Current concepts in feeding dairy replacements.

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Introduction

The cost of raising Holstein heifers to first calving at 24 months is about $1200 (Heinrichs, 1993). One way to decrease these costs is to breed heifers so they calve earlier; in fact, some suggestions for age at first calving are as early as 20 months. However, decreased heifer costs will only increase lifetime profits if profitability after calving is not compromised. Level of milk production is a major determinant of profitability of lactating cows (VandeHaar, 1998). Thus, breeding heifers for earlier calving must not significantly compromise subsequent milk production.

Level of milk production of a cow is determined by the 1) the ability of the mammary gland to produce milk, 2) the ability of the cow to provide the mammary gland with nutrients, and 3) the ability of the farmer to manage and care for the cow. The ability of the mammary gland to produce milk is largely dependent on its content of milk-secreting cells, which are found in the mammary "parenchymal" tissue (Tucker, 1987). The number of milk-secreting cells is determined by genetics and by the environment during mammary development, especially during the rapid mammary growth that occurs before and during the time of puberty, between 3 and 10 months of age (Sinha and Tucker, 1969). A good heifer rearing program is critical to produce animals at first calving that have well-developed mammary glands capable of producing to the animal's genetic potential and that have good body size and body condition capable of high feed intake and delivery of nutrients to the mammary gland. However, calving heifers as early as 20 months requires a body growth rate faster than 2 lb/day or body size at calving below 1250 lb. Both rapid gains and small size at calving can decrease subsequent milk production. Thus, the decreased heifer-rearing costs associated with early calving must be weighed against the potential losses in milk income during the life of the cow. The goals of this paper are to review the effects of nutrition on heifer growth and future milk production and to make recommendations for feeding heifers from weaning to calving for maximum lifetime profitability.

Desired body weight and body condition score at calving

Average milk production of a dairy herd is positively correlated to weight and height of heifers at 24 months and negatively correlated with age at first calving (Heinrichs and Hargrove, 1987). In high-yielding Holstein herds (>22,000 lb milk year), heifers typically conceive at 16 months of age weighing 910 lb and calve at 25 months weighing at least 1360 lb before calving, which results in at least 1210 lb after calving (Hoffman and Funk, 1992). Calving at even heavier weights may be beneficial, since the optimal postpartum body weight for Holsteins after first calving is 1200 to 1300 lb (Keown and Everett, 1986; Van Amburgh and Galton, 1994). In the study of Van Amburgh and Galton, heifers weighing 1270 lb after first calving produced 1000 lb more milk in the first lactation than those weighing 1160 lb. However, in the same study, the researchers found that postcalving weights above 1300 lb for Holstein heifers actually

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decreased milk production. This may partly be due to heavy heifers having excess body fat. Animals with excess body fat before calving tend to eat less and mobilize more body fat before calving, which is associated with a greater incidence of dystocia, ketosis, and mastitis in the first month after calving (Dyk et al., 1995). Thus, optimal body weight after calving is 1250 to 1300 lb for Holsteins (about 90% of mature body weight for other breeds) and optimal body condition score is 3.0 to 3.5.

Effect of nutrition on growth, mammary development, and milk yield

To achieve body weight of 1250 to 1300 lb after calving (1400 to 1450 lb before calving) at 24 months, Holstein heifers must gain an average of 1.8 lb/day. Because daily gain may be slower before 3 months and in late pregnancy, gains in the middle of the growth phase must approach 2.0 lb/day. If calving at 20 months is desired, then gains at peak growth must approach 2.4 lb/day. High energy diets and rapid gains after breeding have little effect on mammary development or subsequent milk production (Grummer et al., 1995; Hoffman et al., 1996; Sejrsen et al., 1982; Valentine et al., 1987), unless they result in less than optimal body size at first calving. Thus, this review will focus on the period of growth before puberty.

The period between 3 and 10 months of age for a heifer is a critical time in mammary development. During this time, mammary growth is rapid and occurs at a faster rate than that of most other body tissues. The mammary parenchymal cells branch out into the mammary fat pad and form the ducts and terminal end-buds which are the foundation for later mammary development during lactogenesis. The number of parenchymal cells present at puberty partly dictates the number of milk-secreting cells that will be present during lactation. The best method to assess the number of mammary cells is by measuring the amount of DNA in the parenchymal tissue.

