USDA Research on Whey and Whey Products as Feed for Cattle

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When liquid wheys are fed to cattle, disposal problems and water pollution are alleviated and large quantities of byproduct nutrients are utilized for food production with no expenditure of energy for drying. Young calves were able to obtain 20–31% of their total dry matter intake from the various types of wheys. Feedlot cattle fed restricted grain intakes were able to obtain as much as 57% of their dry matter intake from liquid acid whey. Ultrafiltration of liquid whey produces a protein concentrate plus a liquid whey permeate. The protein concentrate is being tested as a component of milk replacers for newborn calves. The permeate fraction was concentrated by evaporation into solid lick blocks. Calves derived up to 24% of their total dry matter intake from these blocks. Livestock have the potential of converting large quantities of surplus whey into meat or milk.

Years ago liquid whey feeding was a common practice on farms. Fresh milk was hauled to a processing plant in milk cans and whey was returned to the farm in the same cans. Whey was fed to most types of livestock; therefore, its use as livestock feed is not new. In spite of this practice, detailed nutritional information was not obtained.

Grinstaff (1974) has projected that by 1980 we will have from 16 to 19 billion kilograms of surplus whey to use profitably. Large ruminants offer the best potential for the use of large quantities of liquid whey or whey products for the production of high-quality meat and milk. More quantitative information is needed on whey intakes of ruminants, the most effective methods of feeding whey and ways of supplementing whey for optimal nutritive value.

Experimental research on whey feeding to calves and steers is in progress at the Beltsville Agricultural Research Center. Research in feeding whey to ruminants has also been done at other research centers (Anderson et al., 1974; Anderson, 1975; Nilson and Welch, 1973, 1974; Welch and Nilson, 1973; and Welch et al., 1974). The purpose of this paper is to summarize the results of several feeding trials in which whey or whey products were fed to calves or steers.

Liquid Acid or Sweet Whey. One of our first concerns was to determine the nutritional value of liquid acid or sweet whey when fed to young calves. The major difference between acid and sweet whey is the acidity; sweet whey from cheddar cheese has a pH of 6.2 whereas acid whey from cottage cheese has a pH of 4.6 (Table I). Lactose makes up the bulk of the solids, comprising from 70 to 74% of the dry matter. The protein content averages 11.5–12% depending on the type of whey. Whey protein is nutritionally excellent. Its PER is 3.2; that of casein is 2.5. Whey is also an important source of vitamins and minerals.

The first feeding trial was completed with 16 Holstein calves, averaging 87 kg body weight. These calves were fed liquid acid or sweet whey along with a 31% crude protein dry supplement (Table II). Both wheys and the high protein supplement were fed ad libitum. The calves received no water or hay and were fed for 6 weeks. During the initial part of the experiment, some intake differences were noted, and the calves fed the sweet whey showed faster adjustment to maximal intakes. Final body weights or daily gains of the calves at the end of the 6-week feeding period did not differ (Table III), so this slower adjustment to acid whey intake was not detrimental. Total dry matter intake, protein supplement intake or whey intakes were not different (Table III). Both groups drank an average of 11.5 kg of liquid whey daily, and this amounted to 29% of their total dry matter intake. Three calves died from bloat. Two were fed the acid whey and one was fed sweet whey. Young calves were able to use either liquid acid or

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Table I. Typical Composition of Cheese Whey

item	cheddar, %	cottage, %
total solids	6.50	6.90
lactose	4.81	4.76
total nitrogen	0.12	0.14
fat	0.17	
ash	0.52	0.79
pH	6.20	4.60

Table II. Composition of the Dry Supplement Fed with Liquid Acid Sweet Whey

ingredients	high protein supplement (31% c.p.[a])	low protein supplement (13% c.p.)
alfalfa meal	250	0
corn, cracked	500	352
soybean meal	650	0
linseed meal	200	60
oats, whole	0	352
fish meal	100	0
wheat bran	0	180
molasses	100	50
trace mineral salt	20	6
vitamin A (10 000 IU/g)	74	74

[a] Crude protein.

