On-Farm Concentration Of Milk

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On-farm concentration of producer milk is just one example of how new technology can impact on competitiveness in the marketplace. For many years, membrane concentration has been used in the dairy industry. Other than a few experimental trial situations several years ago, it was not until recently that we have seen membrane concentration used on the farm.

In December 1996 the first ultrafiltration plant on a farm near Roswell, New Mexico started shipping 3X concentrated product to a cheddar cheese plant in Minnesota. Three 50,000-pound loads of raw producer milk were reduced to one 50,000-pound load of retentate. This process of producing one tanker load of concentrated retentate required approximately 10 hours. Since then four additional on-farm concentration plants have been built, making a total of five that we now have in the Texas and New Mexico Marketing Area. Three of these are in New Mexico and two are in Texas. One Texas plant is a reverse osmosis (RO) operation, and the other four are all ultrafiltration (UF) facilities.

The most recent plant built has much greater capacity than the earlier ones. It can reduce 175,000 pounds of producer milk into 50,000 pounds of UF retentate during a five-hour period. This is at a 3.5X concentration. The design is also such that either UF or RO can be produced.

These plants operate using a cold process single pass through method. Maintaining the milk temperature below 45(F minimizes damage to the milk fat globules and helps in maintaining the stability of the milk fat dispersion.

Membrane Concentration...

Reviewing some basics of the membrane separation process might be helpful. The material that does not pass through the filter is called the retentate. The material that passes through the filter is the permeate. The component make-up of these two fractions varies depending on the pore size of the membrane selected. Reverse osmosis membranes have the smallest pore size. Only water and a portion of the non-protein nitrogen passes through the membrane (Table 1).

Table 1: Typical component levels in 3X reverse osmosis (RO) product.

	fat	prot.	lact.	SNF
raw milk	3.5%	3.2%	4.7%	8.7%
RO milk	10.5%	9.6%	14.1%	26.1%

Nanofiltration is the next level of separation having a pore size only slightly larger than the RO. This membrane allows salts to pass through. Ultrafiltration is the next larger pore size and this membrane allows water, lactose, and some salts to pass through the membrane (Table 2).

Table 2: Typical component levels in 3X ultrafiltrated (UF) product.

	fat	prot.	lact.	SNF
raw milk	3.5%	3.2%	4.7%	8.7%
RO milk	10.5%	9.6%	4.5%	15.0%

Microfiltration utilizes a membrane with the largest pore size. The only differences in the permeate from this process and that of the UF is that two-thirds of the serum protein passes through the membrane as well as the other components. All of the casein protein, however, is retained in the retentate fraction (Table 3).

The type of membrane selected depends upon the specific use of the concentrated product. Reverse osmosis retentate is no different from condensed milk in composition other than it has not been subjected to the severe heat treatment and

Table 3: Typical component levels in 3X microfiltered (MF) product.

	fat	prot.	lact.	SNF
raw milk	3.5%	3.2%	4.7%	8.7%
RO milk	10.5%	*7.4%	4.5%	15.0%

**: Two-thirds of the NPN and tho-thirds of the serum protein passes through the membrane, and only the casein protein is retained in the retentate.*

does not have the cooked flavor that condensed milk has. It could be used best for recombining with water for fluid milk, fortifying fluid milk products, production of yogurt, ice cream, and many other food products.

Ultrafiltrated retentate might best be used to produce cottage cheese, cheddar cheese or many other types of cheese. It could also be used to produce lactose-reduced products since two-thirds of the lactose has been reduced.

Microfiltrated retentate is ideal for fractionating the protein. Only the casein portion is retained in the retentate and the serum protein is in the permeate. Approximately 25 percent of the total nitrogen protein, as we currently express the protein percentage in milk, goes into the permeate fraction and could then be recovered by running it through a RO or UF membrane.

Hauling Cost

Though concentrated milk is desirable in the production of various consumer products, the most significant attribute to the dairy farmer is the savings in hauling cost. A 2X concentration would cut the pounds of product hauled to market in half. Rather than having to haul two 50,000-pound loads of milk, you would have to haul only one. Another way to look at it would be to think about cutting the total miles in half. As you increase the concentration, your savings per .5X concentration declines. For example, a distant market that is 1,270 miles from a producer's farm, a 2X concentration would reduce the hundredweight hauling cost from $4.44 to $2.22. If the concentration were increased to 3X, the savings would be an additional 76 cents (Table 4).

Currently plants in our market are operating at a 2.5X concentration for RO and at 3.5X concentration for UF. The smaller pore size of the RO membrane makes it difficult to achieve much higher concentration with the present equipment. Also, none of the lactose passes through the membrane, whereas, in the UF two-thirds of the lactose goes off into the permeate leaving a lower total solids content in the retentate.

