Review and cost analysis of reverse osmosis and ultrafiltration

A Senior Project

presented to

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by

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Abstract

The aim in this study was to determine whether implementing an on farm ultrafiltration system was profitable. Ultrafiltration was researched to reduce the amount of milk hauled from producer to processor. An ultrafiltration system involved milk that flowed through a semi-permeable membrane. Through this process water and small amounts of calcium and ash were pressured through the semi-permeable membrane. This permeate would then be able to feed heifers. The protein, fat, solids nonfat, and small amounts of calcium and ash were retained by the membrane. Through the process of ultrafiltration, raw milk was concentrated to three times its original concentration. With the use of ultrafiltration, the dairyman would need to one load of ultrafiltration milk instead of three loads of raw milk. The reduction in the cost of milk hauled and the feed presented to the heifers were the advantages in ultrafiltration. With the saved money on hauling and feeding of heifers, the initial costs of the system and the annual maintenance cost of the system exceed the benefits if implemented on De Groot Dairies. For the on farm ultrafiltration system to break even in ten years, the producer would need to be paid an additional $1.05 /cwt of retentate. This price included the reduced hauling cost and the money saved on the heifer ration. The difference in net present values on the costs of the system and the savings in permeate and hauling were -$5,072,770.24 over a 20 year period. Due to 87% water in milk, ultrafiltration needed to be examined. A dairyman should always look at his or her option to save money, wherever possible. With the data received from De Groot Dairies, the on-site ultrafiltration system would not be profitable when implementing the propose system at this time.

Keywords: reverse osmosis, ultrafiltration, retentate, permeate, membrane filtration

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Introduction

Since 2006 the California diary industry has been struggling to make a profit, especially producers. From 2008 to January of 2012, around 300 dairies have gone out of business (Woziacka, 2012). I could not find a reputable source to indicate the amount of dairies in financial trouble in 2012, but the times have not gotten better. With dairymen struggling, it is necessary to find ways to save, or make more money and gain equity back. My parents own 4,000 milking cows and their dairy, like most, is struggling.

I wanted to find something that could have an opportunity to help save costs and possibly create a value added product. This was the driving force in my decision to research on farm reverse osmosis and ultrafiltration. With milk being around 87-88% water, it makes sense to filter out the water. Raw milk, with its 88% water, was shipped to a processor and dependent on what type of processing plant received the milk. That processor may remove the water for powder or cheese. I saw it as a waste to haul water if it was going to be removed as soon as it gets to the processing plant. Sustainability was a factor when I considered the research of on reverse osmosis and ultrafiltration. In ultrafiltration and reverse osmosis, most water in milk was removed. This reduced the amount of loads hauled to the processer from three loads to one. This resulted in less traveling and less emissions produced.

The dairyman had to pay for milk hauled per cwt. In essence the dairyman paid the trucking company to haul water, a product not needed when sending to certain plants. Logic would say that reducing the amount of unneeded product would benefit the producer and processor. This was why I chose to research reverse osmosis and ultrafiltration.

When input cost, such as, feed and labor, exceed income, every option needs to be explored. This was another reason to research ultrafiltration and reverse osmosis. I had hoped to find a way to save costs and present a better quality product that may be worth more than regular raw milk. Reduced water in milk allowed for the processor to have one less step in production, thus I believe that the concentrated milk provided by the ultrafiltration or reverse osmosis system was a value added product and should receive a higher price. A higher price for milk would help any dairyman in times of high feed costs. However, my thought proved to be wrong. I was unable find the price that the processors were willing to pay for retentate or concentrated milk.

In Yves Pouliot's (2008) conclusion on Membrane processes in dairy technology- From a simple idea to worldwide panacea, he suggested that the identity of milk may be challenged because many of the components can be selectively removed. He then continued to counter his argument suggesting that it could be the beginning of a new technology that may help develop the industry further. An example he gave was from about a century ago when the centrifugal separations helped processing. I believe that reverse osmosis and ultrafiltration along with all membrane filtrations should be considered in milk processing. It has the ability to change processing protocols.

LITERATURE REVIEW

In this paper I briefly reviewed the four main types of membrane filtration. Then focused on reverse osmosis (RO) and ultrafiltration (UF) to describe the two processes in more detail. I chose to focus on RO and UF systems because I believed that it was the most used membrane filtration systems in the dairy industry.

There are four main types of membrane filtration techniques: reverse osmosis (RO), nanofiltration, ultrafiltration (UF), and microfiltration. The smallest pore size is reverse osmosis then nanofiltration, followed by Ultrafiltration. The largest pore size of the four is microfiltration (Barbano, D. 2013). Reverse osmosis is a concentration processes while nanofiltration, ultrafiltration and microfiltration are fractional processes. In any of these four processes the material that does not pass through the membrane filter is called retentate while the fluid that does pass through the membrane filter is called permeate (Fleming, 1999).

History of Membrane Filtration

The Dairy industry has seen membrane filtration systems since the 1970's. The first on farm ultrafiltration (UF) or reverse osmosis (RO) membrane systems implemented in the 1980's (Pouliot, 2008). In 1996, an ultrafiltration system was built on a farm near Roswell, New Mexico. This on farm plant processed milk at temperatures below 45 degrees Fahrenheit (Flemming, 1999). When milk was put through the system under 45 °F it reduced fouling of the membrane. When the milk was heated to pass through the membrane it burned the milk and compromised the flavor. Having milk flow through the membrane filter cold had allowed for a more consistent product.

Types of Membrane Filtration

Nanofiltration's pore size is comparable to RO. However, the pore is slightly larger and allows for salts to pass through the semi-permeable membrane. This process is used when a processor wishes to de-ash the dairy product at hand (GEA Process Engineering. Membrane Filtration. Reverse, 2013).

