Potential of Alternative Dairy Replacement Heifer Nutrition Programs to Reduce Economic Cost and Environmental Impact

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Take Home Messages

- In general, simple manipulation of dietary protein and energy in replacement heifer diets has not yielded profound changes in feed cost or future animal performance.
- Modestly increasing dietary energy and protein combined with limit-feeding the resulting diet has the potential to reduce feed cost and nutrient excretion without compromising future performance.
- Recent data also suggest supplementation of phosphorus to dairy heifers does not result in improve frame or bone growth and may be minimally required.

Introduction

The goals of a dairy replacement management program are to rear heifers at a low economic and environmental cost without compromising future lactation performance. To meet these objectives, heifers are commonly fed diets containing high fiber forages (MPS, 2003), which meet the low energy requirement (NRC, 2001) of replacement heifers. Feeding heifers low energy, high fiber forages also helps minimize over-conditioning at calving which can be detrimental to lactation performance (Hoffman et al., 1996). Total feed cost and feed efficiency are however often over-looked with feeding heifers diets containing predominately high fiber forages. Historically, research (Van Amburgh et al., 1998, Hoffman et al., 1996, Radcliff et al., 2000) focused on feeding heifers higher energy diets to reduce calving age below recommended (22-24 mo) as a method to shorten the length of the rearing period and correspondingly reduce feed cost. Although this strategy has the potential to lead to an earlier return on feed investment, decreasing the calving age frequently results in a decrease in lactation performance (Van

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Amburgh et al., 1998, Hoffman et al., 1996, Radcliff et al., 2000). Another strategy to reduce heifer feed cost is to feed higher energy diets but to limit the amount of the diet fed controlling average daily gain (**ADG**) which could effectually yield a calving age and body condition score similar to feeding high forage diets. This management strategy will be referred to as limit feeding for the remainder of this paper. Limit feeding has the potential to reduce feed cost, increase feed efficiency and decrease fecal excretion while preserving the rearing period time course which to date has been difficult to alter without negative health and production effects. In addition, dietary phosphorus (P) supplementation to dairy heifers increases diet and environmental cost. If basal feeds contain P levels similar to the P requirement supplemental P may not be required for dairy heifers. This paper will review issues associated with limit feeding and P supplementation to dairy replacement heifers.

■ Pseudo Limit-feeding Research

Limit feeding ruminants is not new or novel. Limit-feeding strategies have been successfully employed with ruminants such as beef cows, (Loerch, 1996), ewes (Susin et al. 1995) and beef heifers (Wertz et al. 2001). Likewise limit feeding dairy replacement heifers is not new or novel and has been a research methodology in a number of investigations. What is different about these investigations is limit feeding was not the central hypothesis; rather limit feeding was merely a methodology to investigate a related hypothesis. The author has arbitrarily classified these research projects as pseudo limit-feeding research.

For example, Lammers et al. (1999) used limit-feeding as a method to control growth rates of prepubertal Holstein heifers to investigate effects of prepubertal growth rates on lactation performance. Differing prepubertal growth rates were achieved by offering different amounts of dry matter (**DM**) of a single diet [(16% CP and 1.21 Mcal/lb of metabolizable energy, (**ME**)]. Prepubertal ADGs were 1.54 and 2.20 lbs/d thus the 1.54 lbs/d treatment was commissural with limit feeding. Heifers limit fed to grow 1.54 lbs/d produced 7.1 percent more milk than heifers fed near ad libitum (2.20 lbs/d) which was attributed to differences in prepuberty mammary development which was the central hypothesis of the experiment. Lammers et al., (1999) observed no negative effects of limit feeding on body weight (**BW**), calf birth weight or dystocia index.

North Dakota researchers (Ford and Park, 2001, Park et al., 1998) have hypothesized that dietary energy restriction followed by realimentation stimulates rapid and greater expression of mammary tissue resulting in improved milk production. The work has demonstrated alteration of hormonal signaling, increased genetic expression of mammary tissue and up to 15% improvements in milk production. Similar to Lammers et al. (1999), the

experimental methodology (Ford and Park, 2001) used to implement energy restriction realimentation protocols was limit feeding. Control heifers were allowed ad libitum access to a diet containing 12% CP and 1.07 Mcal/lb of ME while energy restricted realimentation heifers were limited to 70% of the same diet during energy restriction phases. Limiting feed intake to 70% of the control diet resulted in improving feed efficiency approximately 30%. The hypothesis and design of these experiments was to investigate energy restriction which yielded positive lactation responses. The energy restriction however was facilitated by limit-feeding, not by energy dilution of the diet. Data suggest there were no negative confounding aspects associated with limit-feeding to facilitate limiting dietary energy intake.

