MANIPULATING FORAGE-TO-CONCENTRATE RATIOS TO ENHANCE PERFORMANCE AND CARCASS TRAITS OF HOLSTEIN STEERS

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Introduction

Modern dairy beef feeding requires close attention to a host of nutrition and management factors that affect gain, efficiency of gain, carcass traits, and profitability. One tool the nutritionist and feedlot operator has is manipulation of forage:concentrate (F:C) ratios. Initial research and development in F:C ratios was primarily to determine the performance response by dairy beef steers to increasing dietary energy density. During this process, some determinations were made relative to forage source and grain source and processing. As the dairy beef feeding segment of the US feedlot industry developed, and value-based marketing was implemented in marketing dairy beef steers, feedlot operators and nutritionists must evaluate manipulation of F:C ratios to enhance performance, carcass quality or both. The following is a review of pertinent literature concerning manipulation of F:C ratios with special regard to effects on enhancing feedlot performance and carcass traits. Due to a lack of inclusive research reports, the reader is referred to other excellent reviews in these proceedings for self-interpretation on the interaction of anabolic growth promotants, ß-agonists, intake manipulation strategies, and use of alternative feeds with manipulation of F:C ratios on enhancement of carcass performance and carcass traits, although some speculative remarks as to this interaction are included herein.

Forage:Concentrate Ratios in Growing Diets

Energy concentration in diets of weaned calves is typically based on economics (Chester-Jones et al., 1998). Generally, feeding high-forage diets leads to slower growth rates with variable results on DMI, but lower feed efficiency because of lower diet digestibility of forage relative to grain. However, certain interactions between forage type, concentration and moisture content are noteworthy.

Feeding growing Holstein calves (from 145 kg to 250 kg) a diet containing 71% corn silage (Table 1) led to slower ADG at greater ($P < 0.05$) DMI and feed DM/kg gain (Miller et al., 1986). Gain decreased ($P < 0.05$) and greater ($P < 0.05$) feed DM/kg gain (Table 1) was required when alfalfa hay:high moisture shelled corn ratios increased in diets of growing Holstein calves (180 to 300 kg; Siemens, 1994). Feeding alfalfa hay of higher quality (21% CP, 33% ADF vs 15% CP, 40% ADF) in that study had no effect ($P > 0.05$) on growth or feed conversion unless diets contained 70% alfalfa hay (Table 1). There were no differences ($P > 0.05$) in DMI due to concentration of alfalfa hay in diets or hay quality. Similar results were observed using alfalfa silage and dry shelled corn (Ainslie et al., 1992). Feeding increasing concentrations of alfalfa silage (from 7% to 40% of the diet DM in two trials) resulted in lower ($P < 0.05$) ADG and greater ($P < 0.05$) feed DM/kg gain in growing (start BW: 156 kg end BW: 270 to 400 kg) Holstein steers

(Table 1). Dry matter intake was not affected by diets containing > 8% alfalfa silage. In contrast, concentration of dried sugar beet pulp (ranging from 0% to 30% of the diet dry matter) had no effect ($P > 0.05$; Table 1) on ADG of growing (154 to 320 kg) Holstein calves, although more ($P < 0.05$) feed DM/kg gain was required by calves fed 15% beet pulp (Chester-Jones et al., 1991). At 30% inclusion of sugar beet pulp, ADG, DMI and feed conversion were not different ($P > 0.05$) than at 0% inclusion. Similarly, feeding increasing concentrations of dry distiller's grains with solubles (Table 1) increased DMI ($P < 0.05$), tended to increase ADG ($P < 0.10$), and had no effect on feed conversion ($P > 0.05$) of growing (195 to 320 kg) Holstein steers (Trenkle, 2004). These findings suggest that NDF source and content interact to produce different results on performance. In vitro digestibility of the NDF fraction from ground alfalfa was lower than that of ground beet pulp or dry distillers' grains (Bhatti and Firkins, 1995). Also, at moderate inclusion of barley grain or sugar beet pulp, total tract OM and NDF digestion was greater for diets containing beet pulp (Richardson et al., 2003). Indeed, DM, OM or carbohydrate digestibility of diets containing 0% to 30% dried sugar beet pulp in a continuous fermentation system was similar ($P > 0.05$; Chester-Jones et al., 1991). Although some differences in response to increasing roughage in diets of Holstein steers may exist between typical forages and byproducts, due in large part to NDF digestibility, the response by growing Holstein steers to corn silage or alfalfa as the forage source does not seem to differ. Holstein steers fed 40% corn or alfalfa haylage during the growing phase had similar ADG (Comerford et al., 1992).

Table 1. Forage-to-concentrate ratios in growing diets and Holstein steer performance