Several studies have examined the effects of high energy diets and rapid gains before puberty on mammary development. The studies in Table 1 are representative of those found in the literature and show the wide variation in mammary responses to diets which promote rapid body gains. Some of the variation might be explained by differences in the laboratory techniques used to quantify mammary development. For example, Harrison and coworkers (1983) measured parenchymal weight rather than parenchymal DNA. These different responses might also be the result of differences in the actual rates of "rapid" gains, in the genetic makeup of the animals, in the ages of the heifers during treatment, and in the dietary methods employed for achieving rapid gains. For example, Capuco and coworkers (1995) observed a 48% impairment in mammary development when rapid gains were achieved from high intake of a corn silage-based diet but no impairment from high intake of an alfalfa-based diet. Serjsen and colleagues (1982) found a 32% decrease in parenchymal DNA with heifers growing even more rapidly than Capuco's. More recently, we conducted a study using the same laboratory techniques as Sejrsen et al., but using diets much higher in total protein and in rumen-undegraded protein (Radcliff et al., 1997). Diets were fed from 4 months of age to 2.3 months after puberty, when the heifers were killed. Compared to control heifers, heifers fed a high energy, high protein diet gained 2.7 lb/day, had more carcass

Table 1. Effect of prepubertal daily gain on mammary parenchymal development.

Cattle breed and treatment period / Treatments	Gain, lb./day	Parenchyma per 100 lb body wt.	Percentage response
Holsteins treated from 7 mo. to 700 lb.		DNA	
Alfalfa/grain diet at restricted intake	1.4	223 mg	
Alfalfa/grain diet at ad libitum intake	2.8	151 mg *	-32%
Sejrsen et al., 1982			
Holsteins treated from 7 mo. to 730 lb.		DNA	
Alfalfa/grain diet at low level	1.7	260 mg	
Alfalfa/grain diet at high level	2.1	245 mg	-6%
Corn silage/soy diet at low level	1.7	277 mg	
Corn silage/soy diet at high level	2.2	145 mg *	-48%
Capuco et al., 1995			
Holsteins from 4 mo. old to 2 mo. postpuberty		DNA	
90% haylage/10% grain ad lib	1.7	195 mg	
25% haylage/75% grain ad lib	2.7	200 mg	+3%
Radcliff et al., 1997			
British Friesians treated from 3 mo. to 11 mo.		Weight	
Alfalfa/barley diet	1.3	105 g	
Mostly grain diet	2.6	40 g *	-62%
Harrison et al., 1983			

* Difference is statistically significant at P<0.1 level.

and mammary fat, and reached puberty and were killed 1.6 months earlier, but, surprisingly, they did not exhibit impaired mammary development (Table 2).

Table 2. Heifers fed a high energy, high protein diet had normal mammogenesis.

	Control	Rapid gain	
Daily gain, lb/day	**1.7**	**2.7**	*
Age at puberty, mo.	**10.3**	**8.7**	*
Body weight at slaughter, kg	740	870	
Body condition score	2.9	3.9	*
Carcass fat, lb	62	123	*
Carcass protein, lb	65	80	*
Mammary total fat, g	580	1,130	*
Mammary lean parenchyma, g	213	232	
Mammary parenchymal DNA, mg	**1,470**	**1,820**	
Mammary parenchymal DNA, mg/ lb carcass protein	**22**	**23**	

Other studies have examined effects of prepubertal nutrition on milk production in the first lactation; Table 3 shows three such studies. Decreases in milk production occurred in all three of these studies when heifers gained weight more rapidly than 2.0

Table 3. Effect of prepubertal daily gain on milk production.

Cattle breed and treatment period / Treatments	Gain, lb /day[1]	Month of calving	Weight after calving	4%-Fat-corrected milk	Percentage response
Holsteins, 200 lb to 2 mo. pregnant				lb/305 day	
Alfalfa/grain diet	1.8	27	1180	10,800	
High grain diet	2.4	20	1110	8,820 *	-18%
Gardner et al., 1977					
British Friesians, 3 to 11 mo. old				lb/305 days	
Control diet and late calving	1.3	28	1070	8,560	
High grain and late calving	2.2	28	1000 *	5,340 *	-38%
High grain and early calving	2.4	19	950 *	4,100 *	-52%
Little and Kay, 1979					
Holsteins, 2 mo. to 740 lb.				lb/305 days	
Controlled intake level 1	1.5	24	1190	20,020	
Controlled intake level 2	2.1	21	1140	18,950 *	-5%
Van Amburgh and Galton, 1994					