Component concentration levels in the retentate depend largely on two things. One being the ratio of the pounds of milk you start with compared to the pounds of retentate produced. For example, 150,000 pounds of producer milk reduced to 50,000 pounds of retentate would be 3X concentration. The level of components in the producer milk is the second criteria (Table 5).

Another way of looking at it would be to compare two 50,000-pound loads of 3X RO retentate. One load of milk from a dairy farmer who milks Holsteins and the other load of milk from a dairy farmer who milks Jerseys. The load of 3X RO Jersey retentate would contain 2,400 more pounds of butterfat and 1,050 pounds more protein, but would contain 3,450 fewer pounds of other solids and

Table 4: Comparison of hauling cost from Roswell, NM, to Atlanta, GA, at various concentration levels.

conc. level	equiv. miles	@ .035¢ cwt./10 mi.	difference (savings)	add'l savings per each .5x conc.
1	1,270	4.44		
2.0X	635	2.22	2.22	
2.5X	508	1.78	2.66	0.44
3.0X	423	1.48	2.96	0.30
3.5X	363	1.27	3.17	0.21

Table 5: Comparison of two herds and equivalent RO-concentrated product.

	lbs. milk per day	% fat	% prot.	lbs. fat	lbs. prot.
		Producer Milk			
Holstein	75	3.2	3.0	2.40	2.25
Jersey	55	4.8	3.7	2.64	2.04
		RO-Concentrated Producer Milk			
	lbs. of 3X retentate	% fat	% prot.	lbs. fat	lbs. prot.
Holstein	25	9.6	9.0	7.20	6.75
Jersey	18.3	14.4	11.1	7.92	6.12

water—most of that difference being in the water (Table 6).

If these two loads were delivered to a fluid bottling plant and reconstituted, then the question would be what level would the finished product be standardized?

Table 6: Comparison of 50,000 lbs. Load of 3X RO Concentrate From Two Herds.

	butterfat, lbs.	protein, lbs.	other solids and H_2O, lbs.
Holstein conc.	4,800	4,500	40,700
Jersey conc.	7,200	5,550	37,250
difference	2,400	1,050	3,450
	+50.0%	+23.5%	-8.5%

Laboratory Testing

In our laboratory we have had very little difficulty in calibrating infrared electronic instruments for estimating component levels in these concentrated products. Both mean differences and standard deviations with official chemistry methods have been very acceptable.

The only problem with infrared testing of any milk product for protein content at the wavelength protein is measured is that it only recognizes and can identify the quantity of true protein. Yet, we are attempting to calibrate in most markets to the official Kjeldahl test for total nitrogen. The state of New York is the only state in the United States that switched to true protein for payment testing and this was several years ago.

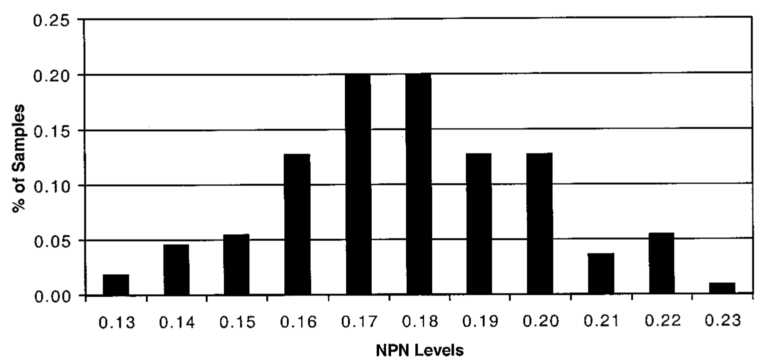
Total Nitrogen and True Protein are both AOAC approved Kjeldahl test methods for determining protein content of dairy products. When expressing protein based on total nitrogen, the percentage is overstated by the amount of non-protein nitrogen (NPN) present in a given lot of milk. Feeding and management practices contribute significantly to variations in NPN levels in different herds. There seems to be little if any correlation to the breed or season as to the level of NPN in the milk. Considerable test results have revealed NPN percentages as low as .12 and as high as .30 despite the level of total nitrogen in the milk from individual herds. On average, however, when randomly selecting milk from various herds over monthly or yearly basis, we seem always to wind up with average NPN levels of approximately .18% (Figure 1).

For milk averaging 3.3% total nitrogen protein, a .18% NPN reflects that 5.45% of the total nitrogen protein has little if any nutritional value. Random producer samples collected and analyzed during a 12-month study period revealed a range from .13% to .23% for individual herds. This reflected NPN as low as 3.94% and as high as 6.97% of the total nitrogen content. It has been estimated that urea contributes about half the NPN content of milk. Creatine, creatinine, amino acids and other minor nitrogen-containing compounds make up the rest.