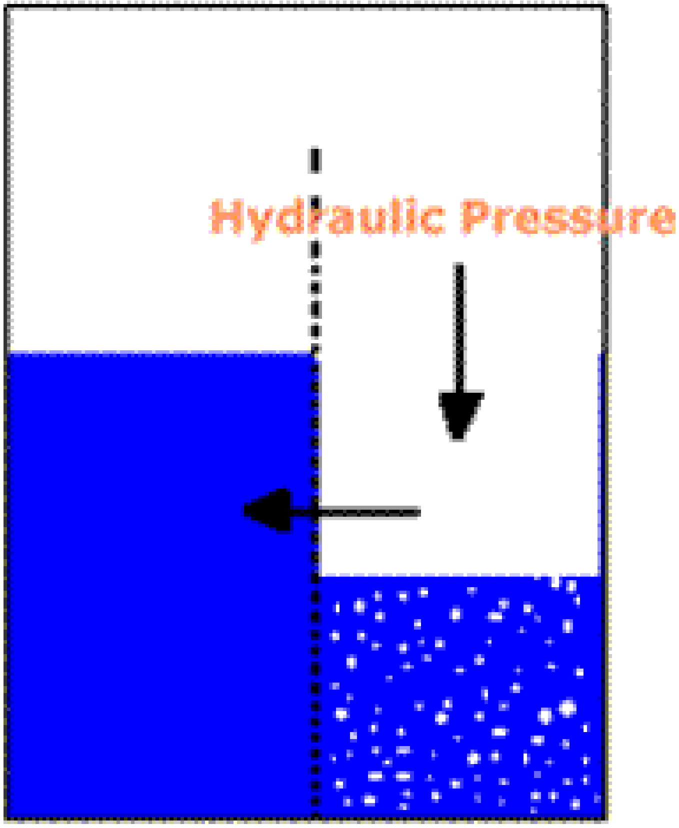

Figure 1. Pressure causing reverse osmosis.

Ultrafiltration is used in processing dairy liquids to produce different kinds of cheeses such as cheddar or cottage. Ultrafiltration had worked good for cheese making because ultrafiltration allowed for more cheese production than traditional processes when given the same volume of milk. Ultrafiltration retains α-lactalbumin, and β-lactoglobulin in the retentate (Kosikowski, 1973).   This concentration process would be best utilized when shipping to a cheese plant (GEA Process Engineering. Membrane Filtration. Reverse, 2013).

Mircrofiltration has been used when wanting to fractionate the protein. The protein that is left in the retentate after processing was casein. The protein left in the permeate is serum protein. To recover the serum protein that was forced through the semi-permeable membrane, RO or UF could be used (GEA Process Engineering. Membrane Filtration. Reverse, 2013).

In reverse osmosis, only water passes through the semi-permeable membrane. There is no difference in the composition of condensed milk and reverse osmosis processed milk. The only difference was that condensed milk was heat-treated and has a subtle cooked flavor. Reversed osmosis milk is utilized in the making of ice cream, yogurt or fortifying fluid milk. Reverse osmosis took less energy and lower cost than evaporation. This made it a great alternative for concentrating the milk(GEA Process Engineering. Membrane Filtration. Reverse, 2013).

Reverse Osmosis and Ultrafiltration

In reverse osmosis only water and a portion of non-protein nitrogen pass through the membrane (Fleming, 1999). Table 1 shows the amount of components that were left after the process of reverse osmosis. The table shows that when the process of reverse osmosis was used, the concentration of the four components increased three fold. Table1

Table 1: Typical component levels in 3x reverse osmosis product

	Fat	Protein	Lactose	Solids Non Fat
Raw Milk	3.5%	3.2%	4.7%	8.7%
RO Milk	10.5%	9.6%	14.1%	26.1%

Redrawn from Flemming (1999)

suggested that three fluid milk trucks would be able to fit into one truck when reverse osmosis is implemented.

Process of RO and UF

In a reverse osmosis system, raw milk is pumped into a semi-permeable membrane. The membrane has a very small pore size that will only allow the water to continue through the system. The pressure added to the inlet side is raised above the osmotic pressure; this forces the water through the membrane (Wichell and Hammond, 1984). Osmotic pressure is the minimum amount of pressure desired to stop osmosis. In reverse osmosis and nanofiltration, the largest amounts of pressure were observed. This was due to the small pore size of the semipermeable membrane. The osmotic pressure in RO or NF was high compared to MF or UF. The pressure applied must exceed the osmotic pressure (Pouliot, 2008).

In an ultrafiltration system, the process was much like that of RO. The main difference was pore size UF was larger than RO. Being that UF had larger pores, it allowed for more than just water to pass through. The permeate of UF milk consists of water, soluble salts, lactose and soluble nonprotein nitrogen (Kosikowski, 1973). The osmotic pressure will be lower than that of RO or NF as seen in figure 2. This was because the larger pore size in UF allowed for the fluid to flow easier through the membrane.

There are two primary determinants of how efficient the milk flows through the system or commonly known as flux. First is temperature, to increase the flux, the temperature should also be increased. However, the membranes are very vulnerable at high temperatures and tend to deteriorate. Adding pressure to the inlet will also cause an increase in flux. Too much pressure may cause damage to the membrane. The concentration of fluid also affected the amount of flux created. Appling more pressure on the flow of milk through the membrane than the osmotic pressure allowed for the solvent

to pass through the semi-permeable membrane. Osmotic pressure was also related to the solutions concentration. (Wichell and Hammond, 1984).

Dealing with Fouling

Fouling of the membrane has always been a concern when running a reverse osmosis system or ultrafiltraiton system. Fouling was caused when microorganisms grew on the semipermeable membrane. These microorganisms caused a biofilm on the membrane pores, which caused a reduction in the amount of flux. This biofilm reduced the efficiency of the system and there was an increase chance for the product to get contaminated which caused an economic loss (Tang et al, 2009). J. Hiddink et al. in Reverse Osmosis of Dairy Liquids (1985), found that Gouda whey fouled at a temperature of 30 degrees Celsius, because the Ca-phosphate precipitation. On the other hand, he stated that skim milk fouled because of the protein involved. To prevent fouling, CIP is used. However, cleaning the RO or UF system could be a challenge. The membrane filter of the system is sensitive to temperatures above 113 °F, high and low pH, do not have great physical strength and membranes need to be wet at all times (Wichell and Hammond, 1984).

