Doped Diamond-Like Carbon (DLC) coated surfaces to reduce fouling from milk

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Dairy fouling

Formation of deposits (proteins, minerals and microorganisms) on processing surface

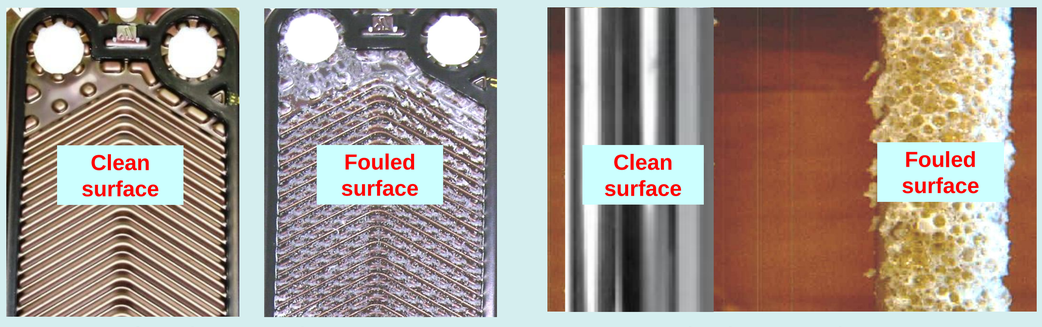


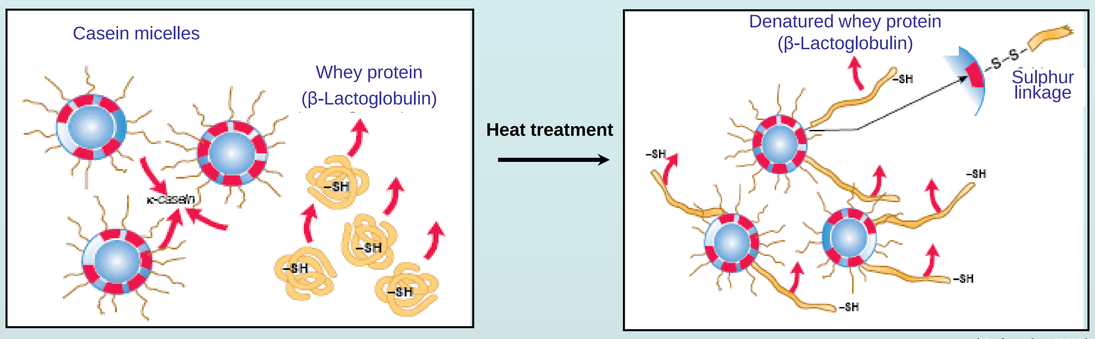
Plate heat exchanger

Tube heat exchanger

Figure 1 Fouling deposits on processing surfaces

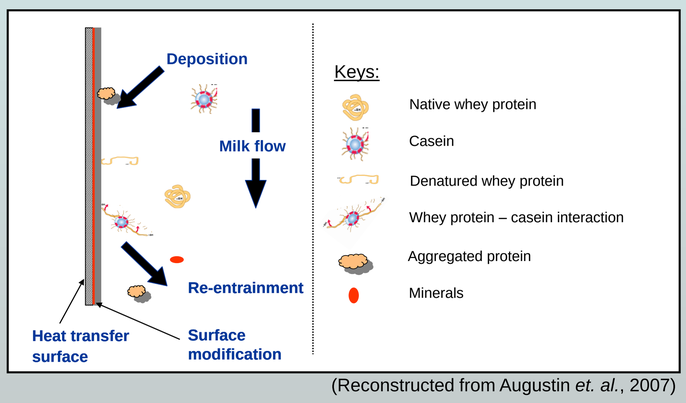
Theory and mechanism of fouling

- ✓ Heat denaturation of proteins
- ✓ Interactions with proteins and minerals



(Bylund, 1995)

Figure 2 Heat induced changes in whey protein and their interactions



(Reconstructed from Augustin *et. al.*, 2007)

