
Acetate:propionate ratio	1.71±0.51	3.50±1.36	1.65±0.40	3.52±0.62

^aHousing = calf barn.^bHousing = calf hutches.^cRefer to Table 1, page 30, for description of ration composition.^dStandard deviation.

percentages of VFA within rations are characteristic of animal fed rations low (1-A) and high (1-B) dietary fiber levels.

Molar percentages values for ration 1-A (18.6 percent ADF) fed to heifers for the first 18 weeks of the experiment, were 50 and 31 for acetate and propionate respectively. Molar percentages values for ration 1-B (32 percent ADF) fed to heifers from 18 weeks until 30 weeks of age, were 67 and 21 for acetate and propionate, respectively. Molar percentage values for ration 2 (21.7 percent ADF) were 66 and 19 for acetate and propionate respectively. When both rations 1-A and 1-B were compared as ration 1 to ration 2, higher significant values ($P < 0.01$) were found for VFA propionate in ration 1. Migioia (77) found significant differences between acetate and propionate in calves fed cottonseed hulls and alfalfa hay from three to 21 weeks of age. In contrast, Murdock and Wallenius (82) reported no differences in VFA values between rations with equal percentages of either cottonseed hulls, alfalfa hay or alfalfa-beet pulp.

Body Weight Gains

Body weight gains of heifers increased with age, independently of treatment effect. Each animal has an inherent mature body size toward which it grows at a genetically controlled rate (108).

Body weight gain values taken from equations developed for heifers by housing and ration are shown in Table 6. For the period of 1 to 18 weeks, calves were reared in either individual outdoor calf hutches or individual pens in a mechanically ventilated barn. Body weight gains

TABLE 6
BODY WEIGHT OF HOLSTEIN HEIFERS*

Age (Weeks)	Housing Ia		Housing IIb	
	Ration 1 ^c	Ration 2 ^c	Ration 1	Ration 2
5	106.57	97.99	108.46	109.77
10	167.29	141.64	164.64	152.83
15	249.28	195.98	232.99	204.88
20	340.64	260.01	312.74	267.50
25	429.47	332.72	403.12	342.26
29	490.72	396.48	482.56	411.85

^aCalf barn

^bCalf hutches

^cRations 1 and 2 refers to Table 1, page 30, for description of ration composition.

*Values of this table are taken from regression equation developed for heifers by housing and ration. Rations were significantly different ($P < 0.05$). From one to 18 weeks of the experiment, neither housing nor housing * ration were significantly different ($P > 0.05$).

for this period of time were not significantly different ($P > 0.05$) between housing systems. This agrees with the results reported in similar studies (76, 97, 120).

Jorgenson et al. (60) reported no significant differences in average daily gain between calf hutches and individual pens in an insulated heated barn for the initial 14 weeks. Van Horn (110) found no differences in growth rates when comparing bedded pens in a closed barn, outdoor movable pens, and elevated slatted floor pens. However, this was not found to be the case in studies conducted by Kurtz (66), Autrey (6), Davis et al. (29). They reported higher body weight gains in animals housed in outdoor pens.

For the period of 19 to 29 weeks, heifers in both housing systems were moved to group pens. At this point the effect of housing on body weight approached significant difference ($P < 0.05$). Greater body weights were observed in heifers reared indoors. Murley et al. (83) reported slightly higher body weights on animals reared in a closed barn than in those reared outdoors. Similar results were also found by Preston (93).

Difference in body weight gain between animals fed rations 1 and 2 was significant ($P < 0.05$) and of a greater magnitude than difference in housing. Superiority of heifers fed ration 1 is exhibited in Table 6. Growth of heifers fed ration 1 exceeded NRC growth standards (86). However, heifers fed ration 2 exhibited lower growth rates than the recommended growth curves by NRC (86).