Components RO and UF Retentate and Permeate

There are many components that make up milk. Each component had a different particle size. Particle size had a huge impact of what pore size was desired for the semi-permeable membrane. To make things simple, table 2 taken from Calvin Covington (2004) presentation on membrane filtration of milk, milk is divided into four components. The table shows the average dimension of milk components. As seen from the table 2, water had the smallest dimension.

Table 2. Size of milk components: water, lactose, casein proteins, and fat

Component in Milk	Average Dimension (nm)
Water	0.2
Lactose	0.5
Casein Proteins	2.0-4.0
Fat	1,000-10,000

Redrawn from Calvin Covington's (2004) presentation.

For RO to work properly, the membrane needed to have a pore size smaller than lactose. GEA Process Engineering, created figure 2 that displays the four processes of membrane filtration. Figure 2 gave five filtration processes, RO, nano-filtration, UF, micro-filtration and particle filtration. The filtration processes were in order of pore size, with RO was the smallest and Particle filtration was the largest. At the bottom of the figure was a measurement of how large the particles were. The particles were measured in microns. Above the measurements was the amount of pressure needed to push the solution through the membrane. Above pressure were the molecular weight of the solutions components. Above molecular weight were the components. The components were in order of size, pressure needed, and molecular weight.

The main difference between RO and UF was that UF concentrates proteins, insoluble salts, and fat, while RO concentrates total solids (Kosikowski, 1973). The two processes did have at least one thing in common; they both permit undenatured proteins to remain undenatured when pumped through the membrane (Kosikowski, 1973).

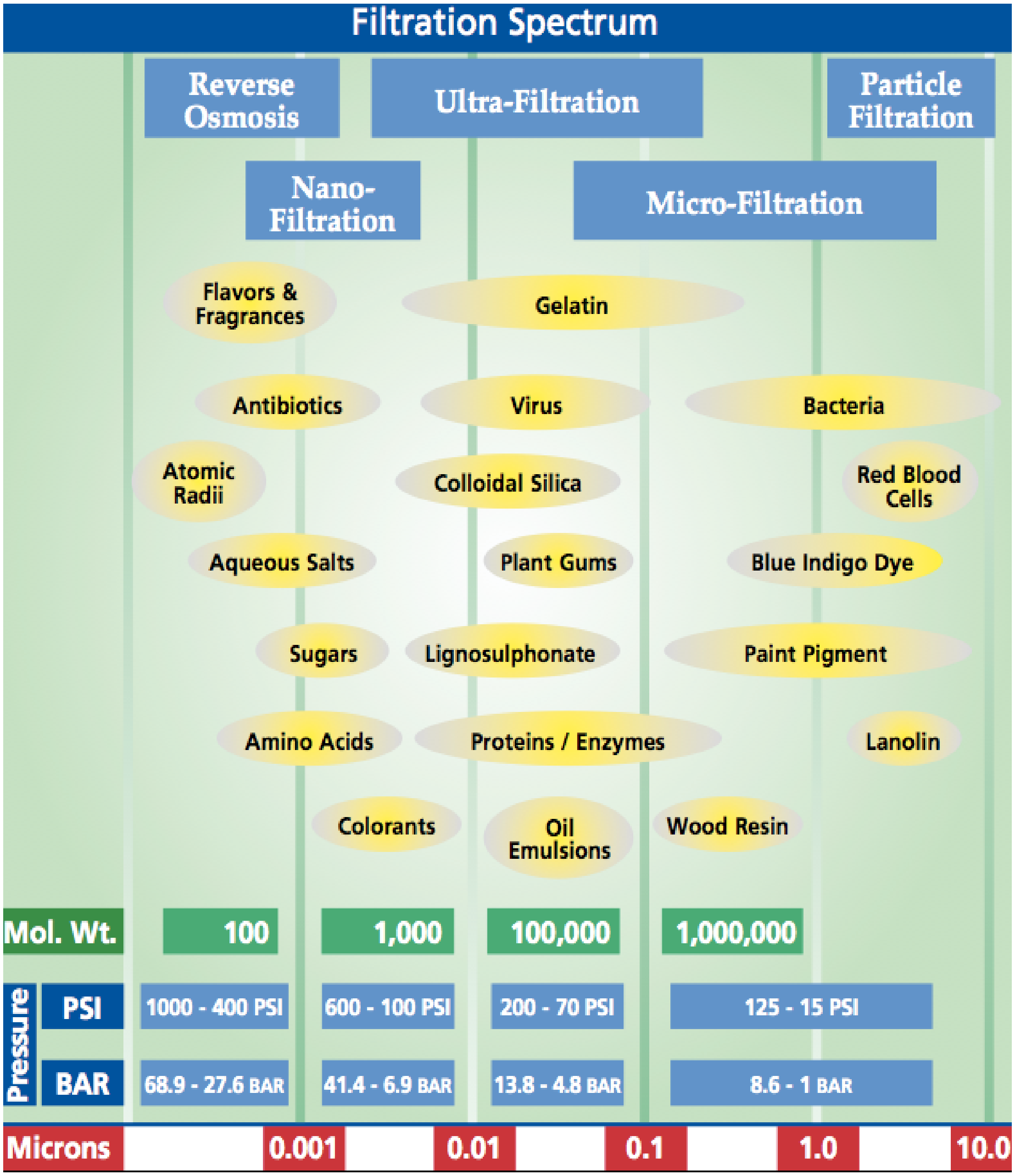

Figure 2. Filtration processes and components were organized in order of size, pressure, and weight. Provided by GEA Process Engineering, Inc.

