Feeding Strategies for Optimum Replacement Heifer Growth

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Fundamentals

Before beginning a discussion of feeding strategies for dairy replacement heifers, a discussion of the fundamentals of replacement heifer growth is required. It is relevant because a basic understanding of growth fundamentals provides the foundation for understanding protein and energy requirements of dairy replacement heifers. Most producers, consultants, veterinarians, educators, etc., are familiar with heifer growth charts which define optimum weight, height to age relationships.

Recent work by Pennsylvania (7) and Wisconsin (8) researchers has provided heifer growth charts for optimum growth of the modern Holstein genotype (Table 1).

Growth charts are invaluable when monitoring the effectiveness of a replacement heifer management program. While invaluable, a heifer growth chart does not, however, provide insight into the complexities of replacement heifer growth.

Often producers, consultants, etc., desire to produce heifers differently than those defined on a growth chart. Reducing the calving age via accelerated growth is a common objective. Accelerating growth rate has a desired effect in increasing the rate of body protein deposition.

Heifers fed diets with enough energy and protein to support 2.2 lbs/d of average daily gain (ADG) will have accelerated body protein deposition as compared to heifers fed diets to gain 1.75 lbs/d.

The differences in body protein deposition between heifers gaining 2.2 vs 1.75 lbs/d are more pronounced in the first year of life. Logically, if accelerated growth enhances body protein deposition, increases in dietary protein supply would be required. There is, however, a major biological obstacle to accelerated growth of replacement heifers. Accelerated growth does increase the rate of body protein deposition, but it also increases the rate of body fat deposition.

Replacement heifers gaining 2.2 lbs/d deposit more fat than heifers gaining 1.75 lbs/d. Differences in body fat deposition become more pronounced in the second year of life. Thus in a way the positive aspects of increased body protein deposition in the first year of life via accelerated growth are negated by negative effects of fat deposition in the second year of life. These combined factors result in the production of replacement heifers which may weigh the same (e.g., 1400 lbs at calving), calve at different ages (20 vs 24 months), but have different body compositions.

Replacement heifers reared to 1400 lbs by gaining 1.75 lbs/d would theoretically have 22.9% body fat vs 36.9% for heifers reared at 2.2 lbs/d. Conversely, 1400 lb heifers which gained 1.75 lbs/d would have 17.4% body protein as compared to 14.4% for heifers gaining 2.2 lbs/d. Differences in body composition at calving have been demonstrated (10) to result in critical differences in first lactation milk yield.

Over the past decade, researchers have been investigating feeding strategies that may override some of these fundamentals of replacement heifer growth, allowing the production of replacement heifers at an earlier age without compromising body composition issues.

I. **Environment vs Heifer Growth**

Large climatic and heifer housing variations in cold climates have a large influence on dietary energy requirements. As a result, using static or NRC energy requirements to feed dairy replacement heifers is of limited value. Numerous ration formulation programs have been developed to adjust energy requirements based on environmental conditions. Base energy requirements for heifers are listed in Table 5. Under diverse environmental conditions, it is critical that dietary energy be adjusted. Heifer growth should be closely monitored to determine if dietary energy adjustments were effective. In many situations, dietary adjustment cannot overcome extremely poor environmental conditions and the environment of the heifers should be adjusted. It is impossible in this paper to define all environmental conditions in which heifers are reared and therefore difficult to give specific recommendations for dietary energy adjustment. Listed below are ten common environmental or management factors in which dietary energy should be adjusted or closely monitored.

