Use of whey in feeding ruminants

with particular reference to pollution problems

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Whey is a slightly acid, yellow-green liquid which is the residue obtained from the coagulation of milk by rennet or by the lowering of its pH. A considerable volume of whey is produced in the world, and it has continued to increase in recent years (Table 1). In 1973 France, the world's second largest producer after the United states, produced 6 million metric tons of whey, of which about 20 percent was wasted.

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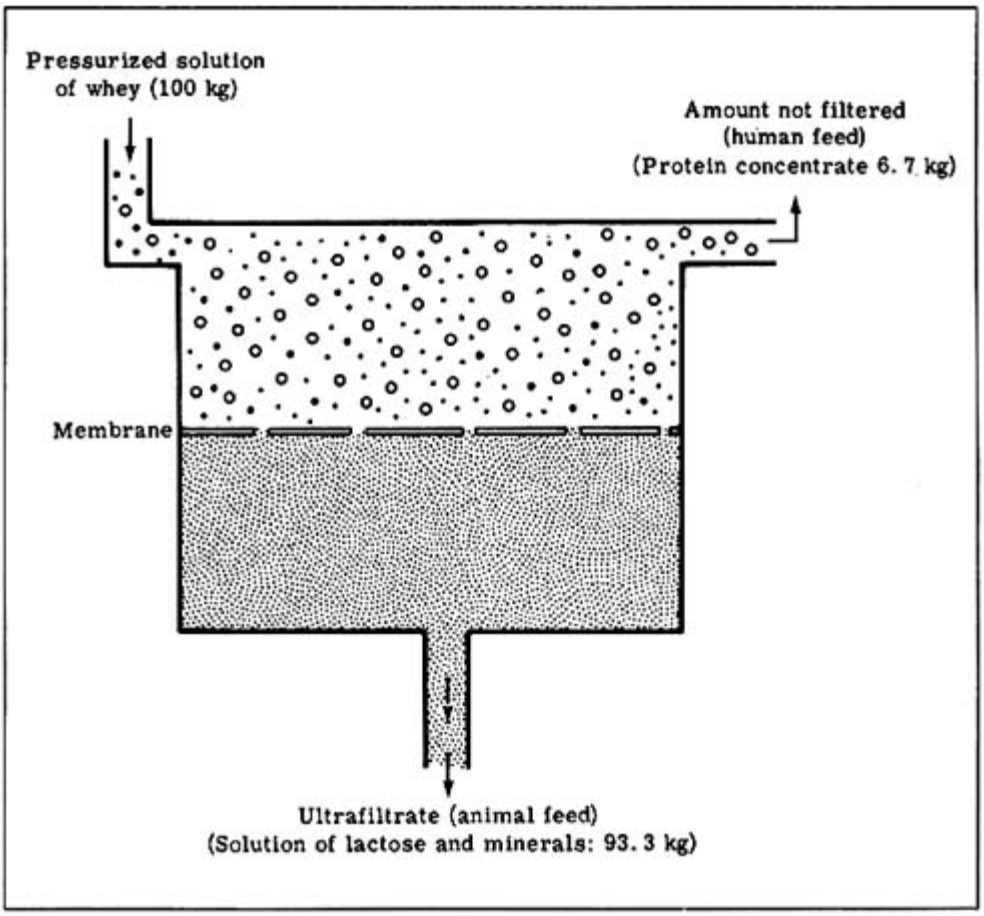
Whey is a strong pollutant when discharged into streams, its high organic matter content leading to a biochemical oxygen demand (BOD5) ranging from 30 to 40 g of oxygen per litre. As a result, the pollution load from a cheese factory processing 100000 litres of milk per day would be equivalent to the pollution of a city of 60 000 inhabitants (Petillot, 1976). Given the large quantity of whey produced worldwide each year, the risks of pollution are therefore extremely high.

There are various methods of utilizing or disposing of whey. It can be dumped at the production site, provided that the land area is large enough and the soil permits the absorption of the mineral elements and the organic matter. The principal constituents of whey can also be separated either by precipitation or by passing through an ultrafilter. The resulting proteins can be utilized for the manufacture of certain types of cheese; the lactose obtained by the crystalization of the raw or concentrated product could be utilized for human food or by the pharmaceutical industry. Whey is also an excellent substrate for the cultivation of yeasts; there are various procedures which make it possible to obtain large quantities of protein, lactic acid, ethyl alcohol and vitamins by this technique.

However, animal feed is by far the principal outlet for whey. It has been used in liquid form, principally for pigs, when the available quantity was not large and could be used nearby, but for practical reasons of transport and storage this pattern of use has been progressively superseded by drying for animal feed. This involves increased production costs which limit its use to the feeding of young animals (calves or young pigs) or fattening pigs.