* Difference was reported or estimated to be statistically significant at P<0.1 level.
[1] Average daily gain of heifers during the treatment period

lb/day before puberty, but the magnitude of the response varied from 5 to 50%. Furthermore, decreased milk yields are not clearly related to impaired mammary development before puberty. For example, in the study of Little and Kay (1979), high gain heifers grew more slowly after puberty and thus calved at lighter body weight; therefore they devoted more energy to growth during their first lactation than control heifers. In later lactations, however, body weight was similar between groups, and rapidly-grown cows still produced 30% less milk and had 40% less mammary secretory tissue than control animals. In contrast, some heifers were continued onto first lactation in the study of Capuco and coworkers (see Table 1), and the decreased mammary parenchyma DNA of rapidly-grown heifers fed corn silage was not associated with decreased subsequent milk production.

Thus, although the relationship between mammary development before puberty and subsequent milk production apparently can be overridden, our current understanding of mammary development is that heifers that are grown more rapidly than 2.0 lb/day are at great risk for decreased milk yield in first lactation. The fact that decreased mammary development and subsequent milk yield are not always observed indicates that specific feeding and management practices might reduce this risk.

Does dietary protein make a difference?

One factor that may explain some of the variation in effects of prepubertal diet on mammary development in heifers is the ratio of protein to energy in the diet. Although we commonly evaluate diets based on protein per unit dry matter, animals actually need a specific percentage of dietary calories to come from protein. So if the energy concentration of a diet is increased, the protein concentration also should be increased. According to the 1978 Dairy NRC, prepubertal heifers should be fed diets with 54 g of crude protein (CP) per Mcal of metabolizable energy (ME). The 1989 NRC increased the recommended CP:ME ratio to 60 g/Mcal for heifers from 3 to 6 months of age and dropped the ratio to 50 g/Mcal for heifers from 6 to 12 months of age.

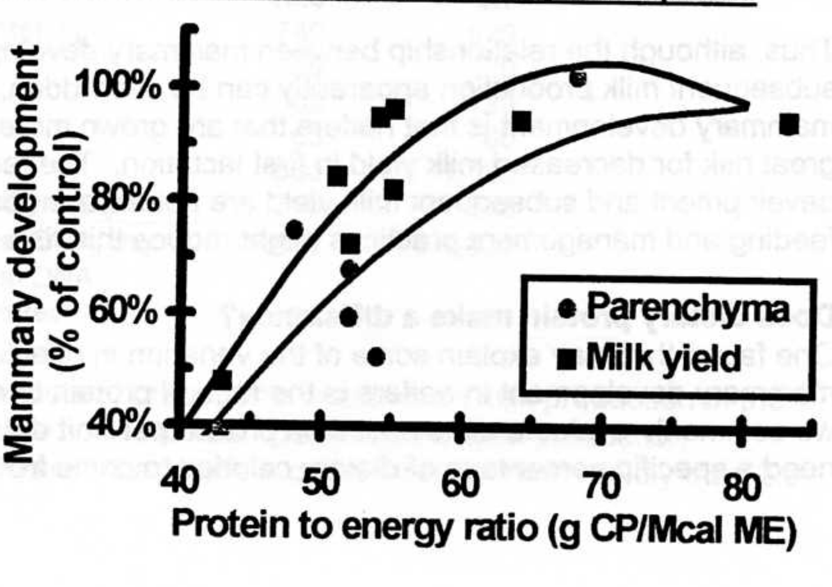
Recently, I analyzed data from several published studies to determine if differences in dietary protein would account for some of the variation in mammary responses to high energy diets and rapid gains (VandeHaar, 1997). Only studies in which rapid gains exceeded 2.0 lb/day and in which diets were adequately described were included in the analysis; thus, groups of heifers from 11 studies were examined. These studies included those of Tables 1 and 3 plus reports from Gardner et al., 1977; Peri et al., 1993; and Petitclerc et al., 1984.

Estimated CP:ME ratio was based on reported nutrient values and ingredient concentrations and varied considerably among the studies, from 43 to 83 g/Mcal. In one study (Valentine et al.) the reported % CP of the high diet was discounted because it contained much more urea (3% of DM) than needed by the rumen microbes. Mammary development was calculated as amount of parenchymal DNA or mass or yield of milk in rapidly-grown heifers as a percentage of that of control heifers in each study. The severity of mammary impairment varied considerably; in some studies, rapidly-grown heifers had only 40% the mammary development of controls and in others mammary development was normal.