Figure 3 Fouling mechanism

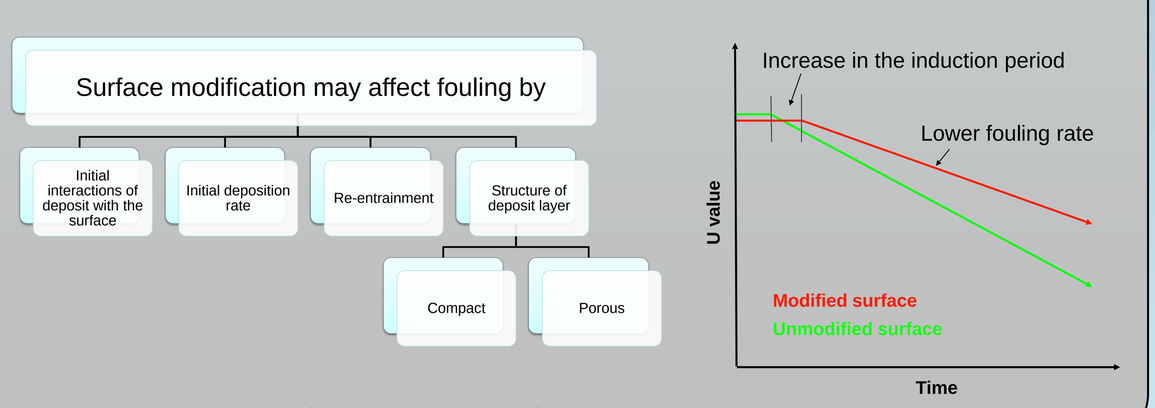


Figure 4 Probable theory for fouling mitigation by modified surface

Materials and methods

Experimental surface

- ❑ Doped Diamond-Like Carbon (DLC)
  - ➢ DLC-1
  - ➢ DLC-2
  - ➢ DLC-3
- ❑ Unmodified stainless steel (316 SS 2B)

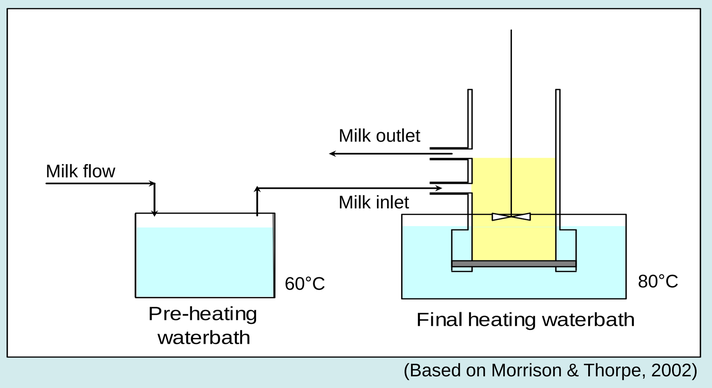
Fouling fluid

- ❑ Raw whole milk
- ❑ Whey Protein Isolate (WPI) solution

Fouling measurement

- ❑ Invasive methods
  - ➢ Weight of fouling deposit
  - ➢ Qualitative - visual observation
  - ➢ Chemical composition
- ❑ Non-invasive methods
  - ➢ Heat transfer coefficient (U-value)
  - ➢ Pressure drop (ΔP)
  - ➢ Hot water inlet temperature

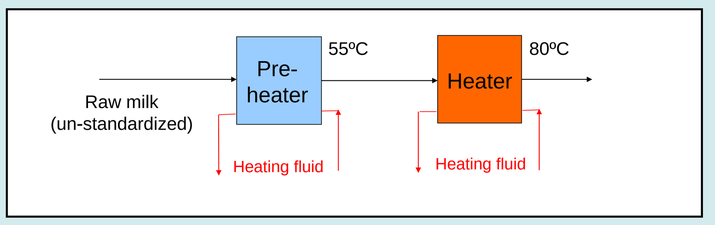
Experimental set up

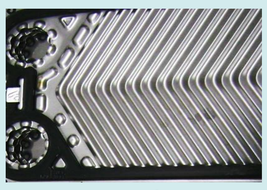


(Based on Morrison & Thorpe, 2002)

Experimental disk

Figure 5 Lab scale set up (four parallel flow streams)





PHE plate

Figure 6 Pilot scale set up (two parallel flow streams)

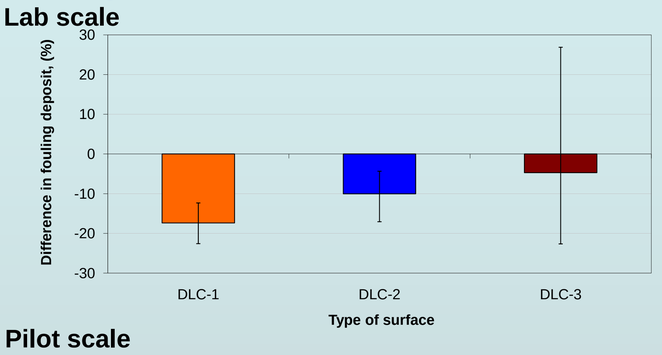
Parallel design

- ❑ To overcome the effect of "daily variation in milk composition"
- ❑ To overcome the effect of "ageing of milk"