There are additional studies in the literature (Carson et al., 2000, Hof and Lenaers, 1984, Sejrsen and Foldager, 1992 and Van Amburgh et al., 1998) that employed some form of limit-feeding to investigate an alternative hypothesis in heifer production and management. While no direct linkage can be made from experimental results to limit-feeding per se the limit-feeding methodology employed in these experiments did not result in any negative effects on milk production. In all experiments outlined above milk production was numerically greater for any treatment, regardless of hypothesis studied, for heifers that were limit fed as a part of the methodology.

■ Limit-feeding Research – Central Hypothesis

As previously stated limit-feeding is not new and has been employed by researchers as a method to execute experimental designs for other hypotheses. Likewise it can be assumed that some forms of limit-feeding heifers have been employed by dairy producers over time. Recently, it has been consciously recognized that limit-feeding methods applied in experiments appear to have a more robust applied utility. Limit-feeding has been utilized in experiments as a method to control growth rates, decrease energy intake, decrease feed usage, improve feed efficiency or improve lactation performance. These are exactly the same goals as the goals of commercial heifer production. As result two recent experiments have been conducted evaluating limit-feeding as a central hypothesis to explore applied applications.

At the University of Wisconsin we explored a simple limit-feeding feeding system for bred replacement heifers (Hoffman et al., 2007). A summary of trial results is presented in Table 1. Bred Holstein heifers were fed diets (C-100, L-90 and L-80) containing 67.5, 70.0 and 73.9% TDN respectively but heifers fed the 70.0 and 73.9 percent TDN diets were limit-fed at 90 and 80 percent of their intake potential. The study was designed to provide iso-caloric and iso-nitrogenous intakes. Limit-feeding resulted in heifers being fed less DM per day but the total amount of calories consumed per day was equal.

We did not observe any differences in the size or body condition scores of the heifers after a 111 day feeding period. The limit-feeding regimen however resulted in a 25% improvement in feed efficiency and heifers excreted significantly less manure. We observed no effects of limit feeding heifers on calf BW or dystocia index. As with pseudo limit-feeding experiments we observed a numerical trend in improved milk yield but true lactation performance was similar between control and limit-fed heifers.

Table 1. University of Wisconsin limit feeding trial: Summary of results (Hoffman et al., 2007)

		Treatment[1]				Effect(P>)[2]		
Item		C-100	R-90	R-80	SEM	Treatment	Linear	C vs R
Diet								
	Forage	94.3	80.3	62.7				
	Concentrate	5.7	19.7	37.3				
	NDF	47.3	41.8	35.6				
Nutrient intake, lbs/d								
	DM	21.3	19.9	18.3	0.4	0.01	0.003	0.006
	CP	2.42	2.54	2.57	0.03	0.07	0.03	0.03
	NDF	10.06	8.29	6.50	0.16	0.0003	0.0001	0.0002
	NE_g, Mcals/d	9.4	9.4	9.5	0.2	…	…	…
Weight								
	Initial, lbs	1036	1021	1011	21	…	…	…
	Final, lbs	1220	1234	1217	19	…	…	…
Feed efficiency								
	lbs DM/lb gain	13.2	10.7	11.1	0.9	…	…	0.09
Excretion								
	DM, lbs/d	7.7	6.9	5.8	0.6	…	0.10	0.10
Parturition								
	Dystocia index[3]	2.2	2.1	1.9	0.3	…	…	…
	Calf BW, lbs	91.4	93.3	95.1	3.1	…	…	…
	Postpartum BW, kg	1238.0	1245.0	1275.0	20.9	…	…	…
Lactation performance (0-150 DIM)								
	Milk yield, lbs/d	68.8	68.9	72.4	1.7	…	…	…
	Milk fat, %	3.89	3.74	3.68	0.09	…	…	…
	Milk protein, %	2.87	2.85	2.89	0.03	…	…	…

[1] C100, control heifers fed ad libitum, L90, limited to 90.0 percent of intake, L80, limited to 80.0 of intake. Treatment means expressed as least square means on a per heifer basis.

[2] C=Control (C-100) vs L=Limited (L90,L80). Entries without values are not significant (P>0.10). Trt = treatment.