Across the studies, actual rate of gain of the "rapid-gain" groups was negatively, but not significantly, correlated with mammary development and accounted for only 7% of the variation in mammary impairment. However, mammary development was inversely correlated ($r = 0.78$, $P<0.01$) with the CP:ME ratio in diets formulated for rapid gains. Furthermore, CP:ME alone accounted for 72% of the variation in mammary parenchyma responses and 81% of the variation in milk yield responses to rapid growth rate (Figure 1).

This analysis suggests that inadequate protein might have been responsible for the impaired mammary development of heifers grown more rapidly than 2.0 lb/day. One problem with this analysis is that increases in dietary CP do not always result in increased protein for absorption. Using estimates of absorbed

Figure 1. Dietary protein and mammary development.



protein might be an improvement for calculating a dietary protein to energy ratio. However, inadequate information on diet composition in these reports and inadequate data to accurately predict microbial yield and ruminal protein degradation in young heifers necessitates the use of CP. Furthermore, the fact that CP:ME alone, despite its inadequacies, accounts for 75% of the variation in reported mammary responses is amazing.

Very few studies have been designed specifically to examine the effects of dietary protein on mammary development. Interestingly, in the study of Capuco et al., high rates of gain did not impair mammary development when the diet was alfalfa-based and contained 83 g CP / Mcal ME ratio but did when the diet was corn silage-based and contained only 54 g/Mcal. Although the authors speculated that the different responses were caused by the different bulk densities of the two diets, the low protein of the corn silage diet seems a more likely explanation. Sejrsen and Purup (1997) report two Danish studies in which the effects of increased daily gain on mammary parenchymal DNA and on milk production were not alleviated by feeding increased bypass protein or total protein. However, in both studies animals actually grew faster when fed the higher protein diet. If we postulate that impaired mammary development is the consequence of both rapid gains and inadequate protein, then these results might not be unexpected. In rapidly growing lambs, feeding high protein diets (CP:ME of 75 compared to 56) before puberty had no effect on mammary glands at puberty but increased parenchymal DNA during lactation and tended to increase milk yield by 15% (Zhang et al., 1995). Certainly more work is needed to determine the effect of dietary protein on mammary growth and to determine the specific ratio of protein to energy to feed growing heifers for optimal mammary growth.

So, what recommendations for protein can be made for feeding heifers, given that the proper studies have not been conducted. First, heifers fed high energy diets for rapid gains before puberty are at risk for impaired mammary development. Second, we have indirect evidence that feeding more protein when heifers are grown rapidly will reduce the risk for impaired mammary development. The amount of protein to feed is not clear, but based on the data of Figure 1, NRC (1989) standards for CP:ME ratio may not be adequate when heifers are grown at rates faster than those suggested by the NRC tables. Note that mammary impairment can be severe even when heifers are fed CP:ME ratios around 54 g/Mcal. Recommendations for protein in NRC seem adequate for good carcass growth and composition at body gains as rapid as 2.2 lb/day (Bagg et al., 1985; Kertz et al., 1987). However, studies examining the protein requirements of heifers have not directly measured effects of protein on mammary development. Such studies, although expensive, are necessary if early calving is to be practiced commonly on farms.

One caution against high dietary protein is that it may decrease fertility. Heifers fed diets high in degradable protein with 81 g CP/Mcal ME had first-service conception rates of 60% compared to 80% for heifers fed standard diets with 57 g CP/Mcal (Elrod and Butler, 1993). Thus, the optimal CP:ME ratio for prepubertal heifers may be 65 to

70 g/Mcal, and this could be dropped 1 to 2 months before breeding occurs. Furthermore, the protein supplement for prepubertal heifers should be from true protein sources rather than non-protein nitrogen sources such as urea.

Effect of heifer feeding program on lifetime profitability

Although the cost of raising a heifer to first calving is not trivial, it is substantially less than the gross income generated from subsequent milk sales. Thus, in developing a cost-effective heifer rearing program, one must weigh the costs of heifer rearing versus the potential impact on net income of the animal after calving. Early calving may decrease heifer costs, but if mammary development or body size at calving is decreased, early calving may be an expensive mistake.