Membrane Filters

There were two different types of membranes, Polymeric and inorganic. Spiral wound, hollow fiber and flat sheet membranes make up the polymeric membranes. On

the other hand, the inorganic membranes were made up of ceramic and stainless steel membranes. The spiral membrane is used when dealing with a solution that was mostly made up of no suspended solids, for example water or milk. Hollow Fiber membranes would be considered for use when there were low solids in the solution. The tubular membranes were used when large amounts of solids were present. For the inorganic type of material, ceramic was used for fractionation of proteins from milk. The stainless steel membrane is durable and effective when the solution has a high solids or viscosity (GEA Process Engineering. Membrane Filtration. Reverse, 2013). In the dairy plants, the most common membrane filter was a spiral bound membrane. The spiral bound membrane has a tendency to foul because of the small membrane leaves and small pore size (Tang et al, 2009). For a visual of what I talked about, figure 3 showed the different types of membranes.

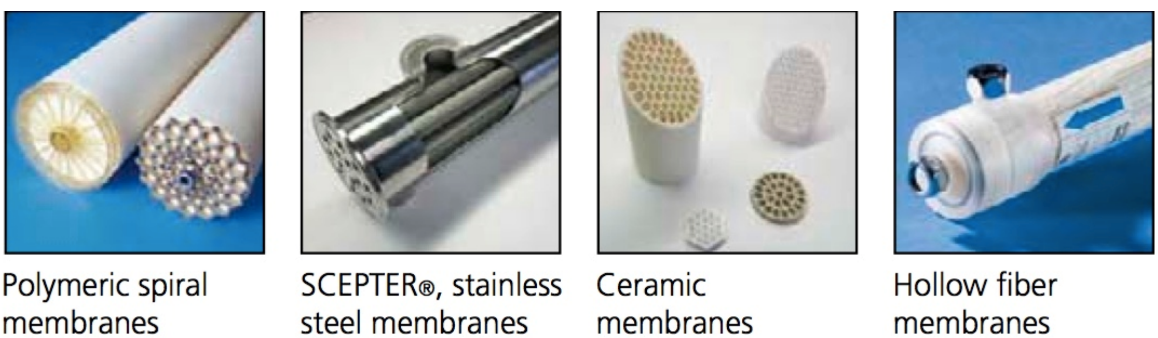

Figure 3. Four types of membranes were presented in picture format. Provided by GEA Process Engineering, Inc.

The spiral-wound membranes were more commonly used in the systems I had researched, because of this I will go into further detail on how it works. The spiral-wound membrane was made with tow membrane sheets that are separated by a support plant and a permeable mesh that were formed as a pocket. Then membranes were sealed

with adhesive. There were many of these spirally wound pockets that were put around one central tube. The spiral wound membranes were then placed in either a plastic or stainless steel tube that were to be pressurized. At both ends, an antitelescoping device was placed so that the spiral in the tube would remain constant when processed (Kuan et al, 1998). The milk was then pushed through the membrane and as the milk flowed through the membrane, the permeate flowed through the pores and collected at the end of the tube. The spiral wound membranes had an increase in effectiveness with packing density, low energy cost and effective mass transfer characteristics. The disadvantage was high probability of fouling of the membrane and was difficult to clean (Kuan et al, 1998).

Waste water after RO and UF

Reverse Osmosis contains retentate and permeate. The permeate is mostly water. The question at hand is what to do with the waste water. Flemming (1999) suggested to run the permeate through the RO system again to increase the concentration of lactose and minerals. If given a 100,000 lbs of permeate, processing it through the reverse osmosis system again will increase the amount of lactose in the retentate. This retentate consist of 33,333 lbs of which 14 percent lactose and 1.5 percent mineral. The retentate could then be fed to the cows. The lactose almost has the same nutritional value as corn and around 2 lbs/day/animal could be substituted (Flemming, 1999).

UF Filtration

Lactose and minerals like calcium were removed from milk in an ultrafiltration system (Vyas and Tong, 2003). In Vyas and Tong's (2003) article, Process for calcium retention during skim milk ultrafiltration, they studied processing skim milk using

ulrafiltraion through a 10-kDA membrane at a 4x concentration. After the UF process, they used heat treatment, pH adjustment, or both processes on the retentate and permeate to determine the amount of calcium, lactose, ash, total solids, and total nitrogen. The study found that about 16% of calcium was found in the permeate of skim milk and 76% of lactose was also found in the permeate.

When shipping to a cheese plant, UF has benefits compared to conventional cheese processing. As stated above, in the types of membrane filtrations, all milk proteins remain in the retentate (Maubois and Mocquot, 1974). In Maubois and Mocquot's (1974) journal article, Application of membrane ultrafiltration to preparation of various types of cheese, he showed that the cheese yield when using UF is increased by 16 to 20%. Maubois and Mocquot came to their conclusion because in every 100g of nitrogenous milk substances used, around 94-95 g remained in the cheese.

Legal Requirements for on farm RO and UF

California Department of Food and Agricultrure (CDFA) provided all information in this section. What is written is not a complete list of all the regulations that are required; rather it is a guide for a California dairyman who is considering implementing an on farm ultrafiltration or reverse osmosis system.

Before operating RO or UF

When an on farm system is installed, the dairyman would then be considered producer-handler. However, before the producer-handler can begin using their ultrafiltration or reverse osmosis system, he or she will need to get permission from the Food and Drug Administration about the proposed plan. The producer handler would

also need a Milk Products Plant License. There would also need to be an inspection of the facilities.

Items needed to operate RO or UF

A producer-handler would need a permit of market milk being produced and Milk Products Plant license with a Grade A Milk Processing Permit. There also needs to be a qualified industry supervisor to test for drug residue, and a licensed weighmaster and sampler to measure and sample the milk before processing. The producer-handler's farm would need to be on the Grade A raw milk list provided by Interstate Milk Shippers program. The RO or UF Facility would also require a separate title in the Interstate Milk Shippers program. When shipping the retentate of RO or UF milk, there needs to be a valid contract with handler. The handler needs to be bonded and licensed as well.

Pool accounting and payment requirements

If retentate was shipped as Class 1 or Class 2, the producer-handler would then be considered a pool plant and Handlers Monthly report is needed. If the retentate were not distributed to Class 1 or Class 2, then the producer-handler would be considered a nonpool plant, and must file Nonpool Plant Receipts and a Usage report. However, if quota was owned, the producer-handler must be a qualifying pool plant.

