By-product and resource utilisation from dairy processing streams

Dr John Tobin
Food Chemistry and Technology Department
Teagasc Food Research Centre, Moorepark
(29th November 2015)
Kieran Downey
General Manager

Liquid Foods & Ingredients
MTL operates an ultra modern pilot plant covering 3,000 sq. metres floor area. Our facility contains the most up-to-date and versatile pilot scale processing equipment.

Pilot Plant Rental
The plant is of sufficient scale to accurately simulate commercial food processing.

Contract Research & Development
MTL provides highly skilled R&D services that generate new products and help build core expertise.

Pre-Commercial Manufacture
A diversity of expertise in food technologies is available at Moorepark to undertake the pre-commercial scale up and manufacture.

Technical Advise & Support
In conjunction with Teagasc researchers, MTL provide practical technical supports and advice for food companies in solving technology issues.

Providing commercial pilot plant & research services to the food industry

Technologies
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Maecenas male uada elt lectus fels.

Product Areas:
- Dairy Products
- Dried Food Ingredients
- Bioprocessing
- Beverages
- Liquid Food & Ingredients
- Yellow Fat Spreads

Our Clients:

Kieran Downey
General Manager
History of the Irish Dairy Industry

1968
Milk Expansion

1968 - 1984
- Expansion
- Prices ↑
- Intervention
- Costs ↑

1984
Introduction of Quotas

1984 - 1995
- Production Stabilised
- Stocks ↓
- Exports ↑

1995
GATT

1995 - 2003
- Consumption ↑
- Prices Stabilise
- Stocks ↓

2004
CAP - Reform

2004 - 2015
- De-regulation
- Prices ↑↓

2015
End of Quotas

2015 - 2020
- Production ↑
- Exports ↑

2020

Source: EU Dairy Market, IDF world Dairy Summit, Parma 2011: Monika Wohlfarth, Zentrale Milchmarkt Berichterstattung GmbH
Current Dairy Trends

Dairy

€3.06 bn

The estimated value of dairy exports in 2014

55% RISE

in the value of dairy exports from 2009 (€1.96bn) to 2014 (€3.06bn)

In 2014, Irish dairy exports are estimated to have increased by

30% to Asia reaching approximately €530mn, two thirds destined for China

18% to North America with both US and Mexico growing strongly

19% to Middle East, led by Saudi Arabia & UAE

3% increase in the value of dairy exports in 2014

1,100tn of farmhouse cheese

A broad range of different types of cheese using cow, goat and ewe milk

172,000 tonnes of cheese produced

35,000tn of speciality cheese

Ireland supplies 10% of the global infant milk formula despite only having 1% of global dairy production

China

is now Ireland’s 2nd most important export market for dairy compared to 13th in 2008

By 2020, dairy production is expected to grow by 50% to over 7.5bn litres

Ireland has 18,000 dairy farmers, with over 1 million dairy cows

Ireland exports to 140 markets worldwide. The top 5 markets are the UK, China, Germany, Netherlands & the United States
Major Dairy Processors in Ireland

Targeted 50% Increase in Milk Production by 2020 (Food Harvest 2020)

- Lakeland Dairies
- Connacht Gold
- Centenary
- Arrabawn
- Tipperary
- Lee Strand
- Kerry Group
- Boherbue
- Carbery
- Kerry
- Cork
- Limerick
- Tipperary
- Clare
- Galway
- Mayo
- Roscommon
- Connacht
- Fermanagh
- Tyrone
- Down
- Antrim
- Down
- Armagh
- Londonderry
- Belfast
- Northern Ireland
- South
- Leinster
- Co. Wexford
- Dairymen
- Wexford Creamery
- North Cork
- Dairygold
- Town of Monaghan
- Glanbia

Innovative Food Product Development Cycle: Framework for Stepping Up Research Excellence of FINS
What Does Standard Dairy Processing Look Like

Step 1: Batch make-up

- Plate heat exchanger
- 10 – 70°C
- 20 – 40% DM

Step 2: Thermal treatment

- Temp 100 * 30sec
- 65; 2000 psi + 500 psi

Step 3: Homogenisation

- Temp 70

Step 4: Holding tank

- Temp 70 – 65 – 55 – 45
- Temp 75; 55 solids
- PHE
- Vapour/Liquid Separators
- Concentrate TS = 50-56%

Step 5: Evaporation

- Steam
- Vapour

Step 6: Drying (Three stage)

- Inlet Air
- Product line TS = 50-56%
- Fines return line for agglomerisation
- Positive displacement pump
- Fluidised bed 1
- Fluidised bed 2
- Rotary valve
- Storage Silo
- Canning
- Concentrate TS = 50-56%
- Powder TS ~ 97%
- Temp 70 – 65 – 55 – 45
- Temp 75
- MAP