Roughage	% [a]	Type or % DM [b]	In wt, kg	ADG, kg/d	DMI, kg/d	kg DM/ kg gain	Reference
Forage							
control	92	RCorn	144	1.10 [c]	5.00 [c]	4.62 [c]	Miller et al., 1986
corn silage	71	35% DM	146	0.96 [d]	5.24 [d]	5.45 [d]	Miller et al., 1986
alfalfa hay [i]	10	HQ	181	1.55 [c]	5.86 [c]	3.79 [c]	Siemens, 1994
alfalfa hay	10	LQ	181	1.47 [cd]	5.99 [cd]	4.08 [cd]	Siemens, 1994
alfalfa hay	30	HQ	181	1.42 [d]	6.35 [cd]	4.45 [de]	Siemens, 1994
alfalfa hay	30	LQ	181	1.45 [cd]	6.40 [d]	4.41 [de]	Siemens, 1994
alfalfa hay	50	HQ	181	1.30 [e]	6.12 [cd]	4.71 [ef]	Siemens, 1994
alfalfa hay	50	LQ	181	1.22 [e]	6.21 [cd]	5.09 [fg]	Siemens, 1994
alfalfa hay	70	HQ	181	1.21 [e]	6.30 [cd]	5.21 [g]	Siemens, 1994
alfalfa hay	70	LQ	181	1.03 [f]	6.03 [cd]	5.83 [h]	Siemens, 1994
alfalfa	7	Silage	156	1.38 [c]	6.14 [c]	4.45 [c]	Ainslie et al., 1992, Trial 1
alfalfa	22	Silage	156	1.25 [d]	5.91 [d]	4.73 [d]	Ainslie et al., 1992, Trial 1
alfalfa	40	Silage	156	1.14 [e]	5.81 [d]	5.10 [d]	Ainslie et al., 1992, Trial 1
alfalfa	8	Silage	156	1.71 [c]	7.53	4.43 [c]	Ainslie et al., 1992, Trial 2
alfalfa	39	Silage	156	1.50 [d]	7.29	4.86 [d]	Ainslie et al., 1992, Trial 2

Table 1. Forage-to-concentrate ratios in growing diets and Holstein steer performance (cont'd)

Roughage	% [a]	Type or % DM [b]	In wt, kg	ADG, kg/d	DMI, kg/d	kg DM/ kg gain	Reference
Dry byproduct							
control	75	RCorn	155	1.45	6.40 [c]	4.41 [c]	Chester-Jones et al., 1991
beet pulp	15	Dry	153	1.37	6.99 [d]	5.10 [d]	Chester-Jones et al., 1991
beet pulp	30	Dry	154	1.36	6.75 [cd]	4.96 [cd]	Chester-Jones et al., 1991
control [j]	83	RCorn	197	1.37	6.03	4.40	Trenkle, 2004
distillers	10	Dry	194	1.38	6.03	4.37	Trenkle, 2004
distillers'	20	Dry	195	1.42	6.17	4.35	Trenkle, 2004
distillers'	40	Dry	196	1.42	6.17	4.34	Trenkle, 2004
Wet byproduct							
corn silage	60	36% DM	197	1.17 [c]	6.66 [c]	5.66	Chester-Jones et al., 1988
sweet corn	60	71% DM	196	0.75 [de]	4.95 [d]	6.62	Chester-Jones et al., 1988
sweet corn	60	78% DM	198	0.75 [de]	4.84 [d]	6.47	Chester-Jones et al., 1988
sweet corn	60	83% DM	192	0.64 [e]	4.20 [e]	6.56	Chester-Jones et al., 1988
control [j]	83	RCorn	197	1.37	6.03	4.40	Trenkle, 2004
distillers'	10	Wet	195	1.33	5.62	4.22	Trenkle, 2004
distillers'	20	Wet	194	1.34	5.44	4.05	Trenkle, 2004
distillers'	40	Wet	193	1.13	4.54	4.01	Trenkle, 2004

[a] For control diet, proportion of gain, or for roughage treatment, proportion of forage in the growing period.
[b] Description of roughage or grain source (control), or DM content of feed in first column. RCorn = rolled corn.
[c,d,e,f,g, h] Means within study with uncommon superscripts differ (P < 0.05).
[i] HQ = high (21% CP, 33% ADF) vs LQ = low (15% CP, 40% ADF) quality.
[j] Linear effects tested by regression.

Moisture concentration of forage may also interact with forage source to affect DMD. Holstein calves fed 60% (diet DM) sweet corn processing waste (Table 1; a mixture containing 90% husk and leaf, 8% cob, and 2% kernel plus washed corn screenings with 5% solids; 17.6% to 28.7% DM; 6.6% to 8.2% CP; 42.3% to 43.8% ADF) of varying moisture content (71% to 83%) had lower DMI (P < 0.05) which resulted in slower (P < 0.05) ADG and greater (P < 0.05) feed DM/kg gain than a control group fed regular dent corn silage at 60% of the diet DM (Chester-Jones et al., 1988). Diet DMD was lower (P < 0.05) for sweet corn processing waste-based diets. In contrast, feeding diets containing increasing concentrations of wet distillers' grains to growing Holstein steers (Table 1) resulted in decreased DMI and gain (P < 0.05), but less (P < 0.05) feed DM/kg gain (Trenkle, 2004). Although total tract OM of dry rolled corn was not different than that of wet distillers' grains, total tract starch and NDF digestion of wet distillers' grains were greater than those of dry rolled corn (Ham et al., 1994).

Forage:Concentrate Ratios in Finishing Diets

Because of changes in feeding and management of Holstein steers toward more integrative feeding and management approaches, availability of heavy Holstein steers for finishing only is diminishing. Thus, studies evaluating responses by heavy Holstein steers to varying concentrations of forage and grain or energy are scarce.