Table III. Performance of Young Dairy Calves Fed Liquid Acid or Sweet Whey for 6 Weeks

item	acid whey + supplement	sweet whey + supplement
final body wt, kg	120.9	126.8
DM intake, kg $head^{-1}$ day^{-1}	2.62	2.56
supplement intake, kg hd^{-1} day^{-1}	1.83	1.85
whey intake, kg hd^{-1} day^{-1}	12.2	10.9
daily gain, kg/day	0.81	0.91
DM from whey, %	30	28
calf mortality	2	1

Table IV. Intakes and Growth Responses of Calves Fed Liquid Acid Whey plus a High or Lower Protein Dry Supplement

item	dry supplements[a]	
	31% c.p.	13% c.p.
calves/treatment	8	9
final weights, kg	148^A	118^B
daily gain, kg	0.86^A	0.68^B
DM conversion, kg/kg of gain	3.14	3.59
DM intake, kg head^{-1} day^{-1}	2.70	2.44
supplement, kg head^{-1} day^{-1}	1.85	1.96
whey intake, kg head^{-1} day^{-1}	13.10^A	7.37^B
DM from whey, %	31	20

[a] Means with similar superscripts are not different ($P < 0.01$).

sweet whey and still maintain reasonable growth rates when a high protein supplement was provided.

One of the problems associated with getting very young calves started on a liquid whey feeding program is that the dry matter intake of young calves and the protein content of liquid wheys are low. We conducted a second experiment in which calves were fed liquid acid whey plus a high protein (31%) dry supplement or a low protein (13%) dry supplement ad libitum (Table II). The high protein dry supplement increased ($p < 0.05$) final weights, daily gain, and whey intake (Table IV). Whey dry matter made up 31% of the total dry matter consumed by the high protein group but only 20% of the total dry matter consumed by the lower protein group. The calves fed the high protein dry supplement consumed 659 g of crude protein daily; the calves fed the low protein dry supplement consumed 303 g of protein daily. The NRC protein requirement for 100-kg calves is 455 g of protein daily (NRC, 1971). The high protein dry supplement fed ad libitum with liquid acid whey supplied enough protein to meet recommended requirements, but the lower protein dry supplement did not. Both these experiments showed that liquid wheys can be used effectively in feeding programs with weaning calves if properly supplemented with adequate protein. Some form of roughage may be necessary to reduce bloat.

In tests to develop guidelines for a liquid whey feeding program for beef production under ad libitum or restricted grain feeding, 30 Holstein calves, 96 kg body weight, were fed liquid acid whey through three 14-week feeding periods (Lynch et al., 1975). Treatments were a water control plus ad libitum grain, acid whey plus ad libitum grain, and acid whey plus restricted grain. The dry feed was adjusted during each of the three feeding periods according to treatments. The calves fed acid whey received no water and hay was fed at 0.4% of body weight. Patterns of liquid intake showed that during the first feeding period the calves below about 180 kg body weight drank whey only to satisfy their liquid needs. Water and whey intakes were similar for all treatments. During the final two periods, the consumption of liquid whey exceeded the water intake of the control group. Calves heavier than about 180 kg more effectively consumed large quantities of liquid acid whey. Restriction of grain intake also proved to be an effective way of increasing whey intakes (Table V). The steers were able to obtain 26% of their total dry matter intake from liquid acid whey under ad libitum grain feeding over all feeding periods and obtained 45% under restricted grain feeding. During the final period, the restricted grain fed steers obtained 57% of their total dry matter intake from whey. Average whey intakes in the final feeding period over all treatments ranged from 24.0 to 55.6 kg daily. Whey intakes increased with high ambient temperature but restricted grain feeding resulted in a consistent increase in whey use.

Table V. Results of Feeding Holstein Steers Liquid Acid Whey for 42 Weeks

item	grain treatments[a]		
	control-w[b]	ad lib-Aw[b]	restricted-Aw[b]
final weights, kg	434	407	389
gains, kg/day	1.14^A	0.96^A	0.79^B
liquid intake, kg/day	22.7w	26.0Aw	43.1Aw
conversion, kg of DM/kg of gain	5.81	6.21	6.16
DM from whey, %	0	26	45
whey consumed, metric tons	0	3.82	6.34
carcass grade	G	Std	Std
panel score	5.99	6.05	6.05

[a] Means with similar superscripts are not different ($P < 0.01$). [b] w = water control, Aw = acid whey.