Plots of body weight regression curves are illustrated in Figure 3. As was already mentioned, beneficial effects of the supplemental fiber

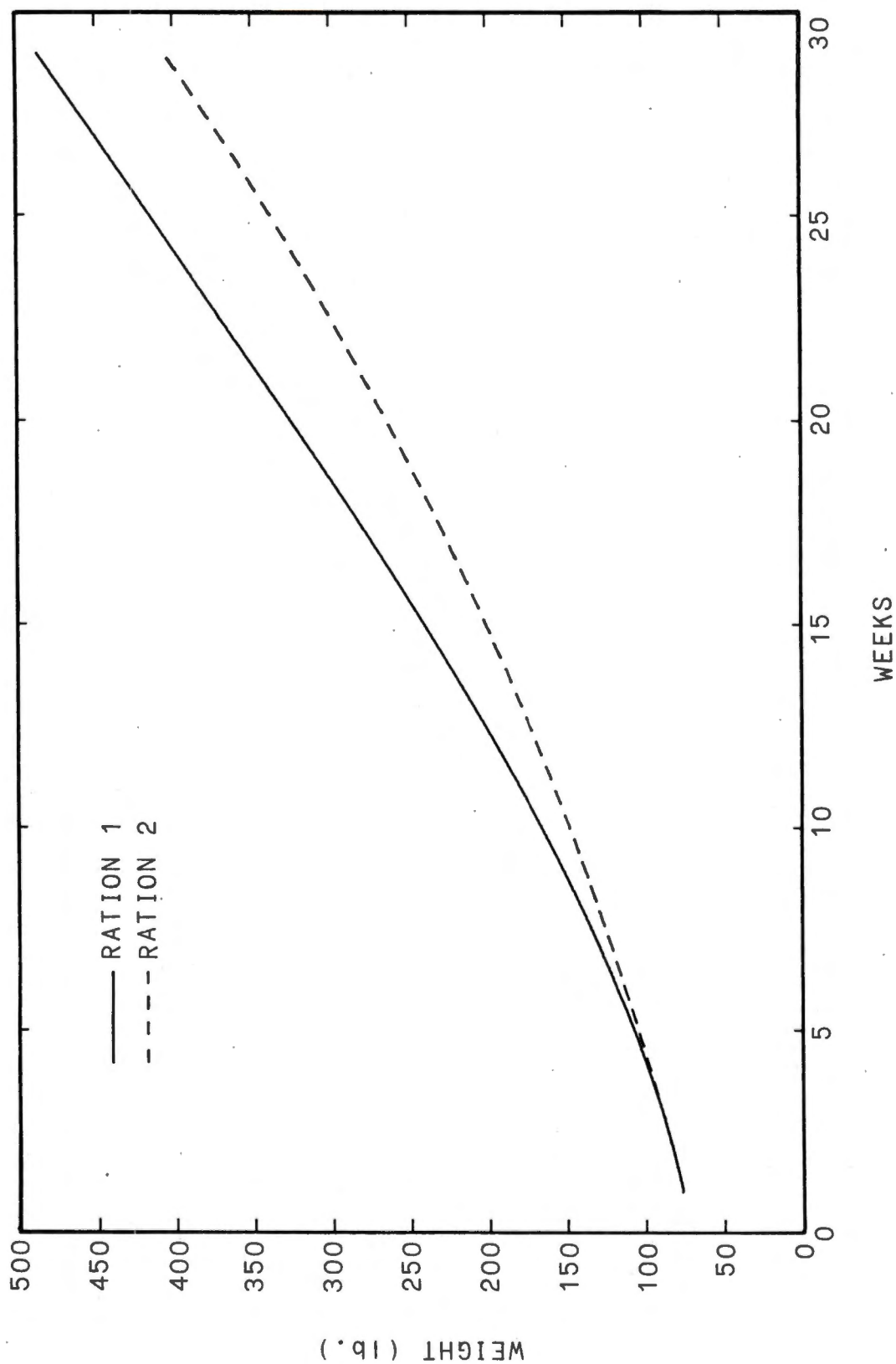


Figure 3. Trinomial Regression Curves for Body Weight of Holstein Heifers.