[3] Dystocia index, 1= no problem, 2 = slight problem, 3 = needed assistance, 4 = considerable force, and 5 = extremely difficult.

A second study with limit-feeding as a central hypothesis was conducted at the Pennsylvania State University (Zanton and Heinrichs, 2007). This study was uniquely different than our study at the University of Wisconsin. Our study was conducted on bred heifers (1000 lbs) with a short experimental period (111 d). The Penn State study was conducted on heifers weighing 275 lbs and heifers were limit-fed for the entire prepubertal period (245 d) and then fed a common diet post puberty. The level of concentrate in the limit fed diet (75%) was more intensive than the level of concentrate we fed to bred heifers (37%). A summary of key results of the Penn State study are presented in Table 2. Limit feeding 300 lb Holstein heifers diets containing

25% forage as compared to feeding diets containing 75% forage ad libitum resulted in no differences in ADG or skeletal growth of heifers. Heifers reached puberty at the same age and had similar reproductive performance. Heifers calved at the same age but limit-fed heifers had numerically higher BW at calving and lost more BW after calving. As with previous studies limit-fed heifers produced numerically higher amounts of milk with similar milk composition.

Table 2. Penn State limit feeding trial: Summary of results (Zanton and Heinrichs, 2007)

		Treatment			
Item		Control	Limit-fed	SEM	P <
Diet					
	Forage	75	25		
	Concentrate	25	75		
Gain					
	Body weight, lbs/d	1.82	1.82	0.02	NS
	Withers height, in/d	0.04	0.04	0.0007	NS
Reproduction					
	Age @ puberty,d	333.0	320.0	6.0	NS
	Conception rate, %	83.0	75.0	7.0	NS
Parturition					
	Age @ calving, mo	23.3	23.5	0.2	NS
	Postpartum BW, kg	1179.0	1232.0	24.2	NS
Lactation performance (0-150 DIM)					
	Milk yield, lbs/d	69.7	76.3	3.2	NS
	Milk fat, %	3.71	3.95	0.11	NS
	Milk protein, %	3.12	3.02	0.04	NS

It is important to recognize the uniqueness of each of these studies. In the Wisconsin study heifers were limit-fed post puberty while the heifers in the Penn State study were limit-fed pre puberty. Both limit-feeding strategies resulted in similar animal performance. To date there are no studies evaluating limit-feeding heifers throughout the majority of the rearing period.

■ Limit-feeding – Changes in Heifer Behavior

There are some changes in heifer behavior as a result of limit feeding. In our study at the University of Wisconsin (Hoffman et al., 2007) we monitored several aspects of heifer behavior and data are presented in Table 3. First, heifers vocalize to a minor extent for approximately one week with vocalization diminishing thereafter. Vocalization is primarily limited to bellowing immediately prior to feeding. In addition, eating time is logically reduced when heifers are limit-fed but heifers appear to compensate for

reduced eating times by standing more which ultimately reduces lying times. Despite observation of changes in behavior, the behavioral changes we observed when heifers are limit-fed appear to be subtle and manageable.

Table 3. Behavior of limit fed heifers when group fed (Hoffman et al., 2007)[1].

	Treatment[2]				Effect(P<)[3]	
Item	C-100	L-90	L-80	SEM	Trt	TrtxWeek
Eating, % of time	19.3	15.7	10.3	0.6	0.0001	…
Standing, % of time	19.6	24.4	32.9	0.7	0.0001	…
Lying, % of time	60.9	59.8	56.7	0.5	0.0001	…
Vocalization, % of time	0.02	0.04	1.10	0.2	0.0001	0.03
Eating, hrs/day	2.3	1.9	1.2	0.1	0.0001	…
Standing, hrs/day	4.7	5.8	7.9	0.2	0.0001	…
Lying, hrs/day	14.6	14.4	13.6	0.1	0.0001	…

[1]Time associated with involuntary behavior such as barn cleaning, blood sampling etc. was not recorded therefore percent of time and hours of time will not equal 100 and 24 respectively.
[2] C-100, control heifers fed ad libitum, L-90, limited to 90.0 percent of intake, L-80, limited to 80.0 of intake. Treatment means expressed on a per heifer basis.
[3] Trt = treatment. Entries without values are not significant (P>0.10).