Feeding 265-kg Holstein steers diets containing 71% corn silage (diet DM) resulted in greater DMI ($P < 0.05$) with no change ($P > 0.05$) in ADG, which led to greater ($P < 0.05$) feed DM/kg gain (Miller et al., 1986). More recently, 410-kg Holstein steers fed diets containing from 0% to 12% corn silage and whole shelled corn had linearly greater ($P <0.05$) DMI with no change ($P < 0.05$) in ADG, thus feed DM required/kg gain decreased ($P < 0.05$) linearly with increasing corn silage content (Parsons et al., 1998a). Apparently, corn processing (dry whole vs dry rolled) had no effect ($P > 0.05$) on performance of finishing Holstein steers fed diets containing 7.5% (Parsons et al., 1998b) or 21% corn silage (Hanson et al., 1984). During the finishing period, Holstein steers fed increasing concentrations of alfalfa hay of high (21% CP, 33% ADF) or low quality (15% CP, 40% ADF; Siemens, 1994) had decreasing ($P < 0.05$) ADG and increasing ($P < 0.05$) feed DM/kg gain. Intake increased ($P < 0.05$) with increasing concentrations of alfalfa hay. No differences due to CP and ADF content of alfalfa were noted.

Increasing energy density of finishing Holstein steer diets by the use of supplemental fat is an alternative to manipulating the F:C ratio. Feeding yellow and griddle grease or a 50:50 mixture enhanced ($P < 0.05$) ADG and less ($P < 0.05$) feed DM was required/kg gain with no effect ($P > 0.05$) on DMI (Plascencia et al., 1999). Yellow and griddle grease represent fat sources with low and high concentrations of free-fatty acids (FFA), respectively. From this study, it appeared that increasing concentrations of FFA enhanced DMI ($P < 0.05$) through greater diet acceptability. This effect led to a linear improvement ($P < 0.05$) in ADG and feed conversion. However, there were no differences ($P > 0.05$) in ruminal or total tract digestion of OM, ADF, starch or N due to fat supplementation or FFA concentration.

It is apparent that performance of finishing Holstein steers fed diets with various F:C ratios is fairly predictable and similar to that of steers of beef breeds under the same conditions. As forage concentration increased, DMI increased, but ADG was unchanged thereby resulting in lower feed efficiency (DiCostanzo et al., 1997, 1998; Loerch and Fluharty, 1998).

Carryover Effects of Growing Diet F:C Ratio on Finishing Period Performance.
Reviewing carryover effects of growing diet energy concentration or F:C ratio on finishing Holstein steer performance is of particular interest because several program feeding schemes rely on manipulating dietary energy concentration or intake via F:C ratios or intake management. Thus, when developing or implementing program feeding schemes, the user must be aware of the potential consequences of dietary

manipulations during the growing phase, and evaluate whether these are ultimately contributing positively to overall performance and profitability.

Table 2. Effects of various forage-to-concentrate ratios in the growing period on Holstein steer performance during the finishing period

Forage	%[a]	Grain [b]	In wt, kg	ADG, kg/d	DMI, kg/d	kg DM/ kg gain	Reference
Control	95	RCorn	269	1.24	7.48 [c]	6.02 [c]	Miller et al., 1986
Corn silage	71	RCorn	269	1.23	8.52 [d]	6.93 [d]	Miller et al., 1986
Alfalfa silage	7	WCorn	290	1.19	8.27 [c]	6.95	Ainslie et al., 1992, Trial 1
Alfalfa silage	22	WCorn	279	1.34	8.47 [d]	6.32	Ainslie et al., 1992, Trial 1
Alfalfa silage	40	WCorn	269	1.31	8.76 [d]	6.68	Ainslie et al., 1992, Trial 1
Alfalfa silage	8	WCorn	419	0.75 [c]	8.72 [c]	11.60 [c]	Ainslie et al., 1992, Trial 2
Alfalfa silage	39	WCorn	389	0.93 [d]	9.35 [d]	10.10 [d]	Ainslie et al., 1992, Trial 2
Control	70	HMCorn	350	1.41 [c]	NA	NA	Schoonmaker et al., 2004
Program gain	70	HMCorn	292	1.69 [d]	NA	NA	Schoonmaker et al., 2004
Haylage	42	HMCorn	284	1.68 [d]	NA	NA	Schoonmaker et al., 2004

[a] For control diet, proportion of gain, or for forage treatment, proportion of forage in the growing period.
[b] RCorn = rolled corn; WCorn = whole corn; HMCorn = high moisture corn.
[c,d] Means within study and trial with uncommon superscripts differ ($P < 0.05$).

Holstein steers fed 71% corn silage (diet DM; Table 2) during the growing period had similar ADG ($P > 0.05$), but as a result of greater ($P < 0.05$) DMI they required more ($P < 0.05$) feed DM/kg gain than steers fed 100% concentrate (corn and supplement; Miller et al., 1986). Similarly, Holstein steers fed 7% alfalfa silage in the growing period (Trial 1; Table 2) had lower ($P < 0.05$) DMI, but ADG and feed conversion were unaffected ($P > 0.05$) during the finishing period (fed a common diet) when compared to steers fed 22% or 40% alfalfa silage in the growing period (Ainslie et al., 1992). In another trial (Trial 2; Table 2) in the same study, Holstein steers fed 8% alfalfa silage in the growing period had significantly lower ($P < 0.05$) DMI, ADG, and greater ($P < 0.05$) feed DM required/kg gain during the finishing period (fed a common diet) than steers fed 39% alfalfa silage in the growing period. Differences in response during the finishing period may reflect greater ADG achieved by steers fed 8% alfalfa silage in Trial 2 vs those fed 7% alfalfa hay in Trial 1 (1.71 vs 1.25 kg/d). Cattle fed lower energy diets during a growing period are known to compensate during the finishing period with increased DMI and ADG. In a study designed to test effects of programmed gain (0.8 kg/d for 55 d, then 1.2 kg/d for 98 d) against ad libitum high-concentrate (80%) feeding or programmed forage feeding (ad libitum 60% haylage for 55 d, then 25% haylage for 98 d), Schoonmaker et al. (2004) observed that Holstein steers fed high-concentrate diets ad libitum had slower ($P < 0.05$) ADG during the finishing period (Table 2).