on increased gains of the heifers fed ration 1 are attributed to the increased dry matter intake. Satisfactory body weight gains for animals fed cottonseed hull rations have been reported by Van Horn et al. (111), Lee et al. (68), and Murdock and Wallenius (82). Van Horn (111) reported that complete rations with 40 or 55 percent cottonseed hulls gave excellent and equal gains from 80 to 180 days of age at either 10 or 12.5 percent protein (air-dry-ration) and with or without 0.89 percent urea. Feeding similar cottonseed hull rations and under similar environmental conditions, Migioia (77) reported greater body weight in heifers fed cottonseed hulls than those fed long alfalfa hay and grain. Body weight for calves fed identical rations were similar to those observed in this study.

Nease (85) reported no differences in body weight among heifers fed isonitrogenous rations containing a 1:1 ratio of hay to grain, 2:1 ratio of corn silage to grain plus soybean meal, and 4:1 ratio of corn silage to grain plus soybean meal.

Observed body weights of Holstein heifers fed a mixed 3:1 corn silage:grain ration, were slightly higher in this study than those found by Nease (85) in which heifers were fed 4:1 corn silage:grain ration.

Average body weight gain reported by Jones (59) in calves fed a 3:1 corn silage:grain complete ration, were similar to those observed throughout our research in calves fed a similar ration.

In the present study, the observed values for accumulative average daily gain were significantly higher ($P < 0.05$) for heifers fed ration 1 (1.99 pounds/day) than those fed ration 2 (1.63 pounds/day). No

significant interactions were found between method of housing and ration effect in body weight gain.

Body Measurements

Body measurement data, recorded from regression equations developed for heifers by housing and ration are listed in Tables 7, 8, and 9. Mean values for heart girth due to housing effect were 42.2 and 42.1 inches for calves housed outdoors and indoors, respectively.

Multivariate analysis of treatment effects on regression coefficients of height at withers, length, and heart girth indicated no differences ($P > 0.05$) between method of housing. These results agreed with those reported by Willet et al. (120) and Erb et al. (33). No significant differences were found for body measurement data when Holstein calves housed in outdoor calf hutches were compared with calves housed in an indoor calf barn. However, Davis et al. (29) reported significantly greater values in height at the withers, heart girth and barrel girth, for calves reared in outdoor portable pens when compared with calves assigned to the barn.

Throughout the current study, calves consuming ration 1, showed significantly higher body measurement values than those consuming ration 2. Average heart girth for ration 1 and 2 were 43.1 and 41.1 inches respectively. In research conducted by Jones (59) values for height at the withers in heifers fed a corn silage complete ration, were similar to those fed a similar ration in this study.

TABLE 7
WITHER HEIGHT OF HOLSTEIN HEIFERS*

Age (Weeks)	Housing Ia		Housing IIb	
	Ration 1 ^c	Ration 2 ^c	Ration 1	Ration 2
5	31.44**	29.99	31.28	30.65
10	33.29	31.76	33.38	32.54
15	35.89	34.01	35.83	34.84
20	38.71	36.57	38.59	37.37
25	41.21	39.32	41.64	39.94
29	42.60	41.54	44.26	41.90

^aCalf barn

^bCalf hutches

^cRations 1 and 2 refers to Table 1, page 30, for description of ration composition.

*Values of this table are taken from regression equation developed for heifers by housing and ration. Rations were significantly different ($P < 0.05$). Neither housing nor housing * ration were significantly different ($P > 0.05$).

**Inches

TABLE 8
LENGTH OF HOLSTEIN HEIFERS*

Age (Weeks)	Housing Ia		Housing IIb	
	Ration 1 ^c	Ration 2 ^c	Ration 1	Ration 2
5	24.89**	23.80	25.21	24.79
10	27.93	26.25	28.32	27.46
15	31.53	29.34	31.55	30.60
20	35.29	32.67	34.88	33.88
25	38.80	35.85	38.30	37.02
29	41.14	38.02	41.04	39.22

^aCalf barn

^bCalf hutches

^cRations 1 and 2 refers to Table 1, page 30, for description of ration composition.