Innovative Food Product Development Cycle: Frame for Stepping Up Research Excellence of FINS
What Does IMF Processing Look Like – Same Challenges

Typical Road Map for Infant Formula Manufacture

Proposed Road Map for Next Generation Infant Formula Manufacture – using a new concept ingredient as a liquid protein base

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What Does IMF Processing Look Like – Same Challenges
WASTE LOSS MANAGEMENT AND CONTROL IN DAIRY PROCESSING
Definition of wastage

• “Wastage is defined as something expended uselessly or that one fails to take advantage of or that is used extravagantly” (IDF Bulletin 385/2003)

• In milk processing wastage is described as:
  “milk purchased that is not sold as primary product”
Material losses in the Irish Dairy Industry

- Historically very high levels of wastage were accepted in the dairy industry
- In the infancy of the dairy industry only milk fat was of interest for processing into butter while skim milk was returned to farmers
- The cheese revolution followed whereby milk solids were converted to a highly stable product – whey became an effluent from this process and was fed to pigs
- Today the dairy industry operates at a very high efficiency due to the low margin on dairy commodities and tight regulations on discharge licenses (Phosphates !!)
Material losses in the Irish Dairy Industry

- Today losses primarily come from:
  - Flushing lines
  - Flushing tanks
  - Product changeovers
  - Deposits in heating equipment
  - Evaporator condensates
  - Spray dryer fines
  - CIP of all of the above

- Recovery mainly focuses on white water recovery by filtration (RO)—use of recovered material can be an issue

- Correct plant design minimises losses
WASTE MANAGEMENT IN THE IRISH DAIRY INDUSTRY

• UP TO MID ‘80S - TRADITIONAL APPROACH - GLS, OVERUN IN BUTTER

• YIELD CALCULATED IS:
  MILK FAT IN PRODUCT
  ─ MILK FAT PROCESSED

• ACCURATE RECORD OF STOCK, COMPOSITION - A SOURCE OF ERROR
  YIELDS > 100%?

• FROM MID 80’S
  - MAJOR INPUT TO OPTIMISE YIELDS.

• DIRECT MEASUREMENT OF LOSSES ADOPTED
  ─ DAILY PERFORMANCE APPRAISED
  ─ MONETARY VALUE OF LOSSES QUANTIFIED

• PROCESS CONTROL/INVESTMENT - NEW TECHNOLOGIES

• COST BENEFIT ANALYSIS
LOSS MEASUREMENT TECHNIQUE (LMT)

A. **Traditional Method:** Material balance inaccurate for daily use due to stock carryover and error in measurement.

B. **L.M.T.:** Requires measuring all loss sources in each process.

C. **Necessary Inputs:** Flow measurement and sampling equipment analysis of effluent, by-product and product.

D. **Expression of Results:** As kg of product lost/day.

E. **Set Target Figures:** For losses on basis of good operating practice.

F. **Avoidable Loss Kg/Day:** = Total loss - target value
Implementation of L.M.T.

DIVIDE PLANT INTO UNITS

INSTALL SAMPLERS METERS. LABORATORY CAPITAL

DRAW UP PROGRAMME OF ANALYSIS AND TARGETS

DAILY RESULTS TO PRODUCTION

ZONE IN ON PROBLEM AREAS

CHANGE TARGETS/ANALYSIS

Innovative Food Product Development Cycle: Frame for Stepping Up Research Excellence of FINS
SUCCESS OF WASTE MINIMISATION PROGRAMME IS BASED ON:

- COMPANY POLICY STRATEGY FOR IMPLEMENTATION
- MANAGEMENT COMMITMENT
- MONETARY/CAPITAL RESOURCES
- A PROGRAMME OF PERSONNEL TRAINING
- OVERCOME CULTURAL BARRIERS
- INCENTIVE SCHEMES
- EMPLOYEE MOTIVATION
- INFORMATION FEED BACK
PROCESS INFORMATION NECESSARY FOR WASTE LOSS APPRAISAL

- PROCESS DESCRIPTIONS
- PROCESS FLOW DIAGRAMS
- PIPE AND INSTRUMENT DRAWING
- OPERATING MANUALS
- DRAINAGE DETAIL AND HISTORY
- WASTE ANALYSIS - FLOW OR CONCENTRATION
- DISCHARGE LICENCE DETAILS
- EMISSION STANDARDS
Where do losses occur?