Cold weather	Increase dietary energy
Wet/muddy conditions	Increase dietary energy
Wind exposure (winter)	Increase dietary energy
Cold, hard resting areas	Increase dietary energy
Well-managed freestalls	Do not overfeed energy
Ionophore feeding	Closely evaluate dietary energy
Solar radiation	Closely evaluate dietary energy
Heat stress	Intake depression, increase H_2O access and dietary energy
Crowding	Closely evaluate dietary energy
Parasites	Increase dietary energy or treat

II. Crude Protein vs Heifer Growth

Calf Starters

High rates of true body protein deposition occurs at very young ages and necessitates that pre-post weaning calf starters be relatively high in crude protein (CP). Minnesota workers (2) fed Holstein calves grain starters containing 15.0, 16.8, 19.6, or 22.4% CP. Overall body weight gains from day 4 to 56 averaged 1.20, 1.23, 1.37, and 1.36 lbs/d, respectively. Throughout the experiment, starter consumption tended to increase and CP content of the starter increased. The researchers concluded that 19.6 % CP in starters was adequate. Wisconsin workers (11) fed Holstein calves starters containing 20.0 or 25.0% CP. Starters were first offered on day 21 prior to weaning at day 26. Calf growth rates were nearly identical (.60 lbs/day) for calves fed starters containing 20.0 or 25.0% CP. Likewise, the researchers concluded that 20% CP in the starter was adequate. These data (2,11) suggest that starters containing 19 to 20% CP on a dry matter basis appear to be adequate in supporting calf growth rates. The reader is cautioned that nutrient compositions of commercial calf starters are listed on an as fed basis. Therefore commercial calf starters listing 17 to 18% CP on the feed tag are actually 19 to 20% on the dry matter basis.

Heifer Diets

Surprisingly, there are few recent studies that have evaluated CP feeding regimens for older heifers. Canadian workers (4) fed heifers from 71 to 126 days 13.3, 16.6, or 19.2% CP followed by 10.9, 14.0, and 17.3% CP from 127 to 182 days. Results suggest that weight and height growth of Holstein heifers was maximized when diets contained 16.6% CP (71 to 126 days) followed by 14% CP (127 to 182 days). Italian workers (14) fed Holstein heifers weighing 220 to 440 lbs diets containing 16.7 or 13.7% CP. Heifers fed 16.7% CP gained 1.72 lbs/d as compared to 1.64 lbs/d for heifers fed 13.7% CP. In a second phase of the study, heifers were fed either 12.5% or 10.4% CP from 440 lbs to 660 lbs. Heifers fed 12.5% CP gained 1.66 lbs/d as compared to 1.54 lbs/d for heifers fed 10.4% CP. Beltsville workers (23) fed Holstein heifers from 400 to 736 lbs alfalfa based diets containing 22.0% CP vs corn silage based diets containing 15.6% CP. Gains were similar between the diets at 1.91 and 1.98 lbs/d. In addition, there were no appreciable differences in body protein gain. In a recent study (9), we fed Holstein heifers weighing 880 lbs diets containing 8.1, 10.7, 12.7, and 15.0% CP, respectively (Table 2).

There were no significant effects on ADG, but wither height, hip width, and heart girth increased linearly with increasing dietary protein, but these were slight decreases or no change in these measurements when heifers were fed 15.0% CP. In addition, blood protein parameters and nitrogen balance of heifers were measured. Blood urea nitrogen levels were extremely low when heifers were fed diets containing 8.1 or 10.7% CP. Nitrogen (CP) retention was maximized in heifers fed diets containing 13.7% CP.

While data are limited, these studies (4, 9, 14, 23) suggest Holstein heifers from 200 to 500 lbs be fed diets containing approximately 15 to 17% CP, heifers 500 to 800 lbs, 14 to 15% CP, and heifers >800 lbs, 13% CP. These guidelines are similar to current NRC (13) recommendations.

III. Bypass Protein and Heifer Growth

Over the past decade there have been a number of studies conducted to evaluate the potential of feeding bypass protein to augment heifer growth and body protein deposition. The following discussion focuses on those efforts.