We have observed some undocumented quirks in heifer behavior as a result of limit-feeding. In preface to explaining these observations it should be noted that in most experiments defined above the heifers were individually fed. For example, in the experiment recently published by Zanton and Heinrichs (2007), the heifers were individually fed via calan gates. Limit-feeding heifers individually does not allow observation of group feeding behavior dynamics which could be altered by limit-feeding. In our study, heifers were fed in pens (6 heifers/pen) because pen was used as the experimental unit. At the time of the experiment we failed to anticipate changes in bunk (eating) behavior and did not quantify these issues. As a result, changes in bunk behavior noted in this paper are empirical but we feel worthy of mention.

Changes in eating behavior of heifers limited to 80-90% of ad libitum intake are subtle and overly aggressive eating behavior was not observed. However, heifers while eating efficiently push feed forward perpendicular to the feed bunk with their muzzle. When fed on a flat feeding surface a large portion of diet will be pushed out of reach by the heifers. If heifers have not reached fill or satiety, heifers will aggressively reach in an attempt to acquire feed that they have displaced too far forward. This reaching behavior requires heifers to splay their fore and hind legs to create torque to lean forward. The long term effect of this behavior on foot and leg health is not known. We corrected this behavior by frequently pushing remaining feed up proximal to the fence line. As a result we would caution that increased feed push ups may be required when limit feeding heifers in a flat manger.

Another undocumented behavioural change we observed is that heifers

appear to become acclimated to limit-feeding regimens and eating behaviors carry over for a short time after limit-feeding is discontinued. After our experimental period we transitioned the heifers to a common high bulk, high NDF diet. For a short period of time (5-7 days) heifers ate this diet as if limit-fed. Visual evidence of additional ruminal distention was obvious. These observations suggest heifers have the ability to rapidly increase rumen volume. Quick and rapid extension of rumen volume has been well documented in lactating dairy cows (Dado and Allen, 1995).

Adequate bunk space is required to assure all heifers have full access to feed because heifers fed to 80% of intake potential will consume all feed available within 2-3 hours. Lack of adequate bunk space could result in displacements at the bunk and ultimately result in un-even ADG. We observed small numerical increases in ADG variance when heifers were limit-fed but variance in ADG was not significant when 1000 lb heifers were allowed 24 inches of bunk space/heifer. The critical lower limit of bunk space per heifer under various limit-feeding scenarios is not known. Finally limit-feeding cannot be implemented where edible bedding such as straw, grass, corn stalks etc is used as heifers will consume bedding to reach satiety.

■ Phosphorus Reduction

Phosphorus requirements, as percent of dietary dry matter (DM) for heifers (0.20-0.35%) and endogenous levels of P in feeds (0.20-35 % of DM) are similar suggesting supplementation of P in heifer diets may be infrequently required. Recently, Esser et al. (2009), fed heifers diets with (0.39%) and without (0.29%) supplemental P from 4-21 mo of age. Two sub-populations of heifers were selected mid-trial for intensive measurement of bone development and metabolism. Thirty-two heifers were evaluated for bone development and measurements included hip height, length, heart girth, hip width, cannon bone circumference, pelvic length, pelvic height, and pelvic width. Tails of heifers were surgically amputated with the 13 and 14th coccygeal vertebrae retained. After tissue removal, the 13th coccygeal vertebrae were scanned using peripheral quantitative computed tomography with cortical, trabecular and total bone densities determined. A second sub-population (n=64) of heifers were evaluated for serum pyridinoline and osteocalcin to assess systemic bone metabolism. Supplementing P had no effect on external frame measurements, bone density, or bone metabolism markers. Bone P content was lower (18.1 vs. 18.6%) in heifers fed no supplemental P. Phosphorus supplementation to heifers modestly increased bone P content but increased bone P was not reflected in frame growth, bone density or bone metabolism. As a result, if dietary feedstuffs contain P proximal to the P requirement supplemental P may not be required for dairy heifers.

Conclusions

To date the following can be concluded about limit-feeding and P supplementation to dairy heifers.

Limit-feeding decreases feed usage, manure excretion and improves feed efficiency of dairy replacement heifers.

There are no research trials indicating that limit-feeding has a detrimental effect on heifer/cow health or future lactation performance.

A hypothesis could be constructed that limit-feeding may improve milk production but mechanisms are not known.

Limit-feeding does result in some minor changes in heifer behaviour, and management may need to be modified to account for such behavior.

Limit-feeding cannot be implemented when bunk space is limited or in housing systems using edible bedding.

Supplemental P can be reduced or eliminated if basal feeds contain P proximal to the P requirements of dairy heifers.

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