A Non-Market Valuation of an Ultrafiltration System for Recycling Poultry Processing Chiller Water

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Importance of poultry industry in the United States

- 311 companies in poultry production/processing
- 536 facilities
- 243,000 employees
- about $38 billion annually
- In Georgia, poultry is the largest agricultural industry, with an annual contribution of $2.5 billion to the state's economy in 2004.
- GA first in broiler production in the US in 2004, with 14.84% of total production

Water use

- Federal sanitation regulations have caused processing plant consumption of water to increase significantly (+29%)
- To ensure products are as pathogen-free as possible, poultry processors have used more water in processing
- Periods of drought can lead to increased competition between industrial and household users of water

Objective

- To evaluate the operational and economic effectiveness of the recycling process of chiller water in a pilot poultry processing plant using a polymeric ultrafiltration membrane system.

- The analysis includes the financial investment and sensitivity analysis.

- *Technical assistance provided by UGA's Food Science & Technology department and filtration system provided by Sepro-Rochem, Inc.*

Industrial process and water consumption

- The poultry industry in US generally produces “ready – to – cook” poultry products.
- <u>The processing activities</u> :
  Receiving → Killing → Bleeding → Defeathering → Eviscerating → Chilling → Weighing, Grading and Packaging → Shipping
  (USEPA, 1975, and observation)

Industrial process and water consumption

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  (USEPA, 1975)

Industrial process and water consumption

- Carcasses should be chilled rapidly to below 40 ^{o}F (from about 70 ^{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.

Ultrafiltration: definition

- Filtration: a unit operation that is designed to separate suspended particles from a fluid media (also called “feed”) by passing the solution through a porous membrane or medium.

- Ultrafiltration: 0.01 microns. Utilizing pressures up to 145 psi (10 bar), concentrates suspended solids and solutes of molecular weight greater than 1,000.

Water Reuse Challenges

- Water to be reused in the carcass - chilling process must meet the USDA – FSIS requirements: at least,

  60% microorganisms reduction, and

  60% LT referred to freshwater

- Wastewater to be discharged must meet the CWA – Athens-Clarke requirements:

  maximum allowed levels of

  BOD = 1000 mg/L, TSS = 750 mg/L, OG = 200 mg/L

GA Wastewater Surcharges

Parameter	Concentration (mg/L)	Charge (per 1,000 lbs)
BOD	251 – 500	$46.00
	501 - 750	$92.00
	751 – 1000*	$138.00
TSS	251 – 500	$103.00
	501 – 750*	$135.00
OG	101 – 150	$80.00
	151 – 200*	$160.00

** Maximum allowed*

Source: UNIFIED GOVERNMENT OF ATHENS-CLARKE COUNTY, GEORGIA
FEE SCHEDULE FOR WATER AND WASTEWATER SERVICES

Reconditioning Guidelines for Chiller Water

Minimum Reduction in Microorganisms (%)	Minimum Light Transmission (%)	Volume of Recycled Water to Replace one Volume of Freshwater (gal.)
60	60	1.75
70	70	1.50
80	80	1.35
90	80	1.25
98	80	1.10

Source: Code of Federal Regulations, Title 9, Section 381.66. (USDA, FSIS. 1987).

Variables Considered

Variable	Units	Description
TSS	mg/L	Total Suspended Solids
BOD	mg/L	Biochemical Oxygen Demand
COD	mg/L	Chemical Oxygen Demand
OG	mg/L	Oil and Grease
LT	%	Light Transmission
TPC	cfu/mL	Total Plate Count
Coliform	cfu/mL	Indicator of fecal pollution

cfu/mL = Colony – forming units per mililiter

Results

Variable		Retentate (Before UF)	Filtrate (After UF)	Reduction (Difference)
TSS (mg/L)	*Mean*	3.838571	1.355	2.475476
n = 14 42 42	*Stdv*	0.059853	0.072052	0.054826
BOD (mg/L)	*Mean*	2,252.00	46.70	2,205.30
n = 3 3 3	*Stdv*	39.606397	2.867442	38.516952
COD (mg/L)	*Mean*	3,240.0	110.0	3,130.0
n = 3 3 3	*Stdv*	45.460606	4.082483	41.432676
OG (mg/L)	*Mean*	455.3	92.0	363.3
n = 3 3 3	*Stdv*	4.988877	1.632993	6.182412
TPC (cfu/mL)	*Mean*	7,822.857543	117.190476	7,741.380952
n = 14 42 42	*Stdv*	980.764447	13.239332	910.022218
Coliform (cfu/mL)	*Mean*	6	0.785714	5.238095
n = 14 42 42	*Stdv*	1.037749	0.716894	1.1001
LT (%)	*Mean*	45.10	91.15	46.05 **=Increase**
n = 2 2 2	*Stdv*	2.83	0.07	2.90

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87.30% ↓

> 90%

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n = 3 3 3				6952
COD (mg/L)				30.0
n = 3 3 3				2676
OG (mg/L)				3.3
n = 3 3 3				2412
TPC (cfu/mL)	*Mean*	7,822.857543	117.190476	7,741.38
n = 14 42 42	*Stdv*	980.764447	13.239332	910.022218
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So, our pilot plant can reuse chiller water at the ratio of 1:10 – 1