Growing-Finishing Programmed Intake or Variable Roughage Feeding Systems

Changes in dairy beef feeding systems occurred recently as a result of increased awareness by cattle feeders of the need to deliver a product of consistent quality to the packer. Initially, one of the issues of greatest concern in carcass quality of Holstein cattle was size required to reach Choice grade. This led to oversized carcasses that dragged off the rails at many packing plants. Concurrently, intake management programs and variations in F:C ratios were being developed for both beef and dairy breeds in an effort to enhance performance in the feedlot and on the rail. Today, because of the increased reliance on value-based marketing, longissimus area and dressing percentage, in addition to adequate marbling, are challenges for the nutritionist formulating diets and recommending dietary manipulations for Holstein steers in integrated systems from calf to finished steer. Thus, it is important to review effects of growing-finishing programmed intake or variable roughage feeding systems on feedlot performance and carcass traits.

Manipulation of F:C ratios during the growing period of Holstein steers was initially attempted to evaluate effects of this strategy on overall performance and profitability. Feeding Holstein steers diets containing 71% corn silage during the growing period, and 27% corn silage during the finishing period had greater ($P < 0.05$) DMI and feed DM/kg gain than steers fed 100% concentrate during the entire feeding period (Miller et al., 1986). The only significant effect of feeding higher proportions of corn silage on carcass traits was reduced yield grade. Holstein steers consuming diets containing corn silage in the growing and finishing periods had the greatest ($P < 0.05$) DMI, while those shifted from high corn silage diets in the growing period to high concentrate diets in the finishing period were intermediate, and those consuming high concentrate diets throughout both the growing and finishing feeding periods were lowest ($P < 0.05$).

Feeding high-corn silage diets in the growing (from 29% to 55% DM basis) period followed by finishing diets containing from 17% to 29% corn silage (Table 3) resulted in greater ($P < 0.05$) ADG and less ($P < 0.05$) feed DM/kg gain, and production of carcasses (Table 4) with more ($P < 0.05$) fat, marbling and higher quality grade than those of steers on two-phase systems (86% or 55% corn silage in the growing, and 9% alfalfa hay in the finishing period; Miller et al., 1986). Similarly, Holstein steers consuming diets containing from 25% to 75% alfalfa hay (DM basis; Table 3) for the growing and finishing periods had slower ($P < 0.05$) ADG and required more ($P < 0.05$) feed DM/kg gain than those fed 75% alfalfa hay in the growing and 9% alfalfa hay in the finishing period (two-phase). Steers on the two-phase alfalfa system had carcasses with higher ($P < 0.05$) marbling scores and quality grades (Table 4). Steers on the two-phase system gained faster ($P < 0.05$) and had carcasses of similar ($P > 0.05$) marbling scores as those fed 9% alfalfa hay in the growing and finishing periods (Miller et al., 1986).

As demonstrated by several studies, the two-phase system may be a viable alternative, as long as forage proportion of growing diets is kept to less than 55% (DM basis). Ainslie et al. (1992) fed growing Holstein steers diets containing from 7% to 40% (Trial 1) or from 8% to 39% (Trial 2) alfalfa silage, followed by finishing diets containing 9% (Trial 1) or 12% (Trial 2) alfalfa silage. They reported no effect ($P > 0.05$) of growing diet on ADG, feed conversion (Table 3) or carcass traits (Table 4). In contrast, Holstein steers fed high-forage diets (> 55% DM) during the growing period (Table 3) were not able to recover gain and required more ($P < 0.05$) feed DM/kg gain during the finishing period (Miller et al., 1986).

Reported differences in response to feeding alfalfa or corn silage as the forage source may be due to diet metabolizability. Holstein steers on a two-phase system based on corn silage had faster ($P < 0.05$) gains with lower ($P < 0.05$) DMI and less ($P < 0.05$) feed DM/kg gain (Table 3) than those on a two-phase system based on alfalfa silage (Comerford et al., 1992). There were no differences ($P > 0.05$) in carcass characteristics, but steers fed corn silage had greater dressing percentage than those fed alfalfa silage (Table 5). Similarly, Holstein steers fed on a corn silage two-phase system had lower ($P < 0.05$) DMI and required less ($P < 0.05$) feed DM/kg gain albeit at slower ($P < 0.05$) ADG than those fed on an alfalfa hay two-phase system (Miller et al., 1986). In the study of Comerford et al. (1992), differences in performance between alfalfa and corn silage were due to greater efficiency of use of corn silage residual ME (ME intake above maintenance) for gain.

