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The Feasibility of Feeding High Levels of Whey Silage and Effects on Production in Growing Cattle

ZoBell, D. R., [1]E. K. Okine, K. C. Olson, R. D. Wiedmeier, [2]L. A. Goonewardene and C. Stonecipher
Department of Animal, Dairy and Veterinary Sciences, Utah State University, Logan, UT 84322-4815, [1]Department of Agricultural Food and Nutritional Science, University of Alberta, Edmonton, AB T6G 2P5, [2]Livestock Development Division, Alberta Agriculture, Food and Rural Division, # 204-7000-113 Street, Edmonton, AB. T6H 5T6

Abstract: Two studies were conducted with the objective of evaluating the feasibility of using whey ensiled with wheat straw and wheat middlings (whey silage), fed at 98% of the diet and determine the levels of production that can be obtained by feeding it to growing cattle. In each study, the control diets contained a diet comprising of wheat middlings, alfalfa hay and corn silage and were isocaloric with the whey silage diets. The average daily gains and feed efficiencies of cattle fed on the whey silage diets were similar ($P>0.05$) to the control diets. However, in the second study, dry matter intake was reduced ($P<0.05$) in animals fed the whey silage diet compared to the control. Whey silage can be included at 98% of the total diet with no adverse effects on gain and feed efficiency. This study provides cattle producers with low cost feeding options that use crop residues and agricultural by products such as whey which can be ensiled and fed to growing cattle.

Key words: whey silage, production, growing cattle, crop residues, agricultural by products

Introduction

Feed accounts for a large part of the cost of beef production in North America. Furthermore, as cattle have the capacity to utilize roughage as a major component in the diet, the inclusion level influences the cost of production. The utilization of less conventional feeds such as agricultural and industrial by-products combined with a variety of roughage sources may provide beef producers with some flexible feeding options, and there are many studies that relate to feeding by-products to ruminants (Clerk *et al.*, 1987; Belyea *et al.*, 1989 and Givens *et al.*, 1993). By-product feeds are produced by a number of value-added processing industries such as brewing, distilling, starch manufacturing, dairy, seed and grain processing (Marx 1999). Such feeds may impact traditional ruminal feeding practices by reducing the amount of concentrate fed to ruminants, providing feeding options when there is a scarcity of feed such as drought, crop failures and can influence feed costs (Clerk *et al.*, 1987; Belyea *et al.*, 1989 and Marx 1999). However, the feed value of by-products may change as cultivar types and processing methods change (Johnston *et al.*, 1995).

Whey is produced by cheese manufacturing plants as a by-product and it is the serum or watery part of milk, separated from the more thick or coagulable part. This has been fed successfully to dairy calves and dairy cattle, with no adverse effects on production (Modler 1987; Economides and Antoniou 1990 and Lehmann *et al.*, 1993). Cattle can consume 20-30% of their total dry matter intake as liquid whey (Schingoethe, 1981). However, bloat can be a problem if cattle consume large amounts of whey in a short time (Modler 1987 and Schingoethe *et al.*, 1988). Blending whey into total mixed diets that contain roughage is one way to control feed intake and avert bloat. Also, small grain straws (cereals) and by products from seed cleaning and processing plants such as bran, polish and middlings are other underutilized feeds that are available for animal feeding, but these have low digestibility and feeding values. Thus combining these feedstuffs and ensiling them with byproducts such as whey can result in a preserved, palatable and nutritious feed for ruminants. There is little information on feeding whey silage made in combination with other crop residues and crop by-products to beef cattle. The objective of this study was to evaluate feasibility of feeding high levels of whey silage made up of whey, wheat straw and wheat middlings and determine the levels of production that can be obtained by feeding it to growing cattle.

Materials and Methods

Whey silage was produced for the two studies using the nutrient profiles and proportions of the feedstuffs as shown in Tables 1 and 2. The cheese whey used for each study varied in dry matter percent and nutrient content (Table 1) and came from separate cheese plants. The feedstuffs whey, wheat straw and wheat middlings were ensiled in a bunk type silo to produce the whey silage. The whey silage was sampled 3-4 weeks later for nutrients, fermentation characteristics, and analyses were continued throughout each feeding trial (Tables 2 and 3). All nutrient and feedstuff analyses reported in these studies were conducted at a commercial laboratory using procedures of Bull (1981), AOAC (2000) standard procedures and those outlined by ZoBell *et al.* (2003). The proportions of whey silage together with the other feedstuffs used to formulate the total mixed diets for the two studies are shown in Table 4. Both studies contained whey silage, and fed at 98%, on a DM basis with a 2% supplement.