(1:10 gal of recycled water to substitute 1 gal of freshwater → maximum achievable)

98.96% ↓

87.30% ↓

> 90%

Results: Generated Variables

Variable	*n = 1000*	Retentate (Before UF)	Filtrate (After UF)	Reduction (Difference)
TSS (mg/L)	*Mean*	3.841696	1.350819	2.490877
	Stdv	0.059563	0.072214	0.095039
BOD (mg/L)	*Mean*	2,251.45473	46.675472	2,204.77926
	Stdv	39.174739	2.936392	39.427615
COD (mg/L)	*Mean*	3,241.49445	109.698912	3,131.79554
	Stdv	45.221577	4.192456	45.537818
OG (mg/L)	*Mean*	455.255990	92.060275	363.195715
	Stdv	4.957678	1.606069	5.241826

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BOD and OG largely exceed the allowed limits for discharging pollutants

(BOD 1,000 mg/L & OG 200 mg/L)

Results

- Cleaning requirements:

  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

Partial budget analysis

- Proposed change: incorporation of a polymeric ultrafiltration unit system in the pilot plant, with the objective of recycling the chiller water by filtering its overflow

- The pilot plant processes 330,000 broilers daily, with a required volume of 165,000 gallons/day of fresh chiller water, recycling using two chillers for two 8-hour shifts, and 260 processing days a year.

Partial budget analysis

- **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 $ 44,169.84
  12 watts/bird = 14% savings

  B.2 Water savings = 27% $ 84,600.75
  (85% efficiency recycling chiller overflow)

  B.3 Sewage costs savings = 59% $ 185,160.57
  (in Athens-Clarke, Georgia, 85% efficiency)

  Total reduced annual costs $ 313,931.16

  Total annual credits $ 313,931.16

Partial budget analysis

- **BUSINESS DEBITS**

- C. ANNUAL RECEIPTS REDUCTION

None	Total reduced annual receipts	$ 0.00

- D. ADDITIONAL DIRECT ANNUAL COSTS

D.1 Depreciation	$ 123,466.67
(4 & 16 units, straight-line method, 10 & 3 years useful life, salvage value = 0)	
D.2 Labor ($9.27 /hour; 1 hour-worker/ 8 hours/ "hard unit")	$ 19,281.60
D.3 Filter - cleaning costs	$ 784.58
(0.1 L of cleaner/ unit/ day * 260 days* 16 units)	
D.4 Miscellaneous	$7,176.64
(5% of the additional direct annual costs)	
Total additional annual costs	$150,709.48
Total annual debits	$150,709.48

Partial budget analysis

- **NET CHANGE IN INCOME (GROSS MARGIN)**

	TOTAL ANNUAL REDUCED COSTS		$ 313,931.16
-	TOTAL ANNUAL ADDED COSTS		$ 150,709.48
	NET CHANGE IN INCOME	**+**	**$ 163,221.68**

Partial budget analysis

- The return rate per additional costs (net change/total annual debits) equals 108.3%, which, compared to the 40.4% profit before taxes/tangible net worth and 12.0% profit before taxes/total assets of the upper quartile in this industry (RMA, 2004), is decidedly superior.

- Considering the initial investment of $488,000 by purchasing the filtration units ((4 x $42,000) + (16 x $20,000)), the pay-back period = 3 years.

Other Financial Analysis Results

- **Return on Investment (ROI):**
  - [cash flow savings / net investment] = 33.4%
- **Net Present Value (NPV):**
  - [cash flow savings x (6% opportunity return, 10 year MACRS tax life)] – net investment = $ 713,233
- **Internal Rate of Return (IRR):**
  - [discount rate when NPV = 0] = approximately 30%
- **Benefit Cost Ratio (BCR):**
  - [PV of inflows / PV of outflows] = 2.46

Sensitivity Analysis

	Change in Debits or Credits Items			
Change with respect to Initial Budget*	5%	10%	15%	20%

** Initial situation: Net Change = $163,222*

Sensitivity Analysis

	Change in Debits or Credits Items			
Change with respect to Initial Budget	5%	10%	15%	20%
A) Increasing Debits Items – Holding Credits Constant:				
Net Change in Income ($)	155,685	148,151	140,614	133,080
Percentage Change (%)	95.4	90.8	86.1	81.5

** Initial situation: Net Change = $163,222*

Sensitivity Analysis

	Change in Debits or Credits Items			
Change with respect to Initial Budget	5%	10%	15%	20%
A) Increasing Debits Items – Holding Credits Constant:				
Net Change in Income ($)	155,685	148,151	140,614	133,080
Percentage Change (%)	95.4	90.8	86.1	81.5
B) Increasing Credits Items – Holding Debits Constant:				
Net Change in Income ($)	178,872	194,625	210,275	225,765
Percentage Change (%)	109.6	119.2	128.8	138.3

** Initial situation: Net Change = $163,222*

Conclusions

- Our initial findings 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 $160k per year, supporting considerable variations on cost scenarios.
- This profitability comes mainly from averted costs the firm can face because of reducing pollutant discharges to the environment.
- WTP for the ultrafiltration system could be affected by level of pollutant reduction's capacity of the system. But this hypothesis remains to be tested in latter stages of the project.

Conclusions

- 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. (x 14.3 = GA)

- 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.

Questions/ Comments?

Thank you!