Some dairy management experts have attempted to examine the economics of early calving with a simple formula. First, they assume that milk production will not be impaired so that the only consideration becomes costs of heifer rearing. Then they assume that if raising a heifer to first calving costs $1200, heifer costs are $50 per month. With this simple model, lifetime profit is increased $200 if calving is expedited from 24 to 20 months. However, this logic fails to consider that early calving does not decrease many types of heifer-rearing costs, such as the initial calf value, the costs of bottle-feeding calves, vaccination costs, and breeding costs. Furthermore, some costs will most likely increase, such as daily feed costs. Perhaps even some nonfeed costs will increase. Better housing and ventilation may be needed, health costs may be greater if heifers are fed more grain, and heifers may require more bedding as they eat more and defecate more. Regarding feed costs, not only will heifers require more calories per day to grow faster, but the feed will likely cost more per calorie as more nutrient-dense feedstuffs are used.

Possible outcomes of a cost-benefit analysis for raising heifers that breaks costs into one-time fixed costs (cost of calf, bottle-feeding costs, vaccinations, breeding), feed costs (dependent on daily ME intake and cost per Mcal ME), and daily non-feed costs (housing, bedding, labor, utilities, taxes, etc.) are shown in Table 4. These are based on a farm profitability model (VandeHaar, 1998) and on possible impacts of heifer management on milk yield from the reported literature. As Table 4 illustrates, feeding for higher rates of gain to calve at heavier body weights is expected to increases profits by $1700 per 100 cows in a dairy enterprise consisting of cows and all replacement heifers (compare programs 1 and 2) if the increased body weight increases milk yield as projected by Van Amburgh and Galton. The net return to heavier calving would decrease if the cost of grains and protein supplements increased relative to forages and byproduct feeds and would increase as milk price increased relative to feed costs. Feeding for higher rates of gain to calve at 22 months instead of 24 months also can increase profits. For example, compared to program 1, program 3 is expected to decrease total heifer costs by $41 and increase profits by $1500 per year per 100 cows.

Table 4. Possible impacts of heifer-rearing program on lifetime income and expenses.

Rearing program:	1	2	3	4	5	6a	6b
Calving age:	24	24	22	22	20	20	20
Weight after calving, lb[1]	1150	1250	1150	1250	1150	1250	1250
Pubertal gain, lb/day[2]	1.8	2.0	2.0	2.2	2.2	2.4	2.4
Mammary development	Okay	Okay	Okay	Okay	Okay	Okay	Impaired[3]
Total heifer costs[4], $	1184	1246	1143	1211	1107	1174	1174
Net income as a cow[5], $	2586	2694	2586	2694	2586	2694	2513
Annual farm profit per 100 cows[6], $	49,400	51,100	50,900	52,300	52,200	53,600	47,200

[1] Body weight after calving assumes a loss of 150 lb at calving time.

[2] Weight gain during the critical period of mammary development, from 3 to 10 months of age.

[3] Assuming milk yield will be decreased 10% in the first lactation but not in subsequent lactations.

[4] Feed costs from birth to calving are calculated, on average, as 11.8, 12.2, 12.2, 12.7, 12.7, and 13.2 cents / Mcal ME, which results in average daily costs of 65.9, 72.7, 70.5, 78.9, 77.0, and 86.0 cents for programs 1 to 6, respectively. Costs other than feed are considered to be $200 plus daily nonfeed costs of 69.0, 70.5, 70.5, 72.2, 72.3, and 74.2 cents for programs 1 to 6, respectively.

[5] Income minus expenses as a cow, assuming cow will be sold at end of third lactation, so life consists of three 305-day lactations and two 60-day dry periods. Income is from sales of milk at $12/100 lb, three calves at $100 each, and final sale of cow at $500. Milk yield during the first lactation is 1000 lb greater for animals weighing 100 lb more according to Van Amburgh and coworkers (1994). Milk yield during later lactations is assumed to be 22,000 lb. Feed costs for cows are calculated using energy requirements based on NRC and an average cost of 8 cents/Mcal NE_L during the lactation and dry periods. Total non-feed costs as a cow are assumed to be $120 per calving plus $3.00/day of lactation and $1.50/day dry.

[6] Profitability on a per cow per year basis of a dairy enterprise including cows and heifers. This was calculated as lifetime profit per animal divided by the 2.83 years spent as a cow times 100 cows.

