Ultrasonic Enhancement of Dairy Ultrafiltration

Shobha Muthukumaran, Sandra Kentish, Muthupandian Ashokkumar, Raymond Mawson

FOOD SCIENCE AUSTRALIA
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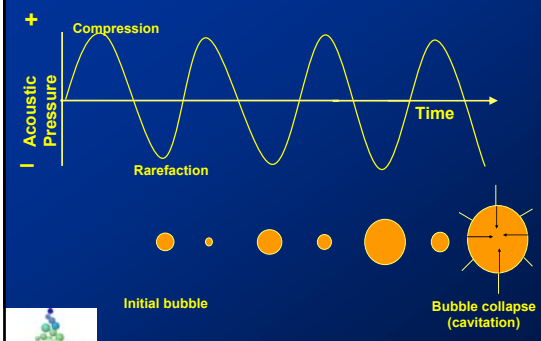
Overview

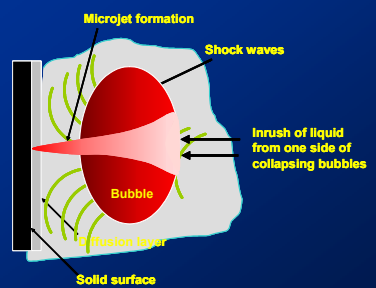
- Fundamentals of Ultrasonics
- Ultrasonics in the Production Cycle
- Ultrasonics in the Cleaning Cycle
- Ultrasonic Effects on membranes and milk
- Conclusions and Future Work

Fundamentals of Ultrasonics

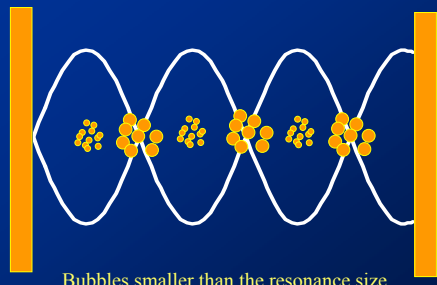
Sonic Waves



Asymmetric Bubble Collapse



Standing Wave Patterns

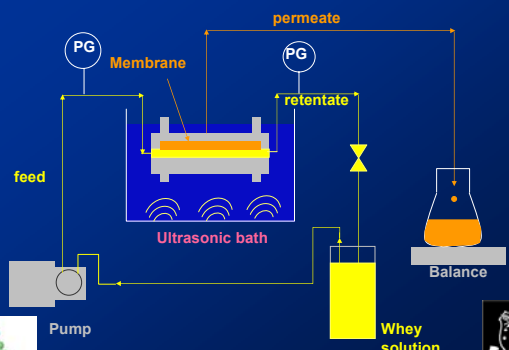


Bubbles smaller than the resonance size accumulate at the pressure antinodes, larger bubbles accumulate at the nodes

Power Ultrasound can:

- Provide vibrational energy
- Agglomerate particles or bubbles
- Disperse particles
- Scour surfaces through cavitational collapse

Experimental Equipment

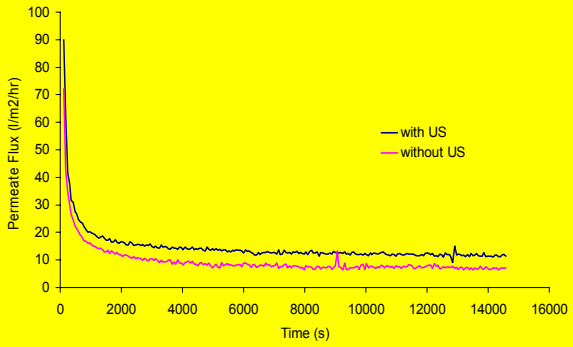


Low Power Delivery

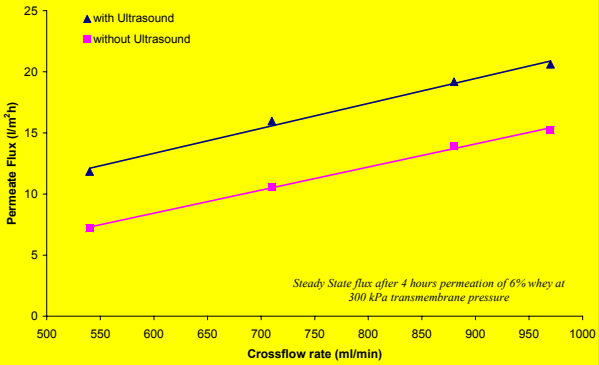
- Power to bath water – 20 W per litre
- Power to membrane – 2 W per litre
- Alfoil test shows minimal cavitation
- Peroxide test shows no free radical formation