Calf Starters

Pennsylvania workers (18) fed calves from birth to 25 weeks starters containing 33, 37, and 46% bypass protein (% of CP). There were no appreciable differences in calf growth rates between the treatments. Slaughter data also suggested no body protein deposition advantages to feeding starters higher in bypass protein because carcass fat and protein levels were nearly identical between the treatments. In contrast, New Hampshire (17) did observe increased growth rates (1.64 vs 1.54 lbs/d) when starters containing 46% bypass protein were compared to starters containing 36% bypass protein. Kansas State workers (1) observed benefits in calf growth when soybeans or corn were roasted, thereby increasing the bypass protein content. Based on these data (1, 17, 18), it is very difficult to ascertain what level of bypass protein may be beneficial to calves. This issue is probably more related to the quality of amino acid availability of the bypass protein source. For example, Pennsylvania workers (18) used blood meal to increase starter bypass contents while New Hampshire (17) and Kansas State (1) workers used heat treated soy based proteins. Differences in bypass source could account for the differences in heifer performance between experiments. While more information is needed, there may be some advantages to feeding calves starters that contain some additional bypass. While speculative, heat treated plant proteins may be more effective than animal proteins in calf starters.

Heifer Diets

There have been a number of experiments conducted evaluating the effects of increased dietary bypass protein on heifer growth and performance. Describing the results of each trial would be tedious, so the author has constructed a summary table for ease of interpretation (Table 3).

In general, supplementing bypass protein to dairy replacement heifers has not resulted in significant or consistent improvement in heifer growth or feed efficiency. Results from two of the trials (3, 6) may be confounded by interactions with energy which also were part of the experimental protocol. This leaves one trial (20) where a true growth response was observed to supplementary bypass protein. The positive responses observed in this study are somewhat inconclusive, however, as only weight gains were improved. Growth of wither height, hip height, and heart girth were not improved by increasing bypass protein content of replacement heifer diets. The body of recent research work suggests major alteration of bypass protein in replacement heifer diets is probably not warranted.

IV. Dietary Protein to Energy Ratio

Michigan researchers (22) proposed that dietary protein to energy ratios are an important factor in replacement heifer diets. This is a logical hypothesis because as dietary energy is increased to accelerate growth, body protein deposition rate is increased, thereby increased dietary protein would be required. This concept was used to evaluate the often conflicting and confusing studies on mammary development. Michigan workers (22) evaluated 11 mammary development experiments and observed that mammary development was inversely related ($r^2 = 0.71$) with the CP to energy (ME) ratio of the diet.

Further, the CP:ME ratio of the diet accounted for 76% of the variation in milk yield from these studies. Simplistically, these data suggest that mammary development and milk yield are impaired when heifers are fed low protein, high energy diets. These data also suggest when high energy diets are fed, increasing dietary protein may be warranted. In studies (15, 16), Michigan workers tested this hypothesis. Heifers weighing 275 lbs were fed a diet containing .53 Mcals/lb of NE_M and 16.3% CP or a diet containing .83 Mcals of NE_M and 19.3% CP. Summary results of this study are presented in Table 4.

The encouraging part of this study was that body protein percent and amount of mammary tissue were not depressed by feeding a high energy, high gain (2.6 lbs/d) diet. Milk production results were, however, discouraging because the high energy, high protein diet resulted in significantly reducing calving age, but also reduced first lactation yield approximately 8.0 lbs/d. The reduction in milk yield cannot be explained by mammary development reductions and likely is the result of body composition differences at calving. It should be noted that these trials contained rBST treatments, which help improve milk yields (59.3 lbs/d) of heifers fed the high energy, high protein diet. While not conclusive, these data (15, 16) suggest protein to energy ratios in heifer diets may be important, but there are insufficient data for field application. The current NRC, 2001 requirements (13) do alter dietary protein levels based on energy supply and at presnet are the best guide available.

Conclusions

Highlights from recent experiments regarding protein feeding of heifers are as follows:

- Calf starters require 19 to 20% CP on a DM basis (17 to 18% CP as fed).

- Calf starters should contain some high quality bypass protein?

- Bypass protein recommendations in the 2001 NRC appear adequate.

- Replacement heifers do not consistently respond to supplemental bypass protein.