*Values of this table are taken from regression equation developed for heifers by housing and ration. Rations were significantly different ($P < 0.05$). Neither housing nor housing * ration were significantly different ($P > 0.05$).

**Inches

TABLE 9
HEART GIRTH OF HOLSTEIN HEIFERS*

Age (Weeks)	Housing Ia		Housing II ^b	
	Ration 1 ^c	Ration 2 ^c	Ration 1	Ration 2
5	34.25**	33.24	34.21	34.23
10	38.89	36.77	38.70	37.82
15	43.41	40.37	42.80	41.28
20	47.54	43.94	46.75	44.64
25	51.05	47.39	50.79	47.93
29	53.23	49.99	54.25	50.54

^aCalf barn

^bCalf hutches

^cRations 1 and 2 refers to Table 1, page 30, for description of ration composition.

*Values of this table are taken from regression equation developed for heifers by housing and ration. Rations were significantly different ($P < 0.05$). Neither housing nor housing * ration were significantly different ($P > 0.05$).

**Inches

Health of Calves

Although calf hutches have been reported as a method of housing used to reduce health problems (28, 32, 48, 50, 76, 122), it was not the case in this study. The general health of the calves was not greatly different between both housing systems. Only one case of pneumonia was observed in a calf housed indoors. Housing treatment had no effect on incidence of scours. Willet et al. (120) and Murley and Calvahouse (83) indicated no housing effect in health of calves. Jorgenson et al. (60) reported no difference in the number of scours between indoor and outdoor housing.

As indicated by Hartman (50) the person feeding and taking care of calves, plays an important role in a successful program of raising healthy calves.

Bedding Requirements

Both indoor calf barn stalls and outside calf hutches were bedded as needed to keep them dry. Calves housed in calf barns required more bedding than calves housed in calf hutches. Jorgenson et al. (60) reported significantly more bedding requirements in calves housed indoors than those housed outdoors.

Labor Requirements

Due to the lack of detailed records, no statistical analysis of labor requirements can be conducted in this study. However, an increase in labor requirement was observed for heifers housed outdoors. This difference was due to the distance from the main barn to the hutches. As reported by McKnight (76), it is doubtful that hutches would require

less labor than calves in conventional housing, when one considers the extra distance traveled and additional trips for milk, water, and medication. However, pens in calf barns required more bedding labor than calf hutches.

Operator comfort is another factor to be considered. Extreme weather during the winter season was less agreeable to operators when they were feeding outdoor heifers. Frozen water during the winter time was an extra problem for those calves housed in calf hutches. This factor increased labor requirements and interfered with water intake.

CHAPTER V

SUMMARY AND CONCLUSIONS

The effect of two housing systems and two complete rations on animal performance were evaluated in a 30-week continuous trial.

Thirty-two Holstein calves were housed in either a conventional type of calf barn or outdoor calf hutches during the first 18 weeks of age. No significant effect of housing ($P > 0.05$) on body weight gain or dry matter intake was observed. However, when heifers were moved to group pens, differences in body weight gains were significant ($P < 0.05$). Calves in calf barn had higher body weight gains than calves in hutches.

No differences ($P > 0.05$) between the housing methods were found for body measurement data.

To determine the effect of a corn silage complete ration and cottonseed hull complete ration on growing dairy calves, Holstein calves were individually fed one of the following rations. Ration 1 consisted of two stages: stage A contained 20 percent cottonseed hulls, 60 percent corn, and 20 percent soybean meal, fed ad libitum up to approximately 300 pounds of body weight; and stage B contained 43 percent cottonseed hulls, 43 percent corn, and 14 percent soybean meal, fed ad libitum from approximately 300 pounds to 30 weeks of age. Ration 2 consisted of a 3:1 ratio of corn silage, plus an 18 percent crude protein grain concentrate, fed ad libitum throughout the study.