Ultrasonics in the Production Cycle

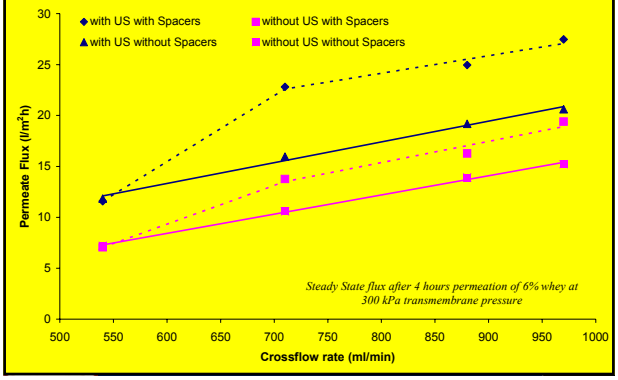
Permeate Flux Improves



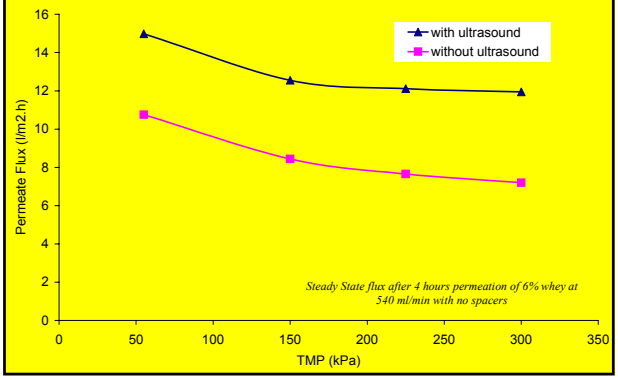
Constant Permeate Flux Improvement



Effect of Spacers



Effect of Trans-membrane Pressure

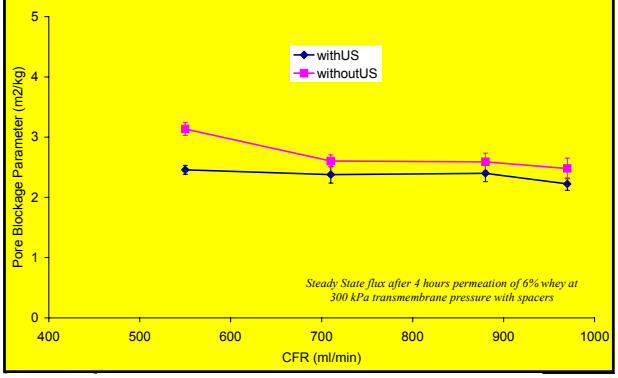


Combined Pore Blockage and Cake Filtration Model Developed by Ho and Zydney

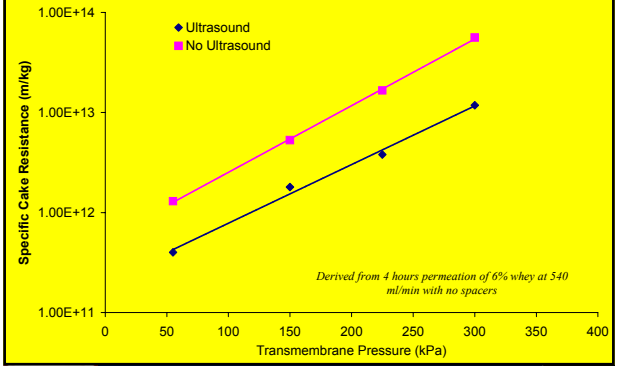
$$Q = Q_0\left[\exp\left(-\frac{\alpha\Delta P C_b t}{\mu R_m}\right) + \frac{R_m}{R_m + R_p}x\left(1-\exp\left(-\frac{\alpha\Delta P C_b}{\mu R_m}t\right)\right)\right]$$

$$R_p = \left(R_m + R_{po}\right)\sqrt{1+\frac{2f'R'\Delta P C_b}{\mu\left(R_m+R_{po}\right)^2}t} - R_m$$