Table VI. Composition of the Moderate and High Protein Dry Supplements Fed to Dairy Calves with Liquid Acid Whey Permeate

ingredient	moderate protein (19% c.p.), g	high protein (29% c.p.), g
alfalfa meal	250	250
corn, cracked, no. 2	900	500
soybean meal (49%)	400	650
linseed meal (36%)	100	200
fish meal (60.9%)	50	100
animal fat	127	127
molasses	100	100
TM salt	20	20
vitamin A (10 000 IU/g)	74	74
crude protein, analysis	19.3	28.9

Each steer on the restricted grain treatment consumed 6.3 metric tons of whey. Each steer on the ad libitum grain treatment consumed 3.8 metric tons of whey. Large ruminants offer a potential of disposing of large quantities of surplus whey.

The carcasses from the steers fed liquid acid whey were lighter, were lower in fat content, and were one grade lower than those from steers fed water and grain ad libitum. Taste panel scores of roasts from the carcasses showed equal overall acceptability scores for all treatments. These scores indicated that in spite of the lower carcass grades of the steers fed whey and restricted grain intake, the carcasses were equal in panel acceptance to those of controls fed grain ad libitum. The use of liquid acid whey along with restricted grain feeding gives the possibility of using a surplus dairy waste product for very economical beef production. In many processing plants whey is available free and the biggest cost is for transportation of the whey to the animal feeding site.

Liquid Whey Permeate. The development of the ultrafiltration process has allowed whey to be fractionated into a protein concentrate consisting of lactalbumin and lactoglobulin that is retained by the membrane and also a permeable fraction called whey permeate (Hargrove et al., 1976). Compositional data show that most of the components of whey pass through the membrane. Whey permeate contains 80–85% of the original whey solids. These components include lactose, amino acids, nonprotein nitrogen, vitamins, and minerals, so the animal feeding value of liquid acid whey permeate remains high.

Thirty Holstein steer calves, average 97 kg at 10–12 weeks of age were fed liquid acid whey permeate for 50

Table VII. Results of Feeding Holstein Calves Acid Whey Permeate (AWP) plus a Moderate or High Protein Dry Supplement

	treatment groups[a]		
variables	control + mod. prot.	AWP + mod. prot.	AWP + high prot.
liquid intake, kg/day	20.90	18.90	15.89
dry supplement intake, kg/day	3.38[A]	2.76[B]	2.30[B]
protein intake, kg/day	0.653[A]	0.485[A]	0.843[B]
DM intake from AWP, %		25.9	25.8
gain, kg/day	1.17[A]	1.25[A]	0.92[B]
conversion, DM/kg of gain	3.38	3.79	3.37

[a] Means with similar superscripts are not different ($P < 0.05$).

days (Table VI). Treatments were a water control plus a moderate (19%) protein dry supplement, and acid whey permeate plus a high (29%) protein dry supplement. Grass hay was fed at 0.4% of body weight. Acid whey permeate was produced from cottage cheese whey with an Abcor Model 44S ultrafiltration unit equipped with HFA 180 membranes. The acid whey was clarified before it was used and ultrafiltration was by batch procedure at 50 °C and 45 psi.

The body weight gains of the calves fed the moderate protein supplement with water or acid whey permeate were higher ($P < 0.05$) than those of the calves fed the high protein supplement with acid whey permeate (Table VII). Feed conversion (dry matter, kg/body weight gain, kg) was similar for all treatments. Intakes of the dry supplements were less ($P < 0.05$) when acid whey permeate was fed than when water was fed. Because body weight gains were similar in the water control and acid whey permeate treatments, the reduction in gains must be due to the high protein supplement and not to the acid whey permeate. The daily protein intake of calves fed the moderate protein supplement was equal to the requirement of 485 g for 150-kg veal calves (NRC, 1971). The amounts of acid whey permeate consumed daily did not differ on the moderate protein supplement (18.9 kg) or the high protein supplement (15.9 kg) compared to the water control treatment (20.9 kg). This lack of difference indicates that 10–20-week-old calves drank only enough acid whey permeate to satisfy their liquid needs. These calves were able to obtain 26% of their total dry matter intake from acid whey permeate. Holstein calves fed liquid acid whey and a 31% crude protein supplement consumed 13.1 kg daily and obtained 31% of their total daily dry matter intake from the acid whey. The difference in the percentage of total dry matter intake obtained from acid whey and acid whey permeate may reflect the higher dry matter content of the acid whey. Acid whey and acid whey permeate seem to be accepted equally by calves.