Holstein steer fed growing-finishing diets containing higher proportions of corn silage (Table 3) required more ($P < 0.05$) feed DM/kg gain and had lower ($P < 0.05$) ADG, marbling, fat depth and quality grade (Table 4), but higher ($P < 0.05$) yield grade (Miller et al., 1986). Holstein steers fed whole corn and a pellet or those fed whole corn, pellet and limit-fed or fed grass hay ad libitum (Table 3), resulting in hay consumption of 4% or 6% hay (DM basis) respectively, had similar ($P > 0.05$) ADG and feed conversion (Chester-Jones et al., 1993). Steers fed free-choice hay tended ($P < 0.10$) to consume more DMI than those fed whole corn and pellet. Changing forage-to-concentrate ratios from 10% to 40% corn silage:high moisture corn in diets of growing-finishing Holstein steers (Schaefer, 1986) had no impact ($P < 0.05$) on DMI, but ADG decreased ($P < 0.05$) linearly (Table 3). There were no differences ($P > 0.05$) in feed conversion for steers fed 10% or 25% corn silage diets. Increasing proportion of alfalfa hay in growing-finishing diets increased feed DM/kg gain, and reduced ($P < 0.05$) ADG, marbling, fat depth, and quality grade (Table 3 and 4). Yield grade increased with increasing hay content (Miller et al., 1986). High (21% CP, 33% ADF) or low (15% CP, 40% ADF) quality alfalfa hay fed in increasing proportions in growing-finishing diets had no effect ($P > 0.05$) on ADG or DMI unless diets contained 70% alfalfa hay (Siemens, 1994). More ($P < 0.05$) feed DM/kg gain was required by steers fed diets containing 50% or 70% high-quality alfalfa hay (Table 3). There were no differences ($P > 0.05$) due to quality other than for ADG ($P < 0.05$) when diets contained 70% alfalfa hay.

Table 3. Forage-to-concentrate ratios in the growing-finishing period and Holstein steer performance

Forage	Growing	Finishing	In wt, kg	ADG, kg/d	DMI, kg/d	kg DM/ kg gain	Reference
Alfalfa hay [a]	9%	9%	179	1.13	6.70	5.93	Miller et al., 1986
Alfalfa hay	25%	25%	187	1.12	7.38	6.61	Miller et al., 1986
Alfalfa hay	50%	50%	184	0.97	6.95	7.20	Miller et al., 1986
Alfalfa hay	75%	75%	174	0.91	7.09	7.83	Miller et al., 1986
Alfalfa hay	75%	9%	176	1.21	7.74	6.43	Miller et al., 1986
Corn silage	86%	86%	176	0.94	6.91	7.33	Miller et al., 1986
Corn silage	86%	9% hay	176	1.15	6.94	6.02	Miller et al., 1986
Corn silage	55%	9% hay	176	1.18	7.20	6.11	Miller et al., 1986
Corn silage	55%	55%	176	1.25	7.51	5.99	Miller et al., 1986
Corn silage	55%	29%	176	1.35	7.53	5.57	Miller et al., 1986
Corn silage	55%	17%	173	1.39	7.59	5.45	Miller et al., 1986
Corn silage	29%	29%	174	1.38	7.61	5.50	Miller et al., 1986
Corn silage	10%	10%	196	1.59 [b]	7.55	4.75 [b]	Schaefer, 1986
Corn silage	25%	25%	196	1.48 [c]	7.50	5.07 [cd]	Schaefer, 1986
Corn silage	40%	40%	196	1.34 [d]	7.36	5.49 [d]	Schaefer, 1986
Corn:pellet	no hay	no hay	156	1.42	7.26	5.15	Chester-Jones et al., 1993
Corn:pellet	1 lb hay	1 lb hay	156	1.37	7.55	5.53	Chester-Jones et al., 1993
Corn:pellet	free hay	free hay	156	1.37	7.92	5.78	Chester-Jones et al., 1993
HQ [f] alfalfa	10%	10%	181	1.51 [b]	7.71 [b]	5.10 [b]	Siemens, 1994
LQ alfalfa	10%	10%	181	1.43 [bc]	7.76 [b]	5.43 [bc]	Siemens, 1994
HQ alfalfa	30%	30%	181	1.51 [b]	7.98 [bc]	5.30 [bc]	Siemens, 1994
LQ alfalfa	30%	30%	181	1.50 [bc]	7.98 [bc]	5.34 [bc]	Siemens, 1994
HQ alfalfa	50%	50%	181	1.43 [bc]	7.85 [bc]	5.49 [cd]	Siemens, 1994
LQ alfalfa	50%	50%	181	1.43 [bc]	8.07 [bc]	5.66 [cd]	Siemens, 1994
HQ alfalfa	70%	70%	181	1.42 [c]	8.21 [d]	5.81 [de]	Siemens, 1994
LQ alfalfa	70%	70%	181	1.32 [d]	8.07 [bc]	6.10 [e]	Siemens, 1994
Alfalfa silage	7%	9%	156	1.26	7.46 [b]	5.92	Ainslie et al., 1992, Trial 1
Alfalfa silage	22%	9%	156	1.25	7.42 [b]	5.79	Ainslie et al., 1992, Trial 1
Alfalfa silage	40%	9%	156	1.25	7.63 [c]	6.15	Ainslie et al., 1992, Trial 1
Alfalfa silage	8%	12%	156	1.17	8.19 [b]	7.00	Ainslie et al., 1992, Trial 2
Alfalfa silage	39%	12%	156	1.16	8.48 [c]	7.30	Ainslie et al., 1992, Trial 2
Corn silage	40%	20%	216	1.11 [b]	8.21 [b]	7.40 [b]	Comerford et al., 1992
Alfalfa silage	40%	20%	211	1.00 [c]	9.01 [c]	9.01 [c]	Comerford et al., 1992

[a] See text for contrasts.
[b,c,d,e] Means within study and trial with uncommon superscripts differ ($P < 0.05$).
[f] High (21% CP, 33% ADF) quality vs low (15% CP, 40% ADF) quality.