Calves fed the cottonseed hulls complete ration had significantly higher ($P < 0.05$) average daily gain than those fed corn silage complete

ration. Average daily gains were 1.99 and 1.63 (pounds/day) for calves fed ration 1 and 2, respectively.

Dry matter consumption was significantly ($P < 0.05$) less in calves fed ration 2 than those fed ration 1. Average dry matter intake was 8.52 and 5.65 (pounds/day) for ration 1 and ration 2 respectively.

Calves fed cottonseed hull complete ration consumed more acid detergent fiber than those fed corn silage complete rations. Average acid detergent fiber was 2.37 and 1.27 (pounds/day) for ration 1 and 2 respectively.

Significantly higher crude protein intake was observed in calves fed ration 1 than in those fed ration 2.

Molar percentages of volatile fatty acid propionate were significantly ($P < 0.05$) higher in ration 1.

Differences in growth parameters due to ration effect were significant.

Heifers fed ration containing cottonseed hulls had better body weight gains than those fed corn silage complete ration.

The housing system did not affect the incidence of scours or pneumonia.

This study suggests that Holstein heifers can be raised successfully in outdoor calf hutches. Further, cottonseed hulls can be used as a fiber source in complete rations fed to heifers growing at a desirable rate of gain.

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APPENDIX

CALF HUTCH DEALERS

Fiberdone, Inc.	P. O. Box 11, Lake Mills, Wisconsin 53551 Phone (414) 648-8376
Bluegrass Farm Distributors, Inc.	Ky. 52 at B. G. Parkway, R. R. #1 Boston, Ky. 40107 Phone (502) 833-4881
Highe Products	P. O. Box 514 Winchester, Tn. 37398 Phone (615) 967-7473
Mekco Means Innovation	1057 West Washington Ave. P. O. Box 126 Cleveland, Wisconsin 53015 Phone (414) 693-8163
Dunn Dairy Equipment Co., Inc.	Route #1, Beeler Road Corryton, Tn. 37721
Fox Agri-Sales and Manufacturing	P. O. Box 189 Goodhue, Minn. 55027 Phone (612) 923-4277
Dairy Farm Leasing Co.	1700 Dupont Avenue South Minneapolis, Minn. 55403

TABLE 10

INTERCEPT AND REGRESSION COEFFICIENTS FOR HOLSTEIN DRY MATTER, CRUDE PROTEIN AND ACID DETERGENT FIBER INTAKE CURVES

Continuous Variable	Discrete Variable	Intercept	B ₁ ^a	B ₂ ^b	B ₃ ^c
Dry matter intake (pounds/day)	Housing = 1 ^d	-1.59111909	0.63854264	-0.00512074	0.00005759
	Housing = 2	-1.53911611	0.57785653	0.00035321	-0.00005693
Crude protein intake (pounds/day)	Housing = 1	-0.33330568	0.13331127	-0.00305485	0.00003543
	Housing = 2	-0.32036201	0.11765526	-0.00149030	-0.00000170
Acid detergent fiber intake (pounds/day)	Housing = 1	0.08944191	-0.03051707	0.01210715	-0.00021662
	Housing = 2	0.02861643	-0.00749611	0.00917839	-0.00012578

*The B_i were not different when tested with Univariate Techniques and there was no housing effect in the Multivariate Analysis.

^aB₁ = linear regression coefficient for week

^bB₂ = quadratic regression coefficient for week.

^cB₃ = cubic regression coefficient for week.

^dHousing = 1: calf barn; Housing = 2: calf hutches.