Feeding trials: Animal and pen numbers and initial weights for the control and treatment groups are shown in Table 5. Growing Holstein heifer calves and growing British-based crossbred steer calves were used in studies 1 and 2 respectively. All calves had been processed similarly prior to trial initiation by receiving a Brucellosis vaccination, parasite treatment (Dectomax, Pfizer Animal Health, Exton, PA), 8-Way Clostridial vaccine (Pfizer Animal Health, Exton, PA) and intranasal respiratory product (BoviShield, Pfizer Animal Health, Exton, PA). The calves were initially placed in pens and received corn silage-alfalfa hay-based diets for 21 days. After the 21-d adjustment period, cattle were either fed the control (C) or treatment (T) diets according to the formulations in Table 4. The C diet in each study contained corn silage, alfalfa hay and wheat middlings (Table 4). The C and T diets in each study were isocaloric and approximately isonitrogenous (study 1: C - NEm = 1.74 and CP = 13.6, T - NEm = 1.74 and CP = 13.3; study 2: C - NEm = 1.69 and CP = 11.7, T - NEm = 1.69 and CP = 12.1, where NEm and CP were expressed in M cal kg^{-1} and % respectively). Calves were fed at 08:00 h daily with about 5% orts. Individual calf weights were recorded at the start of test (Table 5), every 28 days and at trial termination which was 56 days. Feed intake was recorded daily on a pen basis and feed efficiency calculated on a pen basis. The study was approved and conducted according to the protocol established by the Institutional Animal Care and use Committee at Utah State University.

Statistical Analysis: Statistical analyses were performed using the MIXED procedure of SAS (SAS Institute, Cary, NC 1989). Performance traits ADG, DMI and FE from the two trials were analyzed using a completely randomized design with a repeated measures treatment structure. Pen was the experimental unit with 28-d sampling periods as repeated measures of feed treatments. Diet treatment, sampling period, and their interaction were fixed effects and pen was a random effect. In all statistical models, the Kenward-Roger option was used to estimate denominator degrees of freedom. The variance-covariance matrix was chosen for each statistical model in an iterative process wherein best fit was chosen based on the Schwarz's Bayesian criterion. Least squares means were estimated and separated using the pdiff option when fixed effects were significant ($P<0.05$).

Results and Discussion

The dry matter and CP of whey used in the two studies were variable (Table 1). DM values for liquid, condensed and dried whey are reported to be around 7, 64 and 90% respectively (Lardy and Anderson 2003), while CP values of 13% for dried whey (Maiga *et al.*, 1997) and 3.8% for ultra filtrated whey (Schingoethe *et al.*, 1988) have been reported. The DM of the whey used in the studies were in between the values reported for liquid and condensed whey in the literature. The products of fermentation and properties of the silages are shown in Table 3. The pH of all silages was under 4.3. Good quality silage containing less than 65% moisture requires a pH of less than 4.8 (Alberta Agriculture Food and Rural Development 2004). High levels of lactic acid (8.1-8.4%), low levels of acetic acid and ammonia, all of which were found in the silage, used in the two studies characterized the good quality of the silage.

In both studies, the diet x period interaction was not significant ($P>0.05$). The least square means for DMI, ADG, FE and the cost of a kilogram of gain are shown in Table 6 for each study. DMI was higher ($P<0.05$) in C compared to T in study 2, but no differences ($P>0.05$) were obtained between C and T in study 1. The ADG between C and T in both studies was similar ($P>0.05$). No differences ($P>0.05$) in FE were observed between C and T diets in either study, in spite of a lower DMI observed in T compared to C in study 2.

There are no studies to our knowledge on feeding whey silage at such high levels of DM to growing beef cattle. However, there are studies on feeding whey as sources of energy, protein or as a supplement to growing cattle (Thivend 1977; Schingoethe *et al.*, 1988). When dry ultrafiltrate whey was fed at either 25 or 50% (DM basis) of the diet to finishing steers, dry matter intakes of between 7.7 – 7.8 kg d^{-1}, average daily gains of between 1.15 –1.25 kg d^{-1} and FE between 6.8 – 6.4 kg kg^{-1} were obtained (Thivend 1977). These results are similar to the estimates of intake, gain and feed efficiency reported in the present study for the whey silage diets.