During the mid 1990's, interest in managing intake through limit- or program-feeding strategies was fueled by observations that feed efficiency improved as a result of these strategies (Galyean, 1999). In essence both strategies attempt to accomplish the same thing: limit intake so that cattle perform at levels below ad libitum feeding for the growing period, and, through diminished maintenance needs, and enhanced appetite during the finishing period, feed efficiency is improved. Limit-feeding is more difficult to accomplish because level of ad libitum feeding is difficult to know a-priori. Program feeding accomplishes limit-feeding by formulating or feeding diets for a lower rate of gain. Results of program- or limit-feeding with Holstein steers were similar to those observed with beef breeds.

Table 4. Forage-to-concentrate ratios in the growing-finishing period and carcass traits of Holstein steers[a]

Forage	Dress,%	Fat, cm	REA, cm^2	Mrb [b]	QG [c]	YG	Reference
Alfalfa hay [d]		0.92	66.71	4.6	11.1	2.8	Miller et al., 1986
Alfalfa hay		0.89	65.42	4.3	10.6	2.9	Miller et al., 1986
Alfalfa hay		0.66	67.36	3.8	9.4	2.5	Miller et al., 1986
Alfalfa hay		0.71	67.36	3.9	9.6	2.5	Miller et al., 1986
Alfalfa hay		0.92	64.77	4.5	11.0	2.8	Miller et al., 1986
Corn silage		0.74	66.07	3.9	9.8	2.6	Miller et al., 1986
Corn silage		0.79	65.42	4.2	10.3	2.7	Miller et al., 1986
Corn silage		0.84	64.77	4.3	10.6	2.8	Miller et al., 1986
Corn silage		0.84	66.71	4.2	10.4	2.7	Miller et al., 1986
Corn silage		0.97	66.71	4.8	11.6	2.8	Miller et al., 1986
Corn silage		0.87	68.01	4.6	11.2	2.6	Miller et al., 1986
Corn silage		0.97	67.36	4.9	11.7	2.8	Miller et al., 1986
Corn:pellet	59.4 ^{xy}	0.51 ^{x}	71.25 ^{e}	5.7 ^{x}	13.0	2.1	Chester-Jones et al., 1993
Corn:pellet	58.6 ^{x}	0.36 ^{y}	73.84 ^{ef}	5.2 ^{xy}	12.0	1.8	Chester-Jones et al., 1993
Corn:pellet	59.9 ^{y}	0.43 ^{xy}	76.43 ^{f}	4.9 ^{y}	11.0	1.8	Chester-Jones et al., 1993
Alfalfa silage	61.0		72.50	5.5			Ainslie et al., 1992, Trial 1
Alfalfa silage	60.1		72.63	5.5			Ainslie et al., 1992, Trial 1
Alfalfa silage	60.3		71.79	5.5			Ainslie et al., 1992, Trial 1
Alfalfa silage	61.0		69.04	6.1			Ainslie et al., 1992, Trial 2
Alfalfa silage	60.7		71.50	5.9			Ainslie et al., 1992, Trial 2
Corn silage	60.2 ^{e}	0.54	69.17	5.4	70.0	2.8	Comerford et al., 1992
Alfalfa silage	58.5 ^{f}	0.58	65.30	5.2	53.4	2.7	Comerford et al., 1992

[a] Please refer to Table 5 for explanation of treatments.
[b] Marbling, 4 = slight, 5 = small.
[c] Quality grade, 10 = Select °, 11 = Select $^{+}$, 12 = Choice $^{-}$, 13 = Choice °, or incidence of carcasses grading Choice $^{-}$ or better.
[d] See text for contrasts.
[e,f] Means within study with uncommon superscripts differ ($P < 0.05$).
[x,y] Means within study with uncommon superscripts differ ($P < 0.10$).

Holstein steers on a program-feeding strategy (holding gain to less than 1.2 kg/d for 200 d; Table 5) consumed less feed and gained slower (P < 0.05), but required less (P < 0.05) feed DM/kg gain than those fed ad libitum (Milton et al., 1998). In contrast, holding gain to less than 1.2 kg/d for 153 d (Table 5) resulted in similar (P > 0.05) ADG and feed conversion as Holstein steers fed ad libitum, but at lower DMI (Schoonmaker et al., 2004). In that study, managing intake with high-forage diets (feeding 60% orchard grass haylage for 55 d, followed by 25% orchard grass haylage for 98 d) for the first 153 d on feed led to similar ADG (P < 0.05) and feed conversion at lower DMI than those fed ad libitum. Limit-fed Holstein steers to 95% of ad libitum during the finishing period (Table 5) had similar (P > 0.05) ADG, DMI and feed conversion as those fed ad libitum (Chester-Jones, 1988).

Table 5. Forage feeding strategies or intake manipulations in the growing or finishing period and Holstein steer performance