In electronic milk testing instruments, the average NPN level in a set of control samples determines the bias that has to be added to what the instrument is actually seeing to predict total nitrogen. It would be more accurate to calibrate using true protein. Producers can be gaining or losing depending on how the level of NPN in the milk from their individual herd compares with that in the average for the calibration set used in calibration of the infrared instrument for determining their payment test.

Using total nitrogen testing of membrane-filtered products become even less meaningful. Varying amounts of the NPN portion goes out with the permeate, whereas, none of the true protein is lost. The NPN portion has little if any nutritional value so why attempt to account for it.

Figure 1. **Distribution of NPN in Producer Milk Samples Collected during a 12-Month Period**



Examples of On-Farm Concentration

Currently the concentration facilities in the markets that I am responsible for are all on farms milking 2,000 or more cows per day. Some are also receiving additional loads of milk from other farms. For discussion purposes, I am going to use for an example a 2,000-cow herd with a 75-pound daily production average to illustrate how a concentration facility might operate (Figure 2).

With 150,000 pounds of milk being-produced daily this could be reduced to a 50,000-pound load of retentate ready to go to market rather than three loads of producer milk. The remaining 100,000 pounds of permeate which is approximately 94.6% water and 5.4% other solids are left at the farm. Various uses might be made of the permeate.

One example, would be to run it through a RO system to recover the solids that are primarily lactose and a small amount of soluble minerals. Many large farms in New Mexico already have RO systems in use for removing minerals from the water that their cattle drink. Similar systems could be used for the permeate (Figure 3).

Using a 3X RO system, the permeate could be reduced by two-thirds yielding 33,333 pounds of retentate containing approximately 14 percent lactose and 1.5 percent mineral. This could then be fed to the cattle. Lactose has very close to the same nutritional value as corn and up to approximately 2 pounds per day per animal can be substituted.

Higher concentration levels can be achieved if desired due to the low level of solids in the permeate. There are many other possible uses of this type of concentrated product in the food industry.

Figure 2. Breakdown of Components In Producer Milk into Products from 3X UF Process

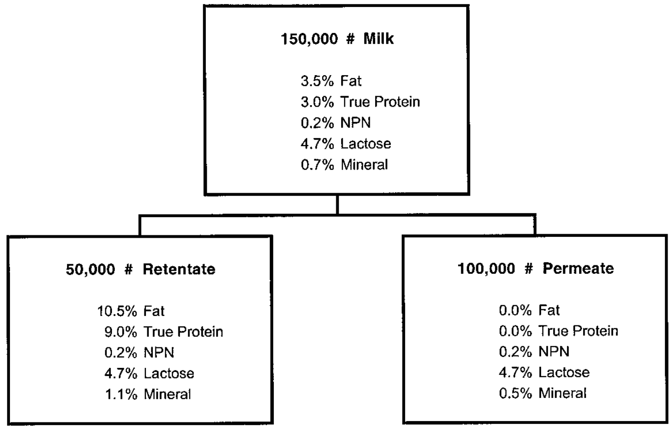
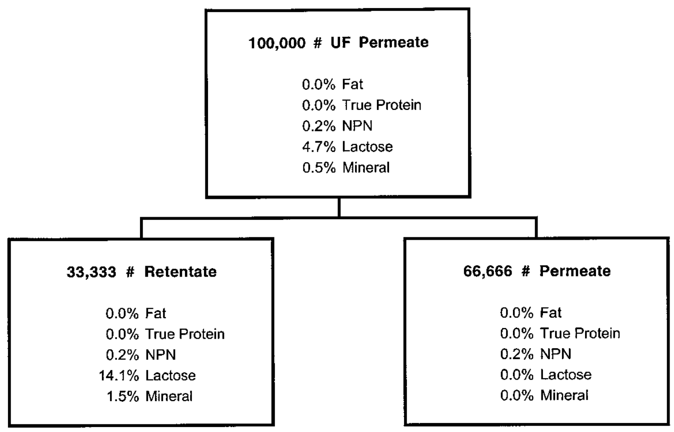


Figure 3. Breakdown of Components In UF Permeate into Products from 3X RO Process



Federal Milk Market

Here are some of the basic principles and definitions as to how these concentration facilities are being handled by the Federal Order as it relates to pooling and pricing:

- The accountability and arriving at skim equivalent factors are all being done on the basis of true protein in our market.
- Ultrafiltration facilities are all treated as plants and the milk used to produce the retentate is classified according to its end product use.
- Reverse osmosis facilities on a farm that received no milk from any other producers are considered own-farm units. The milk equivalent of each load of retentate is priced and classified as producer milk at the receiving plant's location.
- If milk from other producers is received, then the RO facility is considered a plant and the milk is priced at that location and classified based on the end product use of the retentate.

Notes