In both studies, feeding whey silage at 98% of the diet where the whey component was 51.5 to 59.3% of the total mixed diet, had no detrimental effect on ADG and FE, although DMI was lower in study 2 (5.55 kg/d) for T. The literature suggests that whey can be used at levels ranging from 20 to 30% of the total DM in the diet with 30% being the upper limit (Lehmann *et al.*, 1993; Steinwender 1993 and Lehmann and Jans 1993). However, whey has been fed at levels greater than 30% (DM basis) to cattle (Thivend 1977; Windschitl and Schingoethe 1984 and Fisher and Buckley 1985). For fattening cattle, whey can be provided ad libitum provided the mineral composition of the total mixed diet is balanced and hay is provided as a source of fibre (Steinwender, 1993). It was evident in our studies that higher levels of up to 60% whey can be included on a dry matter basis when it is

Table 1: Whey nutrient profiles in each study

Study	DM (%)	CP (%)	Ca (%)	P (%)	K (%)	Na (%)
	Nutrient[z]					
1	31.8	15.4	0.75	0.94	3.43	0.92
2	42.8	14.0	0.51	0.79	2.43	0.74

[z]DM = Dry matter; CP = Crude protein; Ca = Calcium, P = Phosphorus; K = Potassium; Na = Sodium

Table 2: Composition of silage on a dry matter basis, energy values and nutrient analysis for each study

	Silage composition %			Nutrients[z]				
Study[Y]	Whey	Straw	DM	Nem	NEg	CP	Ca	P
1	51.5	38.3	46.4	1.83	1.21	12.7	0.59	0.56
2	59.3	31.7	53.0	1.65	1.03	11.0	0.42	0.55

[z]DM = Dry matter (%); NEM = Net Energy for Maintenance (Mcal kg^{-1}); NEG = Net Energy for gain (Mcal kg^{-1}); CP = Crude protein (%); Ca = Calcium (%); P = Phosphorus (%).
[Y]Study 1 whey DM = 32%; Study 2 whey DM = 43%   [x]WM = Wheat Middlings

Table 3: Fermentation properties of whey silage

Study	pH	Lactic acid (%DM)	Total VFA[z] (%DM)	Ammonia (% DM)
1	3.85	8.1	9.29	2.0
2	4.10	8.4	8.40	1.8

[Z]Volatile fatty acids

Table 4: Feedstuffs and composition of diets used for the two whey silage feedings studies on a dry matter basis and feed cost

Feed[z]	Study Units	1		2	
		Control	Treat	Control	Treat
AH	%	16.7	-	16.4	-
CS	%	40.4	-	41.3	-
WS	%	-	98.0	-	98.0
BG	%	-	-	-	-
WM	%	41.4	-	40.3	-
SBM	%	-	-	-	-
Supp[Y]	%	1.8	2.0	2.0	2.0
Cost[X]	US$ $Tonne^{-1}$	85.03	51.66	71.16	51.39

[Z]AH = Alfalfa hay; CS = Corn (maize)silage; WS = Whey silage; BG = Barley grain; WM = Wheat middlings; SBM = Soybean meal; Supp = Supplement.
[Y]Supplement contained - 11% CP, 5% NaCl, 0.5% P, 8.0% Ca, 0.24% Mg, 0.76% K, 200 ppm Cu, 400 ppm Mn, 650 ppm Zn, 2 ppm Se, 22 ppm I, 9 ppm Co, 121,000 IU/kg Vit A, 37,400 IU/kg Vit D, 55 IU/kg Vit E and 360 ppm Rumensin.
[X]Dry matter basis, cost per metric ton in US $: Alfalfa and corn silage = 98.46, supplement = 218.69, straw = 27.26, wheat middlings = 60.13, whey silage (study 1) = 48.26, (study 2) = 47.99, (Whey prices were dependent on DM content: 43% DM = US$ 57, 32% DM = US$ 62, 22% DM = US$ 67).

Table 5: Number of pens, animals per pen and start weights for cattle on whey silage studies

Diets	Study	N	No. pens $treatment^{-1}$	Head pen^{-1}	Start wt. ± SE (kg)
Control	1	24	3	8	253.2 ± 4.7
Treatment	1	24	3	8	263.6 ± 5.7
Control	2	24	3	8	220.9 ± 4.5
Treatment	2	24	3	8	218.2 ± 5.0

converted to silage and fed to growing cattle without adversely affecting weight gain and FE.