Strategy or manipulation	Growing	Finishing	In wt, kg	ADG, kg/d	DMI, kg/d	kg DM/ kg gain	Reference
Control	NA	Ad lib	332	1.24	8.84	7.13	Chester-Jones, 1988
Limited	NA	95%	331	1.26	8.47	6.73	Chester-Jones, 1988
Control	Ad lib	Ad lib	140	1.33 [a]	7.80 [a]	5.87	Milton et al., 1998
Program [e]	<1.2 kg	Ad lib	140	1.23 [b]	7.26 [b]	5.90	Milton et al., 1998
Control	Ad lib	Ad lib	139	1.40	8.38	5.99	Schoonmaker et al., 2004
Program	<1.2 kg	Ad lib	138	1.37	7.41	5.41	Schoonmaker et al., 2004
Forage (F)	>25% F	Ad lib	138	1.34	7.99	5.96	Schoonmaker et al., 2004
Ad lib [f]	Silage [g]	WCorn [g]	176	1.31 [a]	8.88	6.76 [a]	Reinhardt et al., 1998
Ad lib	Silage	SFCorn [g]	176	1.28 [a]	8.31	6.49 [ab]	Reinhardt et al., 1998
Limit growing	WCorn	WCorn	176	1.17 [b]	7.86	6.71 [a]	Reinhardt et al., 1998
Limit growing	WCorn	SFCorn	176	1.29 [a]	7.14	5.52 [d]	Reinhardt et al., 1998
Limit growing	SFCorn	WCorn	176	1.26 [a]	7.76	6.17 [b]	Reinhardt et al., 1998
Limit growing	SFCorn	SFCorn	176	1.29 [a]	7.22	5.59 [d]	Reinhardt et al., 1998
Ad lib	WCorn	WCorn	176	1.27 [a]	8.64	6.80 [b]	Reinhardt et al., 1998
Ad lib	SFCorn	SFCorn	176	1.40 [c]	8.20	5.88 [c]	Reinhardt et al., 1998
Control [f]	WCorn	WCorn	153	1.42	7.07	4.98	Traxler et al., 1995
F pellet [h]	WCorn	F pellet	152	1.41	8.03	5.71	Traxler et al., 1995
F pellet	F pellet	WCorn	155	1.46	8.33	5.68	Traxler et al., 1995
F pellet	F pellet	F pellet	153	1.42	8.08	5.68	Traxler et al., 1995
Corn:haylage	WCorn	WCorn	154	1.44	8.42	5.85	Traxler et al., 1995
Corn:haylage	CCorn [e]	CCorn	152	1.39	7.96	5.75	Traxler et al., 1995

[a,b,c,d] Means within study with uncommon superscripts differ (P < 0.05).
[e] Programmed BW gain (kg/d).
[f] See text for contrasts.
[g] Silage = corn silage; WCorn = whole corn; SFCorn = steam-flaked corn; CCorn = cracked corn.
[h] Forage pellet.

There were no effects ($P > 0.05$) of limit-feeding on carcass characteristics of Holstein steers (Chester-Jones, 1988). However, steers limit-fed to gain ≤ 1.2 kg/d for 200 d (Milton et al., 1998) had ($P < 0.05$) less fat, smaller longissimus area, fewer of them reached Choice grade (Table 6), and tended ($P < 0.10$) to have lower marbling scores. In contrast, limit-feeding high-concentrate diets for 153 d had no effect on longissimus area or marbling score, but dressing percentage and fat depth tended to be greater, and yield grade was greater for limit-fed steers (Schoonmaker et al., 2004).

Table 6. Forage feeding strategies or intake manipulations in the growing or finishing period and carcass traits of Holstein steers [a]

Strategy or manipulation [b]	Dress, %	Fat, cm	REA, cm^2	Mrb [c]	QG [d]	YG	Reference
Control	58.4	0.58	70.5	4.6	11.0	2.4	Chester-Jones, 1988
Limited	58.1	0.58	68.3	4.6	11.0	2.5	Chester-Jones, 1988
Control	60.2	0.56 [e]	77.7 [e]	5.3 [x]	74.0 [e]	2.4	Milton et al., 1998
Program	60.1	0.48 [f]	71.8 [f]	5.1 [y]	58.0 [f]	2.6	Milton et al., 1998
Control	58.3 [x]	0.91 [xy]	76.8	5.3	68.7	3.0 [ef]	Schoonmaker et al., 2004
Program	59.6 [y]	1.07 [x]	74.2	5.6	60.0	3.3 [e]	Schoonmaker et al., 2004
Forage (F)	59.0 [xy]	0.79 [y]	78.1	5.1	38.9	2.7 [f]	Schoonmaker et al., 2004
Silage [g]	59.0	0.54	68.3	5.2	65.7	2.7	Reinhardt et al., 1998
Limit WCorn [g]	59.1	0.46	78.3	5.4	80.7	2.3	Reinhardt et al., 1998
Limit SFCorn [g]	59.2	0.52	70.4	5.2	69.4	2.6	Reinhardt et al., 1998
Ad lib WCorn [g]	58.5	0.52	68.7	5.0	58.8	2.6	Reinhardt et al., 1998
Ad lib SFCorn [g]	59.2	0.59	78.7	5.1	52.9	2.3	Reinhardt et al., 1998
Ad lib WCorn [h]	59.3	0.45	72.8	5.4	70.1	2.5	Reinhardt et al., 1998
Ad lib SFCorn [h]	58.7	0.56	72.5	5.2	62.6	2.6	Reinhardt et al., 1998
Control [i]	58.3	0.69	70.4	5.4		2.8	Traxler et al., 1995
F pellet [j]	58.5	0.62	69.5	5.4		2.8	Traxler et al., 1995
F pellet	58.1	0.67	68.8	5.6		2.9	Traxler et al., 1995
F pellet	58.3	0.75	69.5	5.6		2.9	Traxler et al., 1995
Corn:haylage	58.4	0.62	72.0	5.4		2.7	Traxler et al., 1995
Corn:haylage	57.9	0.56	68.6	5.4		2.7	Traxler et al., 1995

[a] Please refer to Table 5 for explanation of treatments.
[b] Silage = corn silage; WCorn = whole corn; SFCorn = steam-flaked corn.
[c] Marbling, 4 = slight, 5 = small.
[d] Quality grade, 10 = Select °, 11 = Select $^+$, 12 = Choice $^-$, 13 = Choice °, or incidence of carcasses grading Choice $^-$ or better.
[e,f] Means within study with uncommon superscripts differ ($P < 0.05$).
[g] Main effect in the growing period.
[h] Main effect in the finishing period.
[i] See text for contrasts.
[j] Forage pellet.
[x,y] Means within study with uncommon superscripts differ ($P < 0.10$).