- Crude protein recommendations for heifers in the 2001 NRC appear reasonable for most situations.

- When feeding high energy diets for accelerated growth, formulating diets on a CP to energy ratio may be of value, but it is not a panacea to improve milk production.

- Optimizing rumen microbial protein synthesis is of importance in heifer diets (e.g., dietary carbohydrate inclusion).

- A data base on amino acid supplementation to replacement heifers and its economics is currently unavailable.

The author has attempted to summarize these new concepts in Table 5.

Minerals and Vitamins

Mineral and vitamin recommendations for dairy heifers (13) are listed in Table 6. Dairy heifers are often significantly over-supplemented minerals and vitamins. Special attention should be paid to properly evaluating heifer feeds and diets for macro and micro mineral content and specifically formulating mineral and vitamin supplements for the specific dietary situation. Use of all-purpose heifer minerals or free choice mineral supplementaiton for heifers is discouraged.

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Table 1. Upper and lower ranges of body size parameters and growth rates for Holstein replacement heifers under ideal management.

	Body Size Criteria[1]									
	Upper Range					Lower Range				
Age, mo	BW	ADG	WH	BL	BCS	BW	ADG	WH	BL	BCS
0	93	. . .	30	32	. . .	93	. . .	30	32	. . .
1	139	1.5	32	34	. . .	139	1.5	32	34	. . .
2	185	1.5	34	37	. . .	185	1.5	34	37	. . .
3	242	1.8	36	39	2.2	236	1.7	36	39	2.2
4	298	1.8	39	41	. . .	287	1.7	38	41	. . .
5	355	1.8	40	43	. . .	339	1.7	40	43	. . .
6	410	1.8	41	46	2.3	390	1.7	41	45	2.3
7	467	1.8	43	48	. . .	441	1.7	42	47	. . .
8	522	1.8	44	50	. . .	491	1.7	43	48	. . .
9	580	1.8	44	52	2.4	544	1.7	44	50	2.4
10	635	1.8	46	53	. . .	595	1.7	45	52	. . .
11	692	1.8	46	55	. . .	646	1.7	46	54	. . .
12	747	1.8	47	56	2.8	696	1.7	46	55	2.8
13	804	1.8	48	58	. . .	749	1.7	47	56	. . .
14	860	1.8	49	59	. . .	800	1.7	48	58	. . .
15	917	1.8	50	61	3.0	851	1.7	49	59	3.0
16	972	1.8	50	62	. . .	901	1.7	50	60	. . .
17	1029	1.8	51	63	. . .	952	1.7	50	61	. . .
18	1084	1.8	52	64	3.2	1005	1.7	51	62	3.2
19	1142	1.8	52	65	. . .	1056	1.7	52	63	. . .
20	1197	1.8	53	65	. . .	1106	1.7	52	64	. . .
21	1254	1.8	54	66	3.4	1157	1.7	53	65	3.4
22	1309	1.8	54	67	. . .	1210	1.7	53	66	. . .
23	1366	1.8	55	67	. . .	1261	1.7	54	66	. . .
24	1422	1.8	56	68	3.5	1311	1.7	54	67	3.5
7-d p	1281					1181				
30-d postpartum	1192					1102				

[1] WH = wither height, BL = body length from the point of shoulder to ischium, BCS = body condition score.

Table 2. Growth, blood metabolites, and nitrogen balance of 880 lb Holstein heifers fed 8.1, 10.7, 12.7, or 15.0% CP.

	Diet CP			
Item	8.1	10.7	12.7	15.0
Growth				
ADG, lbs/d	1.40	1.52	1.63	1.54
Height, in/120 d	1.50	2.68	3.54	2.83
Hip width, in/120 d	1.85	2.16	2.40	2.32
Heart girth, in/120d	4.41	5.55	6.41	6.41
Blood Metabolites				
BUN mg/dl	0.4	5.6	9.6	12.4
N-Balance				
N-retention g/d	12.0	17.0	23.0	22.0

Table 3. A review of literature regarding bypass protein supplementation.