With the growth of the cheesemaking industry the increasingly larger quantities of non-utilized whey have resulted in greater pollution hazards, but the organization of a pollution abatement campaign and better knowledge of the nutritional value of whey have led to a search for new ways of disposing of this by-product. Among the different solutions proposed, the utilization of whey in feeds for ruminants constitutes one of the newest and most rapidly exploitable means that may be adopted in the future. It is inexpensive, easy to put into practice, and offers a good method of utilizing nonprotein nitrogen sources suitable for ruminants. The techniques for limiting the pollution resulting from surplus whey production are discussed below.



Source: Maubois (1974).

FIGURE 1. *Ultrafiltration of whey separates high-quality proteins which could be used in food for humans from the ultrafiltrate residue, which can provide an excellent and inexpensive ruminant feed*.

Composition of whey

The dry matter content of whey is very low (6.0 to 7.5%). It is composed essentially of lactose (70 to 73%), protein (N × 6.25 = 12 to 13%) and mineral salts (7 to 11%). It also contains lactic acid in variable quantity (0.5 to 10%), citric acid (about 1%) and some nonprotein nitrogen (0.5 to 0.8%).

The composition of whey varies essentially with the type of cheese of which it is a by-product; sweet whey comes from the production of cooked or pressed cheese curd, while acid or sour whey, which is richer in lactic acid and minerals, is a by-product of fresh cheese. The composition also varies with the method of preservation and with the origin of the milk.

Whey proteins (lactoalbumins and globulins) are of excellent quality; their essential amino acid content is superior to that of egg or casein proteins. They are quite rich in lysine and tryptophane and in the sulphur-containing amino acids (methionine and cystine). Whey is also relatively rich in calcium, phosphorus, sodium, potassium and

chlorine. The concentration of these last three elements in whey is constant irrespective of the origin of the product, but the calcium and phosphorus concentrations are greater in sour than in sweet whey.

Digestion of whey

Schingoethe (1976) stipulated the maximum usable quantities of whey in the feeding of poultry, pigs, rats and ruminants. From these results and from more recent work done, particularly in France (Ehouinsou, 1976; Vermorel and Thivend, 1977), it is evident that adult ruminants are able to use much larger quantities of whey or derived products (ultrafiltrates) than other species. A considerable amount of research has been done on the digestion of these products.

In the rumen, lactose is broken down quite rapidly by bacteria and protozoa and converted into lactic acid, which is metabolized into volatile fatty acids, principally butyric acid. Under normal feeding conditions very little lactic acid is absorbed into the blood, but if the animals are given large quantities of lactose before the microbial population of the rumen has become adjusted to its use, severe fermentation problems may result. Lactic acid in excess penetrates the wall of the rumen and may cause serious metabolic disorders (acidosis).

Lactose is an energy source which makes possible the utilization of nonprotein nitrogen in the rumen. The ammonia concentration of the rumen fluid is not increased by the addition of urea to the ration, provided a proportionately large amount of lactose is combined with it (Thivend and Ehouinsou, 1977); the lactose/urea ratio should be around 5:1 or 6:1. The synthesis of microbial proteins in the rumen is improved by this process.

The digestibility of the nitrogenous matter in whey has been studied only to a very limited extent in adult ruminants. The nitrogen in the whey is converted in the rumen into microbial protein; its apparent digestibility is of the order of 70% (Anderson, 1975). When it is not degraded in the rumen, its digestibility in the intestine is much higher (91% in preruminant calves, according to Toullec et al., 1974). It would therefore be more satisfactory if whey could by-pass rumen fermentation so that the proteins could be absorbed in the intestine, but this is usually difficult to realize in practice. In fact, these proteins should be reserved first and foremost for human food or for monogastric animals. Modern procedures of separation of the different whey constituents (ultrafiltration) will doubtless permit the attainment of this objective.

There is limited data on the digestive utilization of various whey minerals. According to Schingoethe and Rook (1976), the addition of 5% whey to a concentrate feed for dairy cows does not improve absorption or retention of the minerals in the ration. It is important to ascertain whether the use of a higher percentage of whey changes mineral nutrition in ruminants.

The digestibility of the dry matter of whey in ruminants is excellent and amounts to 87% when whey constitutes 30% of the total feed intake (Anderson, 1975). Its net energy value has not been determined but is probably close to that of barley.