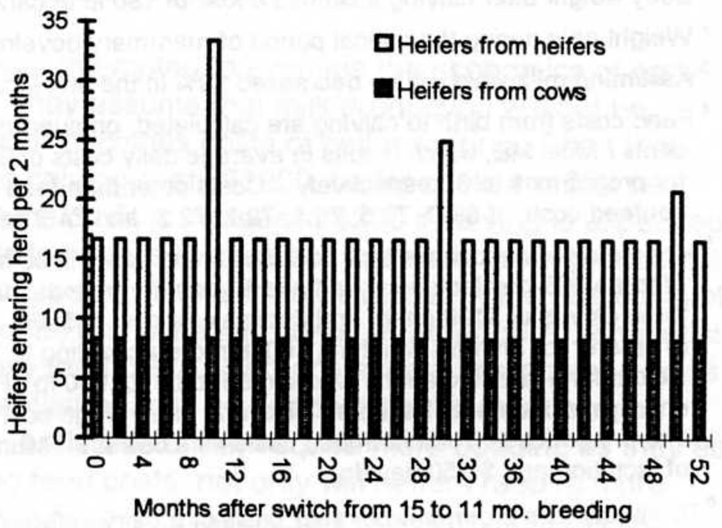
Combining heavier body weights and earlier calving may also be beneficial, and calving even earlier than 22 months may increase profits further. For example, calving at the optimal body weight of 1250 lb at 20 instead of 24 months may increase farm profits $2500 per 100 cows (compare program 2 with 6a). However, decreasing calving age does have risks -- to date, all studies in which heifers gained faster than 2.0 lb/day have reported at least a 5% reduction in milk yield. If milk yield was impaired in the first lactation alone by 10%, calving at 20 months would decrease profits $3900 per 100 cows (compare program 2 with 6b). Of course, more severe first-lactation impairment or impairment into later lactations would decrease profits even further. In addition, these assumptions were based on a milk price of $12 per 100 lb; the loss in profits would be more than $5000 if milk price was $14.

Perhaps high protein diets before puberty can overcome this impairment, but more studies are needed before we can confidently recommend that feeding high protein will eliminate the risk of impaired mammary development. Feeding more protein before puberty would cost ~$15 per heifer. At the present time, this $15 cost seems a reasonable investment given that even prepubertal gains of 2.0 lb/day have impaired mammary development at protein levels commonly used on farms.

Finally, if heifers are grown at the same average daily gain, lifetime profit would be about the same whether they calved at 22 months weighing 1150 lb or at 24 months weighing 1250 lb (compare programs 2 and 3). Thus, the decision on whether to breed heifers for earlier calving should be based on availability of space to house heifers relative to availability of space to house lactating cows. If heifer space is in short supply, perhaps earlier breeding even at lighter body weight should be considered.

One other purported benefit of early calving is more calves born per year. However, this benefit is only a short term one because space for lactating cows generally limits the number of animals on most farms. Therefore, more calves will be born during the time that management is switched to earlier calving, but in the long-run, calves born per year depends on number of lactating cows on the farm (Figure 2) and should not be used in the decision to move toward earlier calving.

Figure 2. Heifers entering a milking herd of 100 cows per two-month period.



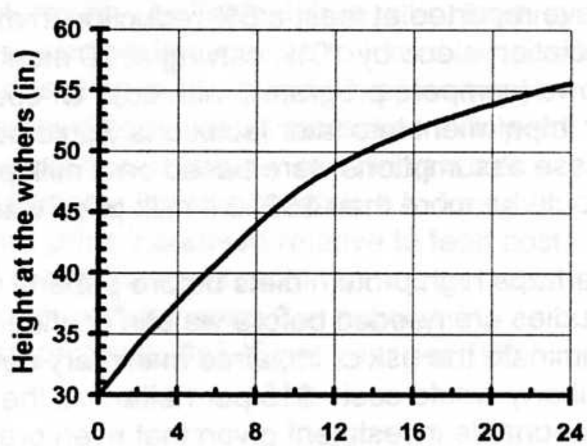
Recommendations

Previous recommendations to calve heifers at 22 to 24 months of age at a body weight of 1200 to 1300 lb after calving seem reasonable (Hoffman, 1996; Van Amburgh and Galton). Thus, targets for calving are:

- Age = 22 to 24 months
- Body weight = 1250 lb
- Height = 56 inches at the withers
- Body condition score = 3.0 to 3.5

To achieve these goals for calving, heifers should follow the curve for growth in height shown in Figure 3, and they should be bred at 13 to 15 months of age, standing 51 inches at the withers and weighing 850 lb.