For payment, the contracted handler must purchase the retentate from the on farm UF or RO system at the minimum class price. If you are sending retentate to a Class 1 or Class 2 facility and were considered a pool plant, then you will have a pool commitment for all bulk milk at the minimum class price. This entitles the producer-handler to pool credits depicted from pool prices and the amount of quota. When the producer-handler's sold retentate to a handler, the Milk Producer Security Trust Fund may cover the retentate

on two conditions. First, the retentate was sold to a licensed and bonded milk handler. Second, a file must be kept with the Dairy Marketing Branch of the contract for the sold retentate.

Reporting and Paying of Producer Assessments on Bulk Milk

The producer-handler will be responsible for paying and reporting any producer assessment on bulk milk that goes into RO or UF. Some include, Pool Administration Fee (For those considered a pool plant), Dairy Council, Milk and Dairy Foods Control Fee, Market Milk Administration Fee, and Market order.

Reporting and Paying of Handler Assessments on Bulk milk

The producer-handler will be accountable for reporting and paying handler assessments on bulk milk that is put through RO or UF. These contain, Market Milk Administration Fee, Dairy Council, Milk and Dairy Foods Control Fee, and California Milk Processor Board.

Hilarides Farms

On February 14, 2013 I visited Hilarides Dairy located in Lindsay, CA. Hilarides Dairy has 9,100 Jersey milk cows averaging 48,000 gallons per day. Hilarides Dairy has an on farm ultrafiltration system. I got the privilege of touring the system from Dan Hilarides, who is involved in managing the ultrafiltration facility and the methane digester facility. I was able to connect my research with the actual process and make connections.

About Hilarides Ultrafiltration Facility

Hilarides' ultrafiltration facility is located on the northeast side of the milk barn or on the right side if looking at figure 4. The room where the UF system was located was kept clean and in order. The system that was installed was form Filtration Engineering co.

Figure 4. Hilarides Dairy, milk barn.

Figure 5. Ultrafiltration unit.

The system is seen in figure 5. The flow rate on this system was around fifty gallons per minute. Hilarides runs ultrafiltration for about sixteen hours a day and three to four hours of cleaning. This system was able to reduce about 3 loads of raw milk to 1 load of retentate.

The process of UF ultimately begins with the cows being milked. At Hilarides, double 80 carousal was milking 9100 Jersey cows that have about 5% fat test and 4% protein test. From there the milk was piped over to one of the two raw milk storage tanks with a 20,000-gallon capacity. The raw milk was then pumped to a 75-gallon holding tank. From the raw holding tank, the milk was pumped through the semi-permeable membrane. The permeate from the membrane was then

brought to another 75 gallon holding tank. Then permeate was pumped through a plastic line to a 20,000 gallon tank on the outside of the barn, shown in figure 6. From this tank the permeate was then pumped to the heifers to drink. As show in figure 7 the heifer loved to drink this. When we drove up to the trough, all the heifers were hovered around it drinking. The permeate was a yellowish clear color. I asked him how often he has to clean out the troughs, and he told me that they hardly ever do. He explained because it is cold and the cows drink it quickly that there was no need to clean them out. He also mentioned that the heifers love it during the summer because it was already cooled down to 40° F from the raw milk tank.

Figure 6. 20,000 gallon bulk tank for UF permeate.

Figure 7. Permeate water trough for Jersey heifer cows.

The retentate from the membranes was then pumped through a plate cooler and cooled to around 40°F. Hilarides mentioned that when it is in the membrane, the retentate gets warmer. From the plate cooler it is transferred to a 50-gallon tank. It is then pumped to the southeast side of the milk barn or left side if looking at figure 4 to one of the two 20,000

Figure 8. Last plate cooler before entering retentate bulk milk storage.

gallon tank, designated for retentate. Just before it entered one of the two tanks, it went through another plate cooler as seen in figure 8. Indian River Transport then picks up the retentate and shipped it to the Hilmar Cheese plant in Texas. Hilarides Dairy ships three loads of retentate a day to Texas and one load of raw milk to Hilmar, located in Hilmar, California.

Clean In Place (CIP) for UF

The clean in place system takes about three to four hours once a day. Sunday, Monday, Tuesday, Friday and Saturday the CIP had a regular wash with Chlorine run through it. However, on Wednesday, more Chlorine than usual is used through the system. On Thursday's acid is used throughout the system. The clean in place was said to cost about twelve thousand dollars and last for about five weeks.

Maintenance of Hilarides Dairy UF

I asked Dan Hilarides how often the ultrafiltration system breaks. He proceeded to roll his eyes and respond with an, "oh ya". He said that about once every three months there will be a big break down and there are always little fixes here and there. Being that there is not much on farm ultrafiltration units around, I asked them how readily are the parts. What I failed to see was that there are many processors that use the same parts on their plants. He found it fairly easy to get parts to fix any problem that may arise.

Figure 9. Ultrafiltration membranes, permeate exiting through clear hose.

Due to some of the articles that I read have

to do with fouling of the membrane, the membranes are in figure 9, I asked him if he had a problem with the fouling. He responded with a simple, no. He did make mention of changing the membranes though. He said that most people recommended to change the membranes every 2 years or so. Hilarides said that their membranes lasted about three and a half to four years and have only replaced them once. The cost of the replaced membranes was around 40,000 dollars. The membranes were purchased from Koch Membrane Systems. Koch was said to be at the forefront of membrane technology (Veenendaal, 2013).

Benefits of UF

The benefits of were seen in the hauling. Hilarides was able to reduce three loads of raw milk into one load of retentate. I asked David Ahlem (2013) from Hilmar Cheese how much shipping would cost form Tulare (close to Lindsay) to Hilmar. He responded that it would cost around $0.70-0.75 per cwt and depending on the fuel price, it may cost another 10 to 15 cents. I calculated out their cost without ultrafiltration to be around $1.45 million per year and the cost of shipping with ultrafiltratrion milk to be $482,000 thousand per year. The difference in hauled milk was $968,000 hauling saved Hilarides Dairy in shipping. This was a lot of money taken out of the milk check to ship milk. Ultrafiltration should be looked at if money can be saved. I would like to see whether or not the input cost were more than money saved on shipped milk, if implemented on De Groot Dairies.