Methods of using whey

IN LIQUID FORM

This is the least expensive method of feeding whey to animals when they are located close to the cheese processing plants. Various trials have shown that ruminants, both young and adult, are able to ingest very large quantities of fresh whey in partial or total substitution for drinking water; according to Anderson *et al.* (1974), dairy cows can drink as much as 100 litres per day, which corresponds to over 30% of the total dry matter intake. Under these circumstances no depressive effect on milk production, duration of lactation or butterfat content has been reported. Growing calves are also able to absorb very high quantities of liquid whey (from 40 to 50 litres per day, or 30 to 50% of the total dry matter intake), and it is estimated that ruminants can generally ingest from 12 to 15 litres of fresh whey per 100 kg live weight.

The intake of liquid whey reduces the amounts of hay or grain consumed, since substitution for grains on a dry matter basis can be virtually total. As a rule sour whey is found to be less palatable than sweet whey, so that it is desirable to provide fresh supplies daily. It is also necessary to ensure that the whey is free of any pathogenic organisms, and during hot weather particular care has to be taken over the cleanliness of feed distribution facilities to prevent both fermentation and an increase in the fly population. The increased urine excretion sometimes observed when large quantities of whey are consumed presents no danger to the animals; on the other hand, digestive disorders such as diarrhea or bloat may occur if the period allowed for adaptation to whey feeding is less than one week.

TABLE 1. - **Estimates of world whey production**

Country	1966	1971	1973
	Thousand metric tons		
United States	8 618	10 883	11 836
France	4 878	5 603	6 136
U.S.S.R.	3 456	3 624	4 016
Italy	3 912	3 840	3 960
Germany, Fed. Rep. of	2 512	3 825	3 568
Other countries of the EEC	4 154	5 234	5 645
Other west European countries	4 649	5 083	5 232
East European countries	4 968	6 088	6 300
Australia and New Zealand	1 352	1 440	1 512
Developing countries	17 344	19 344	20 723
World production	57 113	66 190	70 695

Source: Krostitz and Zegarra (1975).

IN CONCENTRATED FORM

Whey can be used in concentrated form, with a dry matter content ranging from 50 to 60%. If utilized by itself this product is not very palatable and usually rapid sedimentation

occurs as a result of lactose crystallization. When it is mixed with molasses in equal proportions, dairy cows accept it readily (Welch, Nilson and Smith, 1974); when urea and minerals other than calcium (which for technological reasons cannot be added) are added the mixture can be used as a supplemental liquid nitrogen feed for ruminants. In the U.S.A. concentrated whey is sometimes used after it has undergone lactic fermentation and neutralization with ammonia (Henderson, Crikenberger and Reddy, 1974). The product obtained has a 7 to 10% nitrogen content and is used to supplement staple rations of ensiled maize for dairy cows or growing animals. It is very palatable and reportedly results in performance levels similar to those obtained by supplementation with urea or soybean oilcake.

IN DRIED FORM (WHEY SOLIDS)

Whey in the form of dried solids can also be used by ruminants. When introduced in relatively moderate doses (14% of total dry matter) in concentrate feeds, it prevents the lowering of the butterfat content generally observed in dairy cattle when this type of feed is consumed in large quantities (Schingoethe, Stake and Owens, 1973), this phenomenon apparently being due to the presence of both lactose and minerals. If used in small quantities in the rations of fattening lambs or finishing steers, dried whey improves animal performance considerably (Larsen *et al.,* 1963; Woods and Burroughs, 1962). For calves that are being weaned, the introduction of whey at the rate of 10% of the concentrate feeds increases feed intake (Morrill and Dayton, 1974), but if whey is introduced at a rate higher than 20%, the concentrate feed intake decreases.

The high cost of whey drying and the technological difficulties of incorporation of the powder in concentrate feeds have limited the use of dried whey in feeds for adult ruminants. Apart from the trials of Huber, Polan and Rosser (1967), in which whey constituted 50% of the dry matter intake of dairy cows, no other data are available on the use of large quantities of whey over long periods. However, the work of French researchers who used the ultrafiltrate of dried whey (Thivend, 1977) shows that ruminants can consume very large quantities of lactose (up to 72% of the dry matter) without exhibiting digestive disorders. This source of energy could well replace a large part of the cereals in fattening rations for ruminants (Table 3) and enhance the use of nonprotein nitrogen by the rumen microflora.

