ECONOMIC FEASIBILITY OF RECYCLING CHILLER WATER IN POULTRY PROCESSING PLANTS BY ULTRAFILTRATION

Horacio Saravia[1], Jack E. Houston[1], Romeo Toledo[2], and Heather M. Nelson[2]

AUTHORS: [1]Graduate Research Assistant and Professor, respectively, Department of Agricultural and Applied Economics, The University of Georgia, Athens; [2]Professor and Graduate Research Assistant in the Department of Food Science and Technology at the University of Georgia, Athens.
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Abstract. The poultry industry is the single largest agribusiness industry in Georgia and one of the most important in the United States. It is also facing multiple water usage problems stemming from rising water and sewer charges and an increase in pollution regulations. One way to reduce water usage and volume of wastewater is through recycling the chiller water used in processing. Food scientists and applied economists at the University of Georgia are collaborating on research to evaluate the operational and economic effectiveness of ultrafiltration membrane technologies (polymeric) at a pilot poultry processing plant in Georgia. On-site tests of membrane systems are underway. Preliminary economic analysis is highly positive (return rate = 45.6 %) and consistent with results from other manufacturing settings where similar systems have been employed. Economically efficient technological breakthroughs are essential if the U.S. poultry industry is to continue operating competitively.

INTRODUCTION

Poultry production is very important in the United States (US). Economically efficient technological breakthroughs are essential to maintain its competitive edge in processing and marketing. The Census of Manufacturers (1997) reports 260 companies engaged in poultry slaughtering. These companies own or operate 470 facilities, employ 224,000 employees, and produce about $32 billion in value of shipments annually. This industry is highly concentrated in the southeastern states. In Georgia, it represents the largest agricultural industry, with an annual contribution to the economy of $2.2 billion in 2002 (Georgia Agricultural Statistics Service).

Water use is a major issue in the poultry processing industry. Federal sanitation regulations set up three years ago have caused poultry processing plant consumption of water to increase significantly. These regulations require the meat industry to ensure products are as pathogen-free as possible, and poultry processors have used more water in processing to help solve this problem. Water use restrictions during periods of drought can lead to increased competition between industrial and household users of water. Recycling not only reduces water use but also reduces volumes of wastewater. Therefore, finding an effective and efficient (physically and economically) way to deal with this issue could significantly benefit this industry.

OBJECTIVE AND DATA SOURCE

The objective of this research is to evaluate economically the recycling process of chiller water in a pilot poultry processing plant using a polymeric ultrafiltration membrane system. The filtration system to be evaluated is provided by Sepro-Rochem Inc.

The Department of Food Science & Technology of The University of Georgia collects the experimental data for this work and is in charge of the physical evaluation of the filtration system. We also have used information from different suppliers of inputs.

INDUSTRIAL PROCESS AND WATER CONSUMPTION

The poultry industry in US generally produces “ready – to – cook” poultry products. The universal industrial process can be summarized: Receiving → Killing → Bleeding → Defeathering → Eviscerating → Chilling → Weighing, Grading and Packaging → Shipping (USEPA, 1975).

Carcasses should be chilled rapidly to below 40 ^{o}F, to minimize microbial growth and to preserve product quality (Tsai, Higby and Schade, 1995). To do this, most poultry plants use two chilling tanks in series, a pre-chiller and a main chiller. Several studies cited by the US Environmental Protection Agency (EPA), have shown that the volume of water used and wastewater generated by poultry processing can vary substantially among processing plants. Per current USDA regulations, 0.5 gallon of water per bird must be overflowed from the chiller and replaced with fresh water.

ULTRAFILTRATION SYSTEMS: SOME GENERAL SPECIFICATIONS

Several different methods have been tested to evaluate their effectiveness on reconditioning broiler process water (waste-water treatments), such as direct ozonation, with either slow sand filtration, dissolved air flotation or diatomaceous earth filtration. The Food Safety and Inspection Service of the USDA may allow reconditioning and recycling of chiller water. According to the Code of Federal Regulation (1987) cited by Chang and Toledo (1989 b), the basis for approving the use of recycling water includes:

- reconditioning equipment and conditions for use must be approved,
- reconditioning must achieve and maintain at least a 60% reduction in total microorganisms and percentage reduction in coliform bacteria (Escherichia coli or Salmonella spp.) that may be present must be within 60 +/- 10,
- light transmission of the treated water must be at least 60% of that of the fresh water used in the process.