- Spillages to floor and leaks
- Inherent sources such as milk separation, emission losses in drying
- Waste in pipes that do drain easily
- Heat deposits in heat exchangers
- CIP
- **Product losses are also wastage**
  - Over specification such as excess fat in cheese/powders where accurate standardisation is not employed
  - Product returns due to shelf life consideration resulting in downgrading of product – microbiological quality
Effect of heating on bovine milk components

- Microbiological Safety
- Inactivation of enzymes
- Protein structural changes, resulting in inactivation of functional proteins
- Maillardation
- Heat Toxins
- **FOULING !!!!!!!**
- Higher DM + Higher Temperature Exacerbates the Problem
Many Technologies for HHT - Challenges

- Options include
  - DSI (direct contact of steam with product)
  - Infusion (direct contact of steam with product)
  - Tubular (indirect contact of product with heating medium)

All systems are challenged by high DM processes.

HHT requirements are met primarily in the holding section.

Typically the holding tube/section is the initiation zone for fouling.
How to reduce effluent related to fouling in heating processes

• Food Safety is still a major challenge
  • Fonterra crisis highlights vulnerability in the sector
  • The dairy industry is considering higher thermal loads
  • Higher thermal loads = higher effluent loading
  • Consider combination processes to meet equivalent microbial reductions
  • Research needs to consider state of the art processes
    • Instant Infusion (SPX), low temperature bactofugation (Westfalia/Seitel), low temperature Microfiltration (TAMI/Synder/Membralox)

Smart Process Design is key!

Innovative Food Product Development Cycle: Frame for Stepping Up Research Excellence of FINS
What are Teagasc’ Capabilities in Dairy Recovery

- New concepts for liquids – concentrates – powders
- Robustness studies – plant and membrane performance
- Feasibility studies – mapping macro-micro nutrient partition
- Integrated mass balance and process flow design
- CAPEX OPEX and business case evaluation
- Capability to rapidly modify and construct membranes pilots to meet customer requirements
- Reverse Osmosis drives water recovery and water balance in Dairy plants

![Various membrane processes and equipment images](image-url)
Practical techniques to reduce waste in dairy processing

• Good operating practices
  
  • Regular preventative maintenance. Leaking steam valves, product leakage pumps. Calibration of instrumentation and records.
    • E.G. Load cells, flow meters
    • Depth Controller, pH sensors
    • Good communication network.

• Segregate various streams and isolate before reaching drain.

• Segregate storm and flush/CIP where possible.

• Employ on line instrumentation where possible - conductivity, turbidity, or mass flow to give instant alarm.
Techniques continued

• Bunding of silos – standard practice
• Avoid spillages and identify/remove dead lines.
• Remove operator dependency where possible
• Increase automation where possible.
• Train and motivate employees – bonus schemes
• Increase product shelf-life and reduce over specification.
Technology/process changes

• Introduce new equipment which produce less waste
  • *Automatic valve blocks instead of flow plates/swing bends*

• Change process conditions such as agitation, flow rate, thermal load, vacuum, air flow,

• Redesign equipment to avoid losses at start up and shutdown
  • *Minimise mixing of phases*

• Appraise new technologies
  • *Vats, separators, clarifier CIP recovery*
How to Reduce Waste in Dairy Plants – Effluent Load

- Establish waste load reduction targets for your plant and for individual processes within the plant
- Improve maintenance to prevent leaks from valves and piping
- Reduce water use as water used becomes wastewater
- Use condensate from evaporation if available
- Design lines that will allow proper drainage of product rather relying on rinse water to remove product
- Inspect vats and tanks to ensure dairy residues are removed before commencing CIP
- Collect solids from the floor and place in waste containers
- Do not use hoses as brooms
- Seek ideas from employees in reducing waste and implement the best ideas immediately and let them know the outcome
- Train employees toward preventing pollution
What about irrecoverable milk solids?

• Dairygold needed a wastewater treatment plant that could reliably treat process wastewater containing powdered milk and cheese waste, as well as high-strength salty whey.

• This led to the installation of the world’s largest above ground anaerobic digester effluent plants, commissioned in 2012.

• This waste-to-energy system uses effluent from the site to generate gas to contribute to the site’s energy requirements.

• The site, located at Mitchelstown, Co Cork, included a 45,000m digester, 78m in diameter, to treat the process dairy waste load.
What about whey

• Cheese whey used to be the largest effluent stream in the dairy industry

• Whey is now one of the most valuable commodities produced by the dairy processors

• Perhaps cheese could be considered the by-product (waste) of whey processing due to its high commercial value
Next Generation Process Technologies – Cheese Whey Relationship

Inverting the Cheese Whey Paradigm

**Key:**
- Starting Material
- Unit Operation
- Intermediate Stream
- Finished Material

**Whole Milk**

- Skