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Enhancement of heat stability during wet processing

Key external stakeholders:

The Dairy Processing Technology Centre (DPTC) is an industry-led Enterprise Ireland Technology Centre co-funded by eight major Irish dairy manufacturers Aurivo, Arrabawn, Carbery, Dairygold, Glanbia, Kerry, Lakeland Dairies and Tipperary Co-Op. DPTC is governed by a consortium agreement drawn-up in conjunction with all participants which set out protocols for the uptake of results. The project detailed here was in collaboration with University College Cork.

Practical implications for stakeholders:

Significant modifications to in-process and post-process heat stability (e.g. coffee test) can be achieved through understanding and manipulation of dairy chemistry:

- Levels of ionic calcium in whey protein isolate play a key role in heat-induced denaturation, aggregation and fouling
- Addition of calcium binding salts can significantly reduce heat-induced fouling and increase process efficiency
- Aggregation state of protein is equally important as level of denaturation (e.g. as measured by whey protein nitrogen index, WPNI) in the manufacture of fat filled milk powders

Main results:

- Addition of certain concentrations of the calcium-binding salts (CBS); trisodium citrate (TSC); tripotassium citrate (TPC) and; disodium hydrogen phosphate (DSHP) reduced fouling and improved heat transfer during thermal processing of whey protein isolate (WPI) dispersions (3%, w/v, protein).
- Effects of CBS addition were concentration dependent; appropriate levels of addition worked by decreasing ionic calcium concentration; however, lower or higher concentrations destabilised the systems on heating
- Fat filled milk powders (FFMP) made from high heat skim milk with similar whey protein nitrogen indices (WPNI) but with different thermal histories resulted in significant differences in powder structure and coffee stability

Opportunity / Benefit:

As per the DPTC consortium agreement Industry Partners have preferential access to outputs with commercial potential. This project provided new insight into heat stability across a wide number of products and processes relevant to DPTC industry partners. This was evident from the publicly available CBD and FFMP studies, which showed significant changes in heat stability can be achieved through appropriate process modifications.

Collaborating Institutions:

University College Cork
Dairy Processing Technology Centre

Contact Eoin Murphy Email: eoin. murphy@teagasc.ie.

Teagasc project team: Dr. Eoin Murphy
Dr. Yousef Joubran
Dr. Sultan Mahmoud

External collaborators: Dr. Seamus O'Mahony, UCC
Dr. Essam Hebishy, UCC
Eoin Finnegan, UCC

1. Project background:

The Dairy Processing Technology Centre (DPTC) is a consortium of academic and industry partners initiated in 2014 with a strong focus on creating a critical scientific mass to support innovation in dairy processing within Ireland. This DPTC sub-project was a collaboration between Teagasc and UCC (lead institution) and focused on the key unit operation of heat treatment, which ensures microbiological safety of dairy products, however, in-doing so can lead to issues with denaturation/aggregation of proteins along with subsequent issues such as fouling during processing and/or poor product quality.

2. Questions addressed by the project:

- Can detrimental heat-induced changes during processing be mitigated through addition of CBS?
- What type and level of CBS is required?
- Is WPNI an accurate measure to predict heat induced behaviour of skim milks incorporated into fat filled milk powders?

3. The experimental studies:

- **Calcium binding salts (CBS) study** – The effect of trisodium citrate (TSC), tripotassium citrate (TPC) and disodium hydrogen phosphate (DSHP) on heat induced behaviour and fouling of whey protein isolate (WPI) dispersions (3%, w/v, protein) was investigated. CBSs were added at concentrations of 1-45 mM. WPI dispersions were assessed for heat stability in an oil bath at 95˚C for 30 min, viscosity changes using a rheological simulation of HTST and fouling behaviour using a lab-scale fouling rig.