Materials and Methods

A Model was developed using Microsoft excel (2010) to determine the costs of implementing an ultrafiltration system on my current dairy at home. I worked with GEA

filtration to get the prices of the UF system and used the milk flow calculations from De Groot Dairies in Hanford, CA. I researched a few companies in regard to getting prices of filtration systems. I got prices from GEA filtration because I felt that their company was successful and had a good image in the dairy industry. I chose to use an ultrafiltration system because I thought that I would be more logical than a reverse osmosis system. There are a few factors that led me to this decision. First is that Ultrafiltration allows for a higher flow rate because the membrane holes are larger. Second, I noticed that it would be easier to market the product to a cheese processor. Third, it became apparent that the permeate could be quite profitable as well. It could be used to feed the heifers, as stated earlier by Flemming (1999) the permeate could replace up to 2 lbs of corn. Another benefit of using ultrafiltration was that the permeate was valuable for the processors. The processors were able to put the permeate through reverse osmosis to take out the water and what was left was lactose, calcium and ash. The processors were then able to run the permeate through RO to take out the water. Then the retentate was put into a drier where the product was dried to 50%. Processors will then mix this product with skim milk powder to create a more constant product (Veenendaal, 2013). For my budget I acted as if the permeate was being pumped and fedd to the heifers for simplicity.

Materials

First I made a list of all the costs that may pertain to implementing a UF system on farm. This included, labor, cleaning, electricity, repairs, insurance, and supplies. Secondly I proceeded to make a new page that consisted of the cost of materials. Such as

the actual UF system and milk receiving tank. Third, I considered the amount of milk that would be able to be processed in one day.

For my materials I needed to get prices for implementing an Ultrafiltration system on farm. My numbers came from a number of different sources, including Hilmar Cheese, Hilarides Dairy, De Groot Dairy, Jam Construction, Sousa and Company, and GEA Process Engineering, Inc. I wanted to find the initial cost of the whole system installed and then how much it would cost to maintain every year after that.

Initial Costs

My initial costs that I found were $653,170.00. This included the cost of the ultrafiltration system provided by GEA Process Engineering, Inc., building, bulk tanks, expaned cooling system, installation and taxes. GEA Process Engineering, Inc. was very accommodating to my questions and was very helpful with my project. The system that was quoted was a complete system, including membranes, electric set up, small holding tanks, and pumps.

About the proposed UF system

Figure 10 was a blue print of the proposed UF system by GEA Process Engineering, Inc. This system was meant to run milk through twenty hour per day and four hours a day are designated for cleaning the system. The UF system was built to meet the current 3A and USDA standards. The flow rate of the ultrafiltration

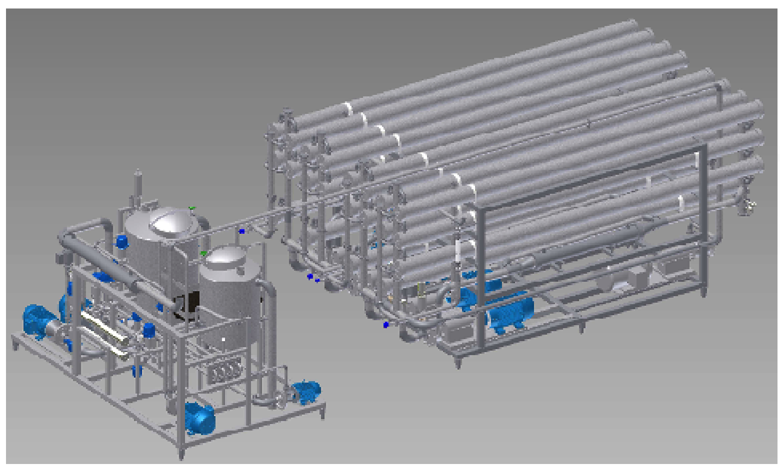

Figure 10. Ultrafiltration system provided by GEA Process Engineering, Inc.

system that was quoted was 17,680 lbs per hour. The concentrate quantity was 5,880 lbs per hour and produced total solids of 25.92%. Whereas the permeate quantity was 11,800 lbs per hour with a total solids of 5.77%.

Figure 11. GEA Process Engineering Inc. logo

	Feed	Concentrate	Permeate
True Protein, %	3.12	9.29	0.04
NPN, %	0.15	0.17	0.14
Lactose, %	4.97	4.53	5.19
Acid, %	0.00	0.00	0.00
Ash, %	0.59	1.01	0.38
Fat, %	3.66	10.92	0.03
T.S., %	12.49	25.92	5.77

Figure 12. List of components in milk and the percent concentration in feed, concentrate, and permeate.
Taken form GEA Process Engineering

This UF system is designed to use clean in place (CIP). There are four steps in the cleaning process. First, the cleaning chemicals are manually added. Second, the cleaning solution is heated. Third, the chemicals were pumped through for a certain amount of time. Fourth, water was flushed through the system.

The system required power to function. The power needed to run the system was 680 Kwh/d. As well as power, the system also needed 328 scf of air, 960 lb/d of steam and 2,810 gal/d of water for the fourth step in the CIP process. These factors play a role in determining the price of operating thus it was needed. I also needed to find the installation cost of the system to get a price on the total initial costs.

Additional equipment needed

There were a few pieces of equipment needed to accommodate the UF system. The first was two 7,000-gallon bulk tanks for the retentate or concentrate to be stored until taken to the creamery. The tanks were $85,000. This price came from Todd Jones (2013) owner operator of Jam Construction. Another additional cost needed was the building where the UF system would be installed. I also thought that it would have been beneficial to have a plate cooler for the retentate before it enters the bulk tank. This was brought to my attention when visiting Hilarides dairy, at Hilarides, the retentate was cooled twice before it went into the bulk tank. I believe that one plate cooler will suffice. Depending on what size pump was on the exit of the raw milk bulk tanks, another pump may be needed. However, the pumps on De Groot Dairies were of sufficient size.