TABLE 2. - **Composition of different types of whey**

Type of origin	Whey		Sheep	Goats
	Sweet	Sour		
	Percentage of defatted extract			
Lactose	78.8	69.7	65.9	63.0
Protein nitrogen (N x 6.25)	13.7	11.7	23.7	14.7
Nonprotein nitrogen	0.6	0.8	1.0	1.1
Lactic acid	0.5	11.6	2.3	13.9
Citric acid	2.0	0.4	1.3	0.2
Minerals	8.0	11.3	7.3	13.4

Phosphorus	0.6	1.0	0.7	1.1
Calcium	0.7	1.9	0.6	2.1
Potassium	2.2	2.3	1.7	2.9
Sodium	0.8	0.8	0.8	0.7
Chlorine	3.3	3.2	3.1	5.3

Source: Collet and Février (1975).

At present dried whey is used primarily for feeding young calves. A considerable volume of research (Schingoethe, 1976) has shown that it could supply most, or even all, of the lactose in calf feeds from 6 to 8 weeks before weaning. In the case of veal calves which are fed exclusively on milk for longer periods (3 to 4 months), the proportion of whey used does not usually exceed 15% of the dry matter because of the large quantity of skim milk powder already included in their feeds. However, Toullec *et al.* (1974) have shown that it is possible to produce veal calves weighing about 160 kg by using feeds in which the lactose and protein is provided solely by whey. Similarly, lactose can also be supplied exclusively by the ultrafiltrate of whey (Toullec *et al.,* 1976).

Whey can also be used to improve the preservation and quality of silage, particularly that made from forage with a low content of rapidly fermentable carbohydrates. The addition of a small quantity of whey (2% of the total dry matter content) to grass or maize silage in dried, concentrated or liquid form improves the digestibility of the main constituents of the mixture (Schingoethe, 1976). Ammonia nitrogen losses are reduced and the silage is made more palatable; moreover, beneficial effects are reflected in the performance of the animals (Schingoethe and Beardsley, 1975).

TABLE 3. - **Utilization of dry whey ultrafiltrate for finishing steers**

	Group I	Group II	Group III
Feed composition			
Ground maize	50	25	0
Dry ultrafiltrate	0	25	50
Soybean oilcake	10	12.5	15
Coarse bran	14.5	22.5	30
Beet pulp	19	9.5	0
Ground straw	0	1.5	3
Molasses	5	2	0
Mineral and vitamin premix	1.5	2.0	2
Animal production			
Number of animals	10	11	12
Dry matter intake (kg/day)	7.76	7.66	7.79
Average daily gain (g)	1 283	1 254	1 149
Feed conversion rate:			
kg dry matter intake per kg of gain	6.05	6.11	6.78

net energy (F.U.) intake per kg of gain	6.74	6.38	6.69

Source: Vermorel and Thivend (1977).

Possible utilization of whey

Whey is one source of energy and nitrogen that is very well utilized by both preruminants and ruminants. Moreover, insofar as ruminants are concerned, the presence of lactose in the ration improves the use of nonprotein nitrogen. The beneficial effects of whey in ruminant feeding have now been fully demonstrated, provided that certain rules for its use are followed:

- The microbial population in the rumen should be allowed to adapt itself to the fermentation of lactose by gradually increasing the amount of whey used over a period of at least one week.
- The bacteriological properties of the feed should be carefully observed, especially when the whey is given in liquid form.
- The ration has to be balanced, care being taken to avoid the simultaneous use of whey and other feeds that may produce an excess of lactic acid, such as beets, cabbage and certain types of silage.
- The mineral imbalance that may result from considerably prolonged periods of whey feeding, especially in dairy cows, must be corrected.

If such precautions are taken, the feeding of whey to ruminants would be a very useful outlet for this product and would limit to the minimum possible the pollution caused by whey.

The dried form of whey (whey solids) is generally too costly except when it is used to replace the skim milk powder usually incorporated in the manufacture of feeds for young ruminant calves. Liquid whey or concentrated whey will probably come into greater use when regular supplies can be assured and when the animals are located close to where the whey is produced; also, because they are highly fermentable products, climatic conditions would affect their possible use.

Conclusion

The use of whey in ruminant feeding could result in an inefficient utilization of the protein that it contains, unless modern techniques for the separation of whey proteins are more universally adopted. Ultrafiltration of whey, for instance, makes it possible to separate the proteins, which are of excellent quality and could be utilized as food for human beings, from the ultrafiltrate residue, which is composed essentially of lactose and minerals (Fig. 1). The ultrafiltrate can be used by ruminants either alone or in combination with nonprotein nitrogen and would provide an inexpensive liquid or concentrate feed (Thivend, 1977).

Ultrafiltration of whey should make it possible to recover an appreciable quantity of proteins for human food, to supply ruminant feeds which, if supplemented with urea, could replace grain, and at the same time to reduce considerably the pollution caused by the dairy industry.

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