Figure 3. Recommended heights for Holstein heifers with 24 month calving.



Decreasing the time to raise heifers to first calving below 22 months could increase profits further but only if milk production is not impaired. To date this risk is not worth

Table 5. Growth goals and recommendations for feeding Holstein heifers ad libitum.[1]

Age months	Weight lb.	Gain lb./day	Height inches[2]	ME[3] Mcal/lb	NE_m[4] Mcal /lb	% CP[5]	CP:ME g/Mcal[6]
2	191	1.74	34.1	1.33	0.80	19.3	66
4	299	1.84	37.6	1.27	0.76	18.4	66
6	411	1.92	40.8	1.18	0.71	17.1	66
8	528	1.96	43.9	1.12	0.67	15.5	63
10	647	2.00	46.7	1.12	0.67	15.5	63
12	767	2.00	48.7	1.08	0.65	14.3	60
14	886	1.99	50.4	1.08	0.65	14.3	60
16	1,005	1.95	51.7	1.08	0.65	14.3	60
18	1,120	1.89	52.8	1.08	0.65	14.3	60
20	1,231	1.80	53.8	1.08	0.65	14.3	60
22	1,334	1.65	54.8	1.08	0.65	14.3	60
23	1,382	1.54	55.2	1.20	0.72	15.8	60
24 precalf	1,425		55.6	1.25	0.75	16.5	60
24 postcalf	1,275		55.6	1.30	0.78	18.0	63

[1] Targets for other breeds could be calculated using these weights as references with the goal of attaining 90% of mature body weight at 24 months. For Holsteins, mature body weight is assumed to be 1410 lb.
[2] Height at the withers.
[3] Concentration of metabolizable energy in diets. ME is approximately NE_m divided by 0.6.
[4] Concentration of net energy for maintenance in diets. NE_{gain} is approximately 0.66 times NE_m.
[5] Concentration of crude protein in diets. Special protein sources high in undegraded protein likely are not needed in most heifer diets. Most of the supplemental CP should come from true protein sources such as legume forages and soybean meal. Urea should not be used as the CP supplement.
[6] Recommended ratio of CP to ME in heifer diets. To calculate this ratio, multiply Mcal ME / lb by 2.2 to give Mcal ME / kg. Then multiply %CP by 10 and divide by Mcal ME / kg. At 66 g/Mcal, about 26% of dietary calories are from protein.

taking. If heifers gain more rapidly than the 1.8 lb/day recommended by NRC, then to reduce the risk of impaired mammary development, they should be fed diets with 60 to 70 g CP/Mcal ME. Recommended weights, daily gains, and dietary energy and protein concentrations at different ages are given in Table 5.

These recommendations assume feed will be offered for ad libitum intake. Whereas most studies, such as Bortone et al. (1994, show that NRC works well when heifers are fed at restricted intake, in our experience heifers generally grow faster than predicted when fed NRC diets ad libitum, partly because they eat more than NRC predicts. Thus, my recommendations for dietary energy concentration are lower than those of NRC 1989 to achieve target gains of 1.8 lb/day. Instead they are based on data collected from the study of Radcliff et al., in which heifers were group-housed in a comfortable yet confined environment with plenty of drinking water, were kept healthy, had feed available all day with plenty of bunk space, and were fed their diet as a TMR. In some situations, higher energy diets may be needed to meet the target gains. The recommendations for protein are higher than recommended by NRC or by many computer programs, including that of Michigan State University (VandeHaar et al., 1992).

Summary

A good heifer rearing program is critical to produce animals at first calving that have well-developed mammary glands capable of producing to the animal's genetic potential and that have good body size and body condition capable of high feed intake and delivery of nutrients to the mammary gland. Weight gains more rapid than 2.0 lb/day before puberty generally decrease development of the mammary gland and subsequent milk production. However, in many of the reported studies, heifers were fed diets with marginal protein content. We recently found that a high energy and high protein diet induced rapid gains with no impairment of mammary development. A cost-benefit analysis shows that high dietary protein before puberty is probably worth the added expense when trying to achieve postpartum body weights of 1250 to 1300 lb and calving at 22 to 24 months. Although calving earlier than 22 months may decrease the costs of raising heifers further, such practices may actually decrease total profits because of decreased income. Heifer-rearing is not just an expense but an investment, and, when done wisely, it can yield great dividends!

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