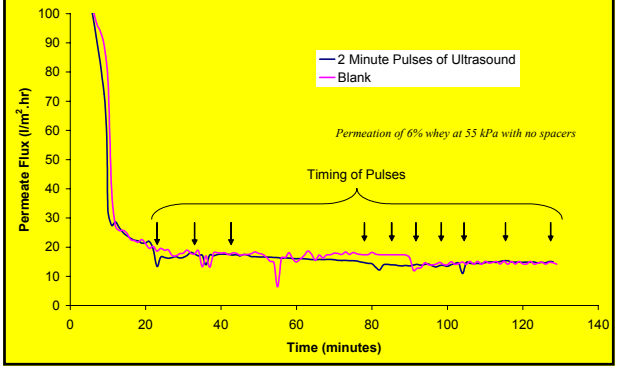
Pore Blockage



Cake Resistance

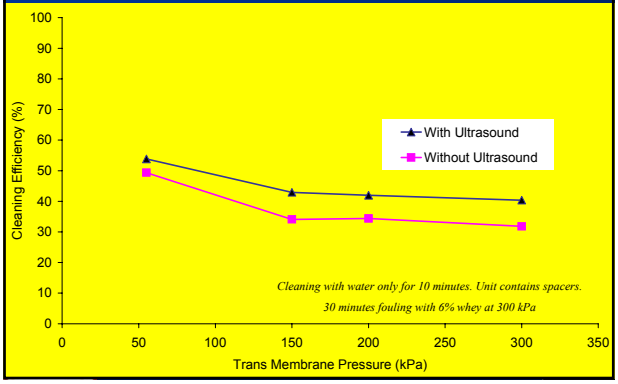


Intermittent Ultrasound is Ineffective

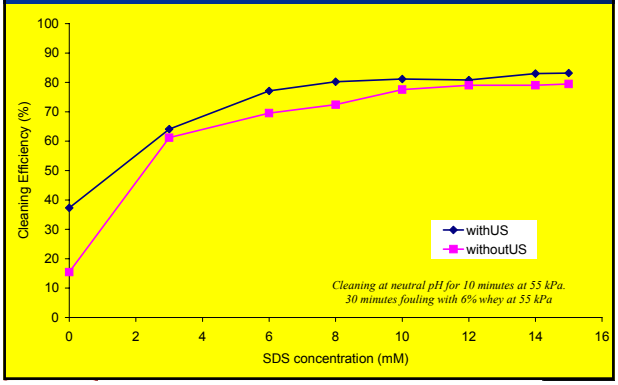


Ultrasonics in the Cleaning Cycle

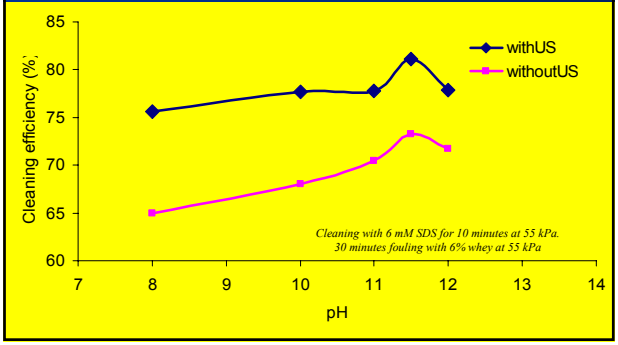
Cleaning Efficiency Improves



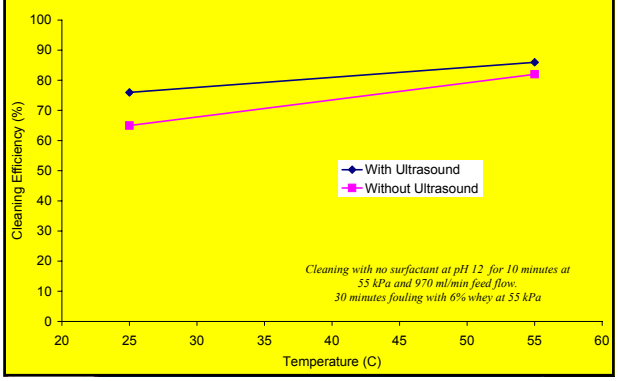
Effect of Surfactant



Alkali Cleaning Cycle at Ambient Temperatures



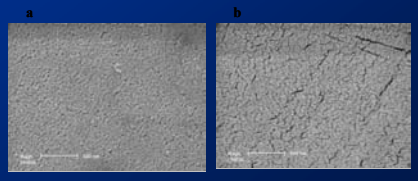
Temperature Effects



Ultrasonic effects on membranes and milk

Membrane Life

- No change in clean water flux over many months of experiments
- No evidence of membrane damage



Damage to Dairy Solutions

- No change in soluble protein composition
- No change in particle size distribution
- Literature indicates that some denaturation of whey proteins can occur at above ambient temperatures

Preliminary Economic Analysis

- Application to production cycle has potential
- Application to cleaning cycle in isolation is unlikely to be economic but may be warranted for triple bottom line
- Capital cost of transducers is a significant contributor

Conclusions

- Production cycle enhancement factors of 1.2 to 1.7
- Some benefits during the cleaning cycle
- No damage observed to membranes or whey solutions
- Low power delivery is the key

Future Work

- Full size Spiral Wound Unit to be built at Food Science Australia
- Economics to be further developed