Results

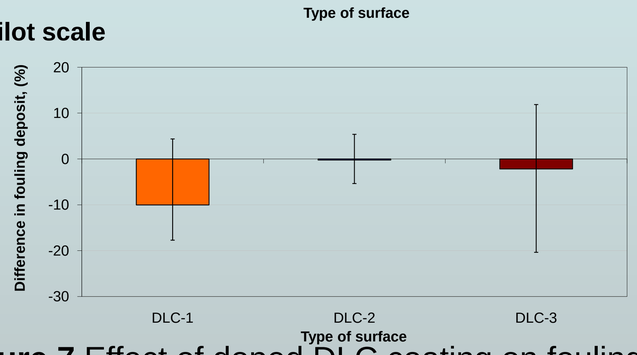
Milk fouling

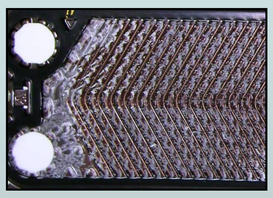
(a) Lab scale



Fouled disk

(b) Pilot scale



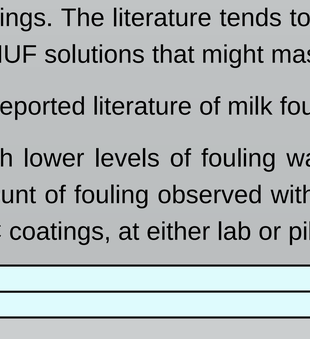


Fouled plate

Figure 7 Effect of doped DLC coating on fouling deposition with milk

WPI fouling

(a) Lab scale



(b) Pilot scale

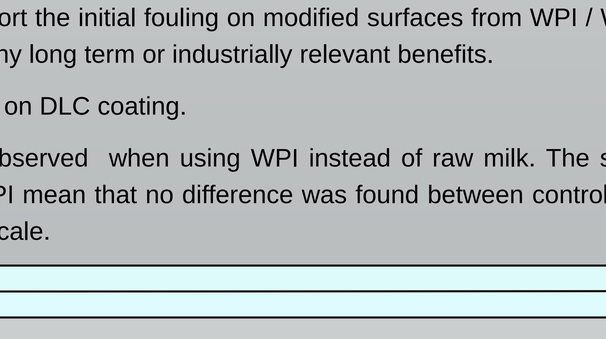


Figure 8 Fouling deposition with Whey Protein Isolate (WPI) solution

Summary

- When raw whole milk was used to study the commercial processing conditions, daily variation in milk composition led to wide variations in fouling behaviour between experiments.
- About 5 - 15 % less fouling deposits were observed on all three DLC coated surfaces at lab scale (Fig. 7a). **The difference between control and DLC-1 was statistically significant.**
- However, **no statistical difference in fouling deposition was noticed between control and coatings at pilot scale** (Fig. 7b). The difference between control and DLC-1 at pilot scale (~10%) was not statistically significant.
- Results in this study contradict the literature for reported benefits in fouling mitigation on DLC coatings. The literature tends to report the initial fouling on modified surfaces from WPI / WPC / SMUF solutions that might mask any long term or industrially relevant benefits.
- No reported literature of milk fouling on DLC coating.
- Much lower levels of fouling was observed when using WPI instead of raw milk. The small amount of fouling observed with WPI mean that no difference was found between control and DLC coatings, at either lab or pilot scale.

Acknowledgement

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Fonterra – Dairy for life

The University of Auckland – New Zealand

Reference

Augustin, W., Geddert, T. and Scholl, S. (2007) Surface treatment for the mitigation of whey protein fouling, Proceedings of 7th International conference on Heat Exchanger Fouling and Cleaning – Challenges and Opportunities, Tomar, Portugal, The Berkeley Electronic Press.

Bylund, G. (1995) Dairy Processing Handbook, Tetra Pak Processing Systems, Lund, Sweden, p. 33.

Morrison, K. R. and Thorpe, R. J. (2002) Spinning disc cleaning of skimmed milk and whey protein deposits, *Food and Bioproducts Processing*, 80 (4): 319-325