Interactions between limit-feeding strategies in the growing period and grain source were evaluated Reinhardt et al., 1998). Holstein steers were either fed corn silage diets ad libitum (similar to a two-phase system), whole or steam-flaked corn diets ad libitum or limit-fed during the growing period followed by feeding whole or steam-flaked corn diets ad libitum during the finishing period (Table 5). Steers on the two-phase system had greater ($P < 0.05$) DMI than those limit-fed whole or steam-flaked corn during the growing period. Steers fed whole corn diets ad libitum had greater ($P < 0.05$) DMI than those fed steam-flaked corn diets ad libitum. Also, as expected, steers fed whole corn diets ad libitum throughout the growing and finishing periods consumed more ($P < 0.05$) feed than those limit-fed whole corn diets during the growing period. Gain of steers on the two-phase feeding system was comparable ($P > 0.05$) to that of steers limit-fed steam-flaked corn diets during the growing period regardless of corn processing in the finishing period, or those of steers limit-fed whole corn diets during the growing period and finished on steam-flaked corn diets (Table 5). Results also demonstrated that ADG of steers on a two-phase system was similar ($P > 0.05$) to that of steers fed whole corn diets throughout the growing and finishing period. Limit-feeding whole corn diets during the growing period supported the slowest ($P < 0.05$) ADG while ad libitum feeding steam-flaked corn diets during the growing-finishing period supported the fastest ($P < 0.05$) ADG. Feed conversion appeared to be dependent on choice of processing during the finishing period. Steers fed whole corn diets during the finishing period required the highest ($P < 0.05$) feed DM required/kg gain unless a steam-flaked corn diet was limit-fed during the growing period. Finishing steers on steam-flaked corn diets led to less ($P < 0.05$) feed DM/kg gain; ranking highest for a two-phase system, intermediate for an ad libitum growing-finishing system, and lowest for limit-fed growing system regardless of corn processing.

Steers fed whole corn diets during the finishing or growing period had carcasses with greater ($P < 0.05$) marbling scores (Table 6) than those fed steam-flaked corn diets during the finishing or growing period, respectively. Marbling scores in carcasses of steers fed corn silage or limit-fed whole or steam-flaked corn during the growing period were higher than those of steers fed whole or steam-flaked corn diets ad libitum during the growing period. Perhaps as a result of slower growth rates, longissimus areas of steers limit-fed whole corn diets during the growing period were larger ($P < 0.05$) than those of steers limit-fed steam-flaked corn diets during the growing period. Similarly, longissimus areas of steers fed corn silage or limit-fed whole or steam-flaked corn during the growing period were larger ($P < 0.05$) than those of steers fed whole or steam-flaked corn ad libitum during the growing period. Fat thickness of limit- or corn silage-fed during the growing period was less than that of steers fed whole or steam-flaked corn diets ad libitum.

Intake and feed DM/kg gain were lowest ($P < 0.05$) for Holstein steers fed whole corn throughout the growing-finishing period (Table 5) when compared to steers fed a built-in roughage pellet (in cracked corn-based diets) in the growing, finishing or growing-finishing period, or hay crop silage and cracked or whole corn throughout the growing-finishing period (Traxler et al., 1995). No differences were observed ($P > 0.05$) in ADG, DMI or feed conversion due to forage inclusion treatment (built-in vs haylage, or continued vs single period built-in roughage inclusion), although steers fed whole corn diets and haylage consumed more feed ($P < 0.05$) and had faster ADG ($P < 0.05$) than those fed cracked corn and haylage. Similar to a two-phase system, built-in roughage inclusion during the growing period led to greater ($P < 0.05$) ADG than built-in roughage inclusion during the finishing period.

Other than greater yield grade in carcasses of steers fed built-in roughage relative to those fed hay crop silage, there were no differences in carcass traits of steers fed whole or cracked corn, or timing of built-in roughage inclusion (Table 6).

Conclusions

Manipulating forage-to-concentrate ratios during the growing period is a strategy that can reduce costs. However, it appears that the upper limit of forage inclusion during the growing period should be no more than 55%. Also, corn silage has a slight advantage over alfalfa hay or silage as the forage source, partially because of greater metabolizability of corn silage over alfalfa. Feeding high-forage diets for longer periods of time or at concentrations greater than 55% may not only reduce gain and feed conversion, but it can adversely affect carcass traits, increasing fat depth while reducing marbling score and quality grade. A two-phase feeding system may be recommended when costs of grain are high. In lieu of this system, managing intake through program feeding is a viable alternative, but length of managed intake may need to be fewer than 150 d to prevent irreversible negative effects on gain and carcass traits. Limit-feeding steam-flaked corn diets during the growing period offers an opportunity to enhance feed conversion; however, negative effects on marbling and longissimus area may prevent its application by feeders who utilize grid marketing. Nothing could be done with manipulating timing or source of roughage inclusion to improve feed conversion or carcass traits of steers fed on a whole corn:pellet system. Amongst the various strategies evaluated herein, program feeding may offer the best management option for enhancing feed conversion and feed cost of gain, but additional research needs to be conducted to determine the length and extent of growth restriction to prevent negative effects on gain or carcass traits.

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