The same authors, using a filtration test unit of their construction, found that sometimes the total microbial reduction fell below 60%, suggesting possible use only when microbicides are added to the reconditioned water prior to recycling. They also found that the rate of filtrate flow dropped rapidly regardless of the use of filter aides, due to the deposition in the filter of two kinds of solids present in the overflow chiller water.

We can distinguish three main filtration categories, depending on the size of particles that are separated:

- Macrofiltration, conventionally defined as the filtration of particles that are 5 micron sized or greater;
- Microfiltration, which is a low-pressure cross-flow membrane process for separating colloidal and suspended particles in the range of 0.1-2 microns;
- Ultrafiltration is a selective fractionation process utilizing pressures up to 145 psi (10 bar). It concentrates suspended solids and solutes of molecular weight greater than 1,000. The permeate contains low-molecular-weight organic solutes and salts.

The main strength of membrane technology is that it works without the addition of chemicals, with a relatively low energy use, and an easy, well-arranged conduction process.

RESULTS

Physical Data Collected by the Food Science & Technology Department

The Food Science & Technology team has conducted experiments with a smaller version of the membrane technology system that they built in their labs. They also have modified the larger, pilot system.

The filtration units should be cleaned frequently: about 2 minutes every 8 hours with 10 liters (l) per unit of a solution containing 0.5% of cleaner, and about 2 minutes every 1 hour without cleaner, only using backflush with permeate. Information obtained with the small filtration unit (Singh et al.) shows a total suspended solids (TSS) amount of 3.88 mg/l in the unfiltered water and an average value of 1.42 mg/l after filtration (average of three samples). From this information we compute the percent average reduction in total suspended solids of the chiller water as:

$3.88 - 1.42 = 2.46 \rightarrow$ average reduction in TSS

$(2.46 / 3.88) \times 100 = 63.4\% \rightarrow$ percent average reduction in TSS

This data is consistent with previous research. Sheldon and Carawan (1989) cited a value of 65% for this TSS reduction.

Data from Other Sources

The average production of pollutants in US poultry processing plants, according to data gathered by EPA, Office of Water, is the following:
Biochemical Oxygen Demand (BOD): 0.14 lb/1,000 LWK (pound per 1,000 live weight killed); Total Suspended Solids (TSS): 0.07 lb/1,000 LWK and Oil and Grease (OG): 0.23 lb/1,000 LWK. Kiepper (2003) found that the average chicken live weight processed in the US industry was 5.8 pounds (lb). We can then estimate the total daily amount of pollutants produced at the pilot plant by multiplying the daily number of processed broilers by 5.8 and then by average pollutant produced per pound live weight killed (lb/LWK). That is, 5.8 x 330,000 = 1,914,000 lb/day LWK, and considering this broiler production and the average pollutant generation, we get an estimate of the average pollutants that our pilot firm is likely to produce in a 260 days- labor based year:

BOD: 68,873.38 lb/1,000 LWK
TSS: 33,292.12 lb/1,000 LWK and
OG: 114,457.20 lb/1,000 LWK.

These data are especially important to compute possible savings if filtration reduces the amount of pollutant discharge. According to Sheldon and Carawan (1989), in some states as in Georgia, there are sewage surcharge costs for industries, based on the level of BOD, TSS and OG of the effluents. Taking into account the average effluent concentrations of BOD, TSS and OG in the poultry industry (EPA, 2002), we used the above-mentioned ranges of surcharges.

In this case, only the Oil and Grease pollutant reaches the concentration level to be surcharged.

Table 1. Budget Information for Pilot Plant Chiller Water Recycling.

Factor		Price/cost/unit
SEPRO ROCHEM Ultrafiltration Polymeric Membrane Unit		$42,000 (pump + tank)
(excluding taxes, with installation costs)		$20,000 (150 m^2 membranes)
Useful life of ultrafiltration unit		3 years, membranes 10 years, unit & pump
Filter cleaner[a] (Ultrasil 25)		$ 1.886/liter
Cleaner use per unit		0.05 liters/8 hours
Labor wage[b]		$ 9.27 /hour
Energy to chill the water[c]		12 watt-hr/bird
Energy cost of kilowatt-hour[d]		$0.0429/kwh
Efficiency of recycling chiller water with the filtration unit[e]		85%
Total daily chiller overflow[f]		624,525 liters
Water[g]	$1.73/100 cubic feet +	$ 23.19/month base charge
Sewage surcharge by level of pollutants[g]		$160/1,000 lb of OG
Sewage surcharge by volume[g]	$1.54/100 cubic feet +	$ 5.60/month base charge
Labor, maintenance and cleaning (daily)[h]		$ 74.16
Annual work-days of pilot plant		260 days