Reference	Weight	Bypass Source	Diet Bypass Level 1	2	3	4	5	Growth Resp.	Feed Efficiency Response
21	200-600	Animal Proteins	30	40				No	No
19	550-1100	Animal Proteins	34	42				No	N/A
6	330	Extruded Soybeans	34.5	35.4				No	N/A
6	330	Extruded Soybeans	28.5	29.1				Yes	N/A
3	220	Corn Gluten Meal	36	53				Yes	Yes
5	400-900	Animal Proteins	30	50				No	Yes
20	500	Animal Proteins	31	43	50	55		Yes	Yes
12	400-1000	Animal Proteins	28	33	30	33	34	No	No
		Animal Proteins	31	38	35	39	40	No	No

Table 4. Results of feeding high CP, high energy diets to Holstein heifers.

Item	Control	High Energy/Protein
Slaughter Study		
Slaughter BW	740	873
ADG, lbs/d	1.7	2.62
Carcass Protein, %	17.4	16.3
Carcass Fat, %	16.6	24.8
Mammary Tissue, g	401	408
Lactation Study		
Calving Age, mo	23.6	20.7
Milk, lbs/d	64.2	56.4

Table 5. Ration specifications for Holstein replacement heifers.[1,2]

Item	Unit	Heifer weight (lbs)						
		175	375	575	775	975	1175	1375
Intake	lbs/d	6.3	11.3	15.3	18.3	22.4	26.4	30.4
Energy								
TDN[3]	% of DM	76.0	69.0	66.0	64.0	64.0	64.0	68.0
ME	Mcal/lb	1.30	1.18	1.12	1.12	1.08	1.08	1.20
Protein								
CP	% of DM	19.0	17.0	16.0	15.0	14.0	13.0	16.0
RUP	% of CP	40.0	35.0	32.0	30.0	25.0	25.0	30.0
RDP	% of CP	60.0	65.0	68.0	70.0	75.0	75.0	70.0
CP/ME	g CP/Mcal ME	65.0	66.0	65.0	63.0	59.0	55.0	61.0

[1] Assumes a calving age of 23 to 24 mo with heifers weighing 1400 lbs pre-calving.
[2] Prepuberty gains = 1.9 to 2.0 lbs/d; postpuberty gains = 1.7 to 1.8 lbs/d.
[3] Energy levels may require reduction if ionophores are fed.
[4] If RDP < 25.0% of CP, increase S to .25% of DM.

Table 6. Mineral feeding guidelines[1] for large breed dairy heifers gaining 1.8 lbs/day.

		Heifer Body Weight, lbs			
Item/Abbreviation	Unit	300	600	900	1200
Calcium/Ca	% of DM	0.45	0.40	0.37	0.36
Phosphorus/P	% of DM	0.30	0.24	0.20	0.18
Potassium/K	% of DM	0.49	0.48	0.46	0.45
Sodium/Na	% of DM	0.09	0.08	0.07	0.07
Chlorine/Cl	% of DM	0.13	0.12	0.11	0.10
Sulfur/S	% of DM	0.20	0.20	0.20	0.20
Magnesium/Mg[2]	% of DM	0.11	0.11	0.11	0.11
Cobalt/Co	ppm	0.11	0.11	0.11	0.11
Copper/Cu	ppm	10	10	10	10
Iodine/I	ppm	0.10	0.30	0.30	0.30
Iron/Fe	ppm	45	35	15	13
Managnese/Mn	ppm	25	20	15	13
Selenium/Se	ppm	0.30	0.30	0.30	0.30
Zinc/Zn	ppm	35	29	20	17

[1] Determined from the Nutrient Requirements of Dairy Cattle, 2001 assuming bioavailabilities of alfalfa silage, corn silage, shelled corn, soybean meal, dicalcium phosphate and limestone.

[2] Diets containing excessive levels of K may require higher levels of Mg.