It is reported that problems such as bloat, diarrhea and sudden death may occur if large amounts of whey are consumed with or without grain over a short time (Schingoethe 1981; Fisher and Buckley 1985 and Modler 1987) and it was recommended that whey should be fed gradually together with hay, such that the risk of bloat and

Table 6: Effects of feeding whey silage to cattle on average daily gain (ADG), dry matter intake (DMI), feed efficiency (FE) and cost of a kg of gain in two studies

Study[Z]	Type[Y]	DMI (kg d^{-1})			ADG (kg d^{-1})			FE (kg kg-1)			$Cost kg^{-1} gain	
		Con	Treat	SEM	Con	Treat	SEM	Con	Treat	SEM	Con	Treat
1	HH	8.00	6.55	0.59[x]	1.09	1.05	0.06[x]	7.38	6.52	0.55[x]	0.63	0.34
2	BS	7.23	5.55	0.32[v]	1.14	1.09	0.03[x]	6.34	5.19	0.31[x]	0.45	0.27

[Z]the composition of control and treatment diets for each study is shown in Table 4
[Y]HH = Holstein heifers; BS = beef steers [x]Treatment means did not differ (P>0.05)
[V]Treatment means differed (P<0.05)

diarrhea is minimized (Schingoethe *et al.*, 1988 and Steinwender 1993). In our studies, no bloat was observed among cattle and furthermore, as the whey was first made into silage and then fed as a total mixed diet, the risk of bloat would have been reduced further as adequate roughage in the form of straw was supplied in the silage. Thus converting whey and straw to silage and feeding it to cattle provides an avenue for the optimum use of both whey and straw. In tropical climes, the process of ensiling with whey could be extended to include tropical plant by products such as rice straw, rice bran and rice polish, and such silage fed to other ruminants such as sheep and goats. Many studies have been conducted on improving the digestibility of cereal straws by ammoniation and alkali treatment (Zorilla-Rios *et al.*, 1991 and Amjed *et al.*, 1992) and ensiling agricultural by products with whey is another way to add value to straw and improve digestibility. Including whey in a total mixed diet has been shown to improve the digestibility of roughage feed (Schingoethe 1976 and Thivend 1977), and dried whey has been added to the diet to increase ruminal fermentation and microbial protein synthesis (Maiga *et al.*, 1996) as it contains 37-72% lactose (Maiga *et al.*, 1995). Whey adds fermentation stimulants such as bacteria and enzymes, and nutrients but is not recommended that it be ensiled with high moisture feeds (Alberta Agriculture Food and Rural Development 2004).

The present study complements other studies that have shown an economic advantage of feeding whey in different forms to ruminants (Modler 1980; Hacker and Lippolt 1983; Schingoethe *et al.*, 1988 and Lehmann *et al.*, 1993). However, the nutrient composition of whey appears to be variable between cheese manufacturing plants. Hence, it is critical that rations be balanced to meet ruminant nutrient requirements for each batch of silage in which whey has been used as a component. Also, there are costs associated with transportation if the whey has to be trucked long distances on a regular basis (Modler1980; Haisch *et al.*, 1983 and Metzler 1983), drying if it needs to be condensed (Thivend, 1977), difficulties in handling and storage as it spoils easily and the pH decreases over time making it less palatable (Maiga *et al.*, 1997). The problems associated with frequent trucking, storage and spoilage of whey and the need to dry whey can be avoided if the whey can be converted to silage by combining it with feedstuffs that have low levels of soluble carbohydrates such as straw and then fed to cattle. Also, due to the high biochemical oxygen demand, whey (as permeate) is recognized as a pollutant (Marwaha and Kennedy 1988), and dumping surplus whey constitutes a waste of potential animal feed (Boukila *et al.*, 1995). While literature supports the feeding of whey either as a total mixed diet or in combination with hay, this study identifies another avenue through which liquid whey may be utilized as a ruminant feed. Ensiling whey can eliminate the need dry, to truck the product frequently, store and prevent or reduce spoilage.

The cost per metric ton of feed (Table 4) was between $ 19.77 to 33.37 less for the whey silage diets compared to the controls, while the cost of a kg of gain was between 18 to 29 cents less for cattle fed whey silage compared to the different control diets. Hence, there is an advantage in feeding whey silage as it reduces the cost of feed. However, these feed prices are subject to change and the cost of feed and gain is also dependent on existing feed price.

Conclusions

These studies demonstrated that whey could be combined with wheat straw and wheat middlings to produce suitable silage for growing cattle. Whey can be included at 60% of the total dry matter in the diet and fed as silage with no adverse effects on production. Fed at 98% of the total diet, weight gains and feed efficiencies were similar to cattle fed diets containing a combination of alfalfa hay, corn silage and wheat middlings. This study provides low cost feeding options combining the use of crop residues and agricultural by products for cattle producers. This process of ensiling with whey could be extended to include tropical plant by products such as rice straw, rice bran and rice polish and fed to other ruminants.

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