- **Fat filled milk powder (FFMP) study** – the effect of WPNI and protein aggregation during manufacture of FFMP was investigated. Four skim milks were heat treated using different time-temperature combinations i.e. 93˚C x 60s, 105˚C x 15 s, 116˚C x 60 s and 136˚C x 15 s. Milks were subsequently evaporated to 42%, at which stage palm oil was added and the subsequent mix was homogenised. Emulsions were then spray dried to yield FFMPs with fat contents of approximately 26% w/w.

4. Main results:

- **CBS study** –
  - *Oil bath heat stability* – the levels of CBS which conferred stability was found to be species-dependent. For the citrate containing salts TSC and TPC, addition levels of between 5 and 30 mM were found to be affective. DSHP, in contrast, was found to be less affective, requiring levels of between 25 and 35mM to confer stability.
  - *Simulated HTST* – based on the oil bath test, three levels of CBS were added to WPI dispersions and subjected to simulated HTST (95 ˚C for 2 min). The three levels represented concentrations at: i) below the stability zone ii) within the stability zone and iii) above the stability zone. At levels below the stability zone, viscosity increased markedly during simulated HTST, as a result of insufficient binding of calcium. In the stability zone, viscosity did not increase during simulated HTST. Above the stability zone, dispersions gelled during simulated HTST, possibly as a result of the high level of salt addition which reduced electrostatic repulsion.
  - Fouling rig - WPI dispersions were recirculated at 80 ˚C through a bespoke heat exchanger for a period of 1.5 hours. When CBS was not added, it was found that the temperature gradually decreased over the duration of the experiment, indicating significant fouling of the heat exchanger surfaces and a concomitant reduction in heat transfer efficiency. When CBSs were added, at levels within the stability zone, temperature remained constant over the duration of the experiment, indicating that increased heat stability conferred by binding of ionic calcium also resulted in less heat exchanger fouling.

Contact Eoin Murphy Email: eoin. murphy@teagasc.ie.

- **FFMP study** –
  - FFMP manufactured from high heat skim milk powders exhibited significant variability in behaviour which could not be explained by WPNI. It was found that differences in protein aggregation state play an important role in the subsequent stability of FFMPs. High heat FFMPs manufactured from skim heated for 136˚C x 15 s (WPNI = 1.3 mg WPN/g) was found to have significantly higher free fat, lower solubility and lower coffee stability compared to when 116 ˚C x 60 s (WPN = 1.1 mg WPN/g) was employed.

5. Opportunity/Benefit:

This project provided new insight into heat stability across a wide number of products and processes relevant to DPTC industry partners. This was evident from the publicly available CBD and FFMP studies, which showed significant changes in heat stability can be achieved through appropriate process modifications. Further investigation into the dairy chemistry governing heat stability represents a significant opportunity to improve process efficiencies and product quality through control of heat-induced denaturation/aggregation. Addition of CBS is an interesting option for processors experiencing heat stability and fouling issues associated with high levels of free ionic calcium. In addition, a strong suggestion arising from this project is that level of denaturation in dairy protein streams alone is not a reliable predictor of behaviour. Processors should obtain more detailed information relating to the aggregation state of the proteins, which can result in significant improvements in process and product characteristics.

6. Dissemination:

As a project within an industry-led technology centre, the work was mainly disseminated to project partners in the form of confidential consortium-wide or partner-specific reports. Dissemination outside of the technology centre was subject to approval by industry partners.

Conferences & Workshops:

- Joubran, Y., Hebishy, E., Murphy, E., & O'Mahony, J. A. (2017). Improving thermal stability of whey protein isolate using calcium binding salts. *NIZO Conference 2017*
- Industrial Workshop *"Understanding, Predicting and Monitoring Heat Stability"* for DPTC industry partners was held in University College Cork on 23rd of June 2017

Main publications:

- Hebishy, E., Joubran, Y., Murphy, E., & O'Mahony, J. A. (2019). Influence of calcium-binding salts on heat stability and fouling of whey protein isolate dispersions. *International dairy journal*, *91*, 71-81.

7. Compiled by: Eoin Murphy

Contact Eoin Murphy Email: eoin. murphy@teagasc.ie.