Two calves were lost on the acid whey permeate treatments. The permeate tanks were empty overnight, and when the tanks were filled, the calves drank heavily and bloated. Bloat seems to be a problem associated with liquid whey feeding and may require more attention under practical feeding conditions where attempts are being made to optimize intakes of a readily fermentable substrate.

Whey Permeate Blocks. One of the most promising ways of using large quantities of whey or permeate is to convert the solids into "lick blocks" for livestock (Hargrove and Lynch, 1974). In this process, the whey protein is removed by ultrafiltration and the permeate is condensed to about 30% solids before it is neutralized to pH 6.0–6.2 with anhydrous ammonia. Evaporation is continued to 65–70% solids and the concentrate is piped directly into suitable forms. We used 18-kg Wilson cheese hoops. Lactose crystallization occurs, tying-up the remaining moisture, and the concentrate solidifies. The lick blocks can be removed from the forms in 12–24 h and are ready for feeding after air-drying for 1–2 days. Each block represents about 340 L of liquid permeate. Lick blocks can also be made from whole whey that has not been subjected to ultrafiltration. In addition to easier handling and shipping, the process has the advantage of avoiding the energy expenditure in spray-drying. As a result of increased energy costs, dried whey for animal feed now costs 2–4 cents/lb above the selling price of the powder (Graf, 1976). Lick blocks can be produced for about one-third the cost of drying, thus a loss is turned into a profit (De Laval, 1977).

Sixteen calves, average 91 kg, were assigned to unsupplemented whey permeate blocks, ammonia-supplemented whey permeate blocks, and urea-supplemented whey permeate blocks with a no-block control group (Hargrove and Lynch, 1974). A 9.3% protein pelleted ration (80% concentrate, 20% wheat straw) was fed ad libitum with the blocks for 60 days. Average daily block intakes were 0.8 kg for the unsupplemented blocks, 1.1 kg for the ammonia blocks, and 1.0 kg for the urea blocks. The calves on the ammonia and urea supplemented blocks ate less ($P < 0.05$) of the pelleted ration and obtained 20–24% of their total dry matter intake from the blocks. Analysis of the free plasma amino acids of these calves showed that total essential plasma amino acid levels of calves fed ammonia-supplemented blocks were lower ($P < 0.05$) than those of the control calves or of the calves fed urea-supplemental blocks. This suggests that protein quality was inadequate or that the calves were unable to utilize the added ammonia in these blocks.

In a second experiment, 50 calves, 92 kg body weight, received unsupplemented permeate blocks (control) or blocks supplemented with ammonia plus molasses, ammonia plus urea, ammonia, and whey protein for 60 days. The calves received the same (9.3%) protein pelleted ration ad libitum that was fed in the first experiment with whey permeate blocks. The calves receiving the ammonia plus

Table VIII. Results of Feeding Holstein Calves Supplemented and Unsupplemented Permeate Blocks for 60 Days

		block treatments			
item	control	NH_3 + molasses	NH_3 + urea	NH_3	whey protein
final weight, kg	122.1	124.8	137.7	125.0	132.8
gain, kg/day	0.50	0.55[A]	0.75[B]	0.53[A]	0.65[B]
intakes, kg/day					
total DM	3.96	3.75	4.51	3.93	4.12
pellets	3.44	3.00	3.55	3.04	2.86
block DM	0.52[A]	0.76[A]	0.96[B]	0.89[A]	1.25[B]
DM from blocks, %	13.2	21.4	20.8	21.3	30.5

[a] Means with similar superscripts are not different ($P < 0.05$).