TABLE 11
INTERCEPT AND REGRESSION COEFFICIENTS FOR DRY MATTER, CRUDE
PROTEIN AND ACID DETERGENT FIBER INTAKE CURVES

Continuous Variable	Discrete Variable	Intercept	B_1^a	B_2^b	B_3^c
Dry matter intake (pounds/day)	Ration = 1d	-1.41081239	0.53658268	0.01078165	-0.00024995
	Ration = 2	-1.72487286	0.67842990	-0.01590306	0.00025621
Crude protein intake (pounds/day)	Ration = 1	-0.38812331	0.14738256	-0.00226942	0.00000717
	Ration = 2	-0.25977973	0.10034230	-0.00210833	0.00002328
Acid detergent fiber intake (pounds/day)	Ration = 1	0.40287721	-0.14474345	0.02109729	-0.00032584
	Ration = 2	-0.31589646	0.11817801	-0.00087230	0.00000422

*The B_i were not different when tested with Univariate Techniques; however, there was a significant ration effect for using Multivariate Technique.

aB_1 = linear regression coefficient for week.

bB_2 = quadratic regression coefficient for week.

cB_3 = cubic regression coefficient for week.

d = Refer to Table 1, page 30, for ration composition.

TABLE 12
INTERCEPT AND REGRESSION COEFFICIENTS FOR
HOLSTEIN GROWTH CURVES

Continuous Variable	Discrete Variable	Intercept	B ₁ ^a	B ₂ ^b	B ₃ ^c
Weight (pounds)	Housing = 1 ^d	73.02331538	3.13541108	0.60236056	-0.00915611
	Housing = 2	69.65647500	6.90087566	0.19533982	0.00053905
Height (inches)	Housing = 1	29.94347692	0.04276366	0.02693009	-0.00048061
	Housing = 2	29.45377500	0.24670199	0.01184745	-0.00014305
Length (inches)	Housing = 1	22.63576154	0.22313088	0.02828575	-0.00054094
	Housing = 2	22.56009375	0.43216618	0.01225349	-0.00021515
Heart (inches)	Housing = 1	29.79523077	0.77261112	0.00632674	-0.00023708
	Housing = 2	29.79483750	0.93410503	-0.01056056	0.00018024

*The B_i were no different when tested with Univariate Techniques and there was no housing effect in the Multivariate Analysis for body measurements; however, there was for body weight.

^aB₁ = linear regression coefficient for week.

^bB₂ = quadratic regression coefficient for week.

^cB₃ = cubic regression coefficient for week.

^dHousing = 1: calf barn; Housing = 2: calf hutches.

TABLE 13

INTERCEPT AND REGRESSION COEFFICIENT FOR HOLSTEIN GROWTH CURVES

Continuous Variable	Discrete Variable	Intercept	B ₁ ^a	B ₂ ^b	B ₃ ^c
Weight (pounds)	Ration = 1 ^d	71.64270667	4.55266864	0.56660078	-0.00794665
	Ration = 2	70.65472143	5.92030893	0.17550805	0.00062823
Height (inches)	Ration = 1	30.17481333	0.13708328	0.02150890	-0.00035884
	Ration = 2	29.13595714	0.17477930	0.01550119	-0.00022529
Length (inches)	Ration = 1	22.52754667	0.43986831	0.01481585	-0.00027205
	Ration = 2	22.66522857	0.22980969	0.02439520	-0.00045671
Heart (inches)	Ration = 1	29.39750000	0.99525974	-0.00573412	0.00001397
	Ration = 2	30.22092143	0.71862349	-0.00005068	-0.00002913

*The B_i were not different when tested with Univariate Techniques; however, there was a significant ration effect for using Multivariate Technique.

^aB₁ = linear regression coefficient for week.

^bB₂ = quadratic regression coefficient for week.

^cB₃ = cubic regression coefficient for week.

^dRefer to Table 1, page 30, for ration composition.

VITA

Pedro Chaverri was born in Heredia, Costa Rica, on September 17, 1949. He graduated from Liceo de Heredia in 1966. He enrolled at University of Costa Rica, where he received an Agronomic Engineer degree in 1973. He taught Animal Science in the Escuela Tecnica Agricola for three years. He was the head of the Agronomic Department of the Instituto Tecnologico de Costa Rica from 1977 to 1979. He entered graduate school at The University of Tennessee, Knoxville, to study Dairy Nutrition. He received the Master of Science degree in December 1982.

He is married to Teresa Arroyo of Costa Rica and is father of Florita and Karla Chaverri.