I also needed to include the cost of installation and taxes enforced. For installation costs, it seemed it would be a laborious process, thus I decided to go with an installation cost of $10000. Taxes for the initial start up were calculated with an 8.5% tax rate. The 8.5% tax rate came from Kings County, where De Groot Dairies was located.

Table 3. Initial start up cost of UF System

UF system	$457,000.00
Building	$35,000.00
Bulk tank for 2 Retentate 7000g	$85,000.00
Expand existing cooling system	$15,000.00
Installation of system and tank	$10,000.00
Taxes	$51,170.00
Total	$653,170.00

Table 4. Yearly cost of the UF System		
	Costs	
Labor	$156,000.00	
CIP	$115,200.00	
Electric	$24,000.00	
Repairs	$55,200.00	
Insurance	$600.00	
replacement parts	$5,000.00	
replacement membrane	$18,100.00	
Hauling	$146,000.00	
Milk Promotions	$288,000.00	
Depreciation on building	$1,750.00	for 20 years
Depreciation on Equipment	$54,200.00	for 10 years
Misc	$5,000.00	
taxes	$69,124.00	
Total	$938,174.00	

Yearly Costs

I then needed to find the yearly cost of running the ultrafiltration system. For this I made a list of all the materials or expenses that would be required to process through milk through the UF system. The yearly expenses include: labor, CIP, electric, repairs, insurance, supplies, replacement membrane, hauling, milk promotions, depreciation on building, and depreciation on system.

To find the amount of labor needed to oversee the production of retentate, I used two full time employees and one part time employee. This number was taken from the amount of labor needed on Hilarides Dairy. To find what to pay the employees I asked Eddie Veenendaal (2013), plant manager at CDI in Fresno, how much his floor employees get paid. He replied that they were paid a starting rate of $18.50 per hour plus benefits. These benefits were around another $18.50. This seemed a little elevated to me for an employee working on an ultrafiltration system on a farm, so I calculated that the employees were would earn twenty dollars per hour.

To clean the system a CIP was used, every day chemicals were used. The chemicals were not cheap. According to Dan Hilaredes (2013), his chemicals run about $12,000 for 5 weeks of cleaning. To get the price of chemicals needed for one year I took 12000/5 to find the amount of dollars per week then times by 52 to find the cost for the full year. This cost can be seen on table 5 under CIP.

The system would require electricity run. According to GEA Process Engineering, Inc., the system takes 680 Kwh/d. To find the electricity cost, I looked up a previous bill from Southern California Edision (2013) and found what it had cost for one Kwh. Multiplied 680 times 365 to get how many Kwh/yr. then multiplied that by the price of one Kwh.

Similar to any system on a dairy, there were breakdowns. This area was harder to calculate the cost of because it was unsure what part needed to be replaced or modified. For my calculations I looked at how much De Groot Dairies were spending on repairs each month. This past year was a big year for repairs due to pumps going out. I thought that $55,200 would be sufficient for money set aside.

The ultrafiltration needs to be insured. To do this I found what it currently costs De Groot Dairies to insure their milk barn which was around 4000 for the full year. Then I found what the initial cost had been for the milk barn and found a ratio of initial cost to insurance cost. The ratio gave me a cost of $600.

I estimated the cost of replacement parts to be $5,000. This was because I felt that throughout the year parts will wear out eventually. These parts needed would be considered almost like maintenance parts. The system was still functioning, but the part needed to be replaced to let the system be more efficient, or to prevent a larger repair.

The system had spiral bound membranes. Those membranes were susceptible to fouling. The pores on the membrane would overtime become corrupted and the efficiency of the system will decline. GEA Process Engineering, Inc. recommended that the filter be replaced every year. The cost of the membranes was $18,100 to replace.

The milk was hauled three times less than if no ultrafiltration was present. To find the hauling I took the price of hauling for the full year of 2012. This was $438,000. I then divided that by three because it would be one load of retentate to three loads of raw milk. That would be the cost of hauling UF milk.

Milk promotions cost consist of many different fees. The fees include Dairy Council, Regional Quota Adj, National Dairy Promotion, Market Milk, Dairy Food Control Fee, Market order, Inspection fee, and Pac Contribution. These costs would not be different. Milk promotions will cost the same for raw milk and retentate. The cost of De Groot Dairies milk promotions was $288,000.

Over time most equipment or buildings lose their value. For this reason I included a depreciation cost for the building and the UF system. To find the depreciation cost of a building I called Sousa and Company (2013). They informed me that a building depreciates at 1/20 for 20 years. This means that every year the building decreases in value by $1,750.

The depreciation of the system was said to be 1/10 for 10 years. The one tenth came from Sousa and Company who was certified public accountants and consultants. I used Sousa and Company because they helped consult with De Groot Dairies and their budgets.

I also included a miscellaneous cost. I thought that it would was necessary because sometimes problems arise and it might not fit as a cost in another category. In a way it is an insurance policy.

Taxes were then added with an 8.5% rate. This 8.5% came from the taxes in Kings County, where the proposed facility is located.

SAVINGS

I then proceeded to find the money that would be saved, by the implementation of the ultrafiltration system. Hauling milk was reduced to one load instead of three loads. For this I used De Groot Dairies cost of hauling milk per year and times it by 2/3 to find how much they would save on hauling.

The other factor that I calculated in finding the money saved on the implementation of the ultrafiltration system was the savings in the heifer ration when permeate was fed. I then found the amount of heifers on De Groot Dairies, which was 3,677. According to Flemming (1999) when permeate was fed it replaces two pounds of corn per day per cow. I then took the price of earlage which was valued at $200 per ton. To find how much earlage would be replaced I used 3677 heifers times by 2 lbs per day times by 365 days and then divided it by 200 to get how many tons were consumed per year. I then calculated the savings with all heifers for the entire year to get a savings of $268,421.

Results

For the results of my project, I made a running balance for all the costs involved with the ultrafiltration system, this included the yearly and initial cost. The running costs are shown in table 4.