[a] Ecolab, Food and Beverage Division.
[b] Poultry & Egg Association an U.S. Department of Labor, 80% above the federal minimum wage
[c] Graham, Strasser, and Mannapperuma, (2002).
[d] Advantage Georgia, (1998).
[e] Sheldon and Carawan, (1989).
[f] 165,000 gal, estimated from EPA requirement of 0.5 gallon per bird, multiplied by the 330,000 broilers/day that the pilot plant actually processes
[g] Department of Public Utilities, Unified Government of Athens Clarke County, GA
[h] Assuming 1 hour-worker/ 8 hours/ "hard unit" for maintenance and cleaning; firm has two 8-hour shifts.

Partial Budget Analysis.

With the available information thus far, the partial budget method permits us an acceptable first approach to an economic evaluation of the recycling of chiller water. The proposed change in the pilot plant's processing is the incorporation of a polymeric ultrafiltration system. This system is composed by 150 m2 membrane sets, and also pumps and tanks. Every pump and tank can handle up to 4 membrane sets. Considering a flow rate of 16.33 liters/hour per m^2 (average, considering membranes are fouled during the recycling operation causing the original flux to drop), the total number of units required to filter the daily chiller overflow is 16 membrane units. Other budgetary information and assumptions are presented in Table 1.

Table 2 presents the partial budgeting results in the pilot plant, accounting for the cost to discharge pollutants into surface waters. By recycling the chiller water, this plant could avert $219,465 in water, sewage and energy costs annually. Approximately 39% of this amount would come from water savings, 41% from sewage cost savings, and 20% from energy savings (energy required to chill the water). These annual dollar savings exceed the additional costs of recycling, which amount to $150,709 annually. The main component of the additional costs is amortization of the filtration system (82%), followed by other items, such as labor (12%, especially for cleaning and maintenance), cleaning costs and miscellaneous. Thus, the net annual change in income or gross margin after the proposed change is $68,756. The return rate per additional costs (net change/total annual debits) equals 45.6 %, which, compared to the 35.5% profit before taxes/tangible net worth and 12.4% profit before taxes/total assets of the upper quartile in this industry (RMA, 2003), is decidedly superior.

CONCLUSIONS

Our initial findings in this approach to the economic feasibility of incorporating an ultrafiltration chiller water recycling unit in the pilot poultry processing plant indicate positive impacts for the profitability of this plant by more than $60k per year. Importantly, this technology addresses the water quantity and quality issues that have been raised in this industry by reducing primary water use by approximately 36.5 m gallons and electrical energy use to chill water by nearly 1.03 gigawatt-hours annually in our pilot plant. Given that such poultry processing plants can have very large local impacts, these averted water and sewage treatment savings are quite significant to municipalities and stressed watersheds.

Table 2. Partial Budget for Incorporation of Ultrafiltration Units to Recycle Chiller Water in Pilot Plant, with Sewage Surcharge.

BUSINESS CREDITS	
A. ADDITIONAL ANNUAL RECEIPTS	
None Total additional receipts	$ 0.00
B. REDUCED ANNUAL COSTS	
B.1 Energy savings by returning recycled chiller water (12 watts/bird)	$ 44,169.84
B.2 Water savings (85% efficiency recycling chiller overflow)	$ 84,600.75
B.3 Sewage costs savings (in Athens Clarke, GA, 85% eff.)	$ 90,695.00
Total reduced annual costs	$ 219,465.59
Total annual credits	$ 219,465.59
BUSINESS DEBITS	
C. ANNUAL RECEIPTS REDUCTION	
None Total reduced receipts	$ 0.00
D. ADDITIONAL DIRECT ANNUAL COSTS	
D.1 Depreciation (4 & 16 units, straight-line method, 10 & 3 years useful life, salvage value = 0)	$ 123,466.67
D.2 Labor ($9.27 /hour; 1 hour-worker/ 8 hours/ "hard unit")	$19,281.60
D.3 Filter - cleaning costs (0.1 L of cleaner/unit/day * 260 days* 16 units)	$ 784.58
D.4 Miscellaneous (5% of the additional direct annual costs)	$ 7,176.64
Total additional annual costs	$150,709.48
Total annual debits	$150,709.48
NET CHANGE IN INCOME	$68,756.10

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