Table IX. Nitrogen Utilization of Calves Fed Various Milk Replacers Through a 14-Week Experimental Period[a]

treatments	N balance, g/day	N digested, %	N retained, %
whole milk	33.1	96.9	71.8
commercial replacer	21.2	88.4**	59.9**
whey protein replacer	15.7**	93.9*	63.3*
fat plus whey protein replacer	16.4**	96.2	66.3**
SD	5.5	3.3	9.8

[a] (*) $P < 0.05$; (**) $P < 0.01$.

urea and the whey protein supplemented blocks gained most (Table VIII). The calves receiving the whey protein supplemented blocks used 30.5% of their dry matter intake from blocks; calves fed the plain unsupplemented control blocks used only 13.2%. Urea and whey protein supplementation of whey permeate blocks increased ($P < 0.05$) intake of the blocks as well as growth of the calves. Results in this study show that a high-quality protein such as whey protein added back to the block will improve the growth rate and increase block dry matter intake of young calves. Supplementation of ammonia plus urea resulted in equal performance by these calves. The economic advantage of feeding whey permeate blocks supplemented with nonprotein nitrogen is obvious. Further research is in progress to test other block supplements.

Whey Protein Milk Replacers. For many years farmers have been using milk replacers to raise baby calves from birth to weaning. These milk replacers usually contain a large percentage of skim milk and dried whey as basic ingredients. We have shown that the permeate fraction of ultrafiltered whey can be used as animal feed in the liquid or block form. Because of high nutritional value, the protein fraction has obvious uses in human food fortification. The fact occurred to us that the protein concentrate could be used to replace skim milk solids in calf milk replacer formulations.

Sixteen male Holstein calves were assigned to treatments of whole milk, a typical commercial milk replacer, a whey protein milk replacer and a whey protein milk replacer with added fat (Lynch et al., 1977). These replacers were fed for 14 weeks beginning at the third day of age (after colostrum feeding). All treatments were isonitrogenous and fed at 10% of body weight. Four 5-day balance periods were run during the experimental period. Performance of the whey protein milk replacer in terms of nitrogen digestion and nitrogen retention was equal to that of the commercial milk replacers (Table IX). Adding fat to the whey protein milk replacer increased its nitrogen digestibility to be equal to that of whole milk; however, most measures of nitrogen utilization indicated that the formulated milk replacers did not equal the values obtained with whole milk (Table IX).

SUMMARY

In experiments reviewed, whey or whey products were fed to calves or steers. Young calves were able to obtain about 30% of their total dry matter intake from liquid whey. Adequate protein supplementation is necessary for adequate growth of the young calf on liquid whey feeding programs. Calves under about 150 kg body weight will consume only enough whey to satisfy their liquid requirements. Older steers fed a restricted grain feeding will consume up to about 45% of their total daily dry matter intake from whey during a long feeding period. Steers fed a restricted grain intake will consume up to 57% of their total daily dry matter intake during the latter part of the feeding period if fed a restricted grain intake. Carcasses from steers fed a restricted grain intake were equal in taste panel acceptability to carcasses from steers fed grain ad libitum getting water or whey.

Liquid acid whey permeate, when fed with a 19% protein dry supplement, produced adequate body weight gains in calves. The calves obtained about 26% of their total dry matter intake from liquid acid whey permeate. Liquid acid whey permeate was made into lick blocks for cattle. Blocks supplemented with ammonia and urea produced faster body weight gains than unsupplemented blocks produced. Nonprotein nitrogen in blocks made from surplus whey permeate makes a very economical feed for finishing beef steers.

The whey protein concentrate resulting from the ultrafiltration of whey was used in the formulation of milk replacers for baby calves. The digestibility of this milk replacer was improved by increasing the fat content. The nutritional value of the whey protein milk replacer for calves was equal to that of a typical commercial milk replacer.

The use of surplus whey or whey products in feeding programs with ruminants offers the possibility of using large quantities of surplus whey for the economical production of milk and meat.

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The following paper was presented at the Symposium on the Chemical and Nutritional Aspects of Dairy Wastes but not printed in this issue: "Large-Scale Gel Filtration of Whey and Whey Proteins", by J. K. Donnelly and R. A. M. Delaney.