Table 5. Ultrafiltration system running balance of costs		
Year	cost	running balance
0	$653,170.00	$653,170.00
1	$938,174.00	$1,591,344.00
2	$938,174.00	$2,529,518.00
3	$938,174.00	$3,467,692.00
4	$938,174.00	$4,405,866.00
5	$938,174.00	$5,344,040.00
6	$938,174.00	$6,282,214.00
7	$938,174.00	$7,220,388.00
8	$938,174.00	$8,158,562.00
9	$938,174.00	$9,096,736.00
10	$938,174.00	$10,034,910.00
11	$883,974.00	$10,918,884.00
12	$883,974.00	$11,802,858.00
13	$883,974.00	$12,686,832.00
14	$883,974.00	$13,570,806.00
15	$883,974.00	$14,454,780.00
16	$883,974.00	$15,338,754.00
17	$883,974.00	$16,222,728.00
18	$883,974.00	$17,106,702.00
19	$883,974.00	$17,990,676.00
20	$883,974.00	$18,874,650.00

I then made a running balance of the savings that was from reduced transportation and reduced feed costs. This is shown in table 5.

	Table 6. Feed and transportation savings	
Year	Savings	running balance
1	$560,421.00	$560,421.00
2	$560,421.00	$1,120,842.00
3	$560,421.00	$1,681,263.00
4	$560,421.00	$2,241,684.00
5	$560,421.00	$2,802,105.00
6	$560,421.00	$3,362,526.00
7	$560,421.00	$3,922,947.00
8	$560,421.00	$4,483,368.00
9	$560,421.00	$5,043,789.00
10	$560,421.00	$5,604,210.00
11	$560,421.00	$6,164,631.00
12	$560,421.00	$6,725,052.00
13	$560,421.00	$7,285,473.00
14	$560,421.00	$7,845,894.00
15	$560,421.00	$8,406,315.00
16	$560,421.00	$8,966,736.00
17	$560,421.00	$9,527,157.00
18	$560,421.00	$10,087,578.00
19	$560,421.00	$10,647,999.00
20	$560,421.00	$11,208,420.00

The objective was to determine whether the implementation of an ultrafiltration system was profitable. To do this, I found the breakeven point after 10 years and 20 years. The price for ultrafiltration milk was needed to find the breakeven point. Therefore I used the price of $49.50 /cwt of retentate. Because retentate was three times the concentration of raw milk, the price should also be three times more than that of raw milk. Therefore 16.50 times 3 were used to get the price of retentate. De Groot Dairies produced 126,005,738 lbs of milk in 2012. To get the cwt, I divided 126,005,738 by 100 and then I divided that by 3 to find the amount of retentate that would be produced. The result for the amount of retentate in one year produced by De Groot Dairies would be 420,019.13 cwt.

This 420,019.13 cwt was multiplied by the price of $49.50 cwt, which would be the same as the price of raw milk and not using the ultrafiltration system. This was needed to find how much more of a bonus or premium was needed to break even with all the added costs of running the system minus the benefits of feed and transportation.

I wanted to find the breakeven point at ten years and twenty years. To do this I took the running balance of the costs at 10 years minus the savings in feed and transportation at 10 years and determined costs exceeded feed and hauling savings by $4,430,700. Then I divided it by 10 because I wanted to find the loss per year, which gave me $443,070. The next step was to find how much more per hundred weight of retentate was needed to break even. For this I took $443,070 divided by the amount of retentate produced in a year which was 420019.13, which equals $1.05 cwt of retentate. This means that in order to breakeven after 10 years, the price of retentate would need to be $50.55 cwt. I followed the same steps to find the breakeven price at 20 years and needed an additional price of $0.91 cwt. The final price needed to break even after 20 years was $50.41 cwt of retentate.

Net present value (NPV) was also calculated for the costs and the savings of the system. The net present value of costs after 20 years given a rate of 5% was $12,056,854.63. NPV shows the present value of future money today, in this case, 20 years in the future. The NPV for the savings was $6,984,084.38. This shows that in 20 year, the dairyman will loose $5,072,770.24a in today's value of money. This was calculated by taking $12,056,854.63 – $6,984,084.38 = $5,072,770.24.

Discussion

There were many different variables in calculating the costs of the system. The system chosen will have an impact on the initial price of the system. The system was designed for De Groot Dairies and their milk flow. Every dairy was different and needs to be looked at individually.

There are many dairies that may have a long haul to the processing plant. The ultrafiltration and reverse osmosis would be a great tool to reduce the hauling cost. To find the savings on hauling, divide the current hauling cost of the dairy at hand by three. This would calculate new cost of shipping retentate. Then subtract the old cost by the new cost to find the savings. The longer the haul, the more likely the system will be able to pay for itself.

It was difficult to find the price given for UF milk. I emailed David Ahlem (2013) from Hilmar Cheese asking for the price, however, he replied saying that they do not share their pay formula because it is proprietary. I also contacted California Dairies Inc. to find the price, however they said that they do not have customers with UF milk, thus they do not have a price. That was why I had to use the regular price of $16.50 for regular raw milk and multiplied it by three, for being three times concentrated.

If done again I would change a few things. The first would be to install a larger system. I would want the system to process all of the milk and clean up in half the time. It was seen that the labor costs are high. The Implementation of a larger system will allow for one less employee needed to run the system. Secondly I would research the rules and regulations more in depth. The CDFA website had a good start, but I believe that a more in depth look at the regulations would be beneficial. Third, I would try harder to get a hold of the price that processors give for UF milk or retentate.

Conclusion

The results of my partial budget for ultrafiltration milk showed that when an on farm UF system was implemented, the dairyman would get a hauling and feed benefit. However when I calculated the costs saved, the input and yearly costs outweighed the benefits. All research done was according to De Groot Dairies projected milk weights and milk price. I would recommend that if researching on farm ultrafiltration, that the data is changed to match the proposed dairy. I would conclude that at this point in time, on farm ultrafiltration was not a viable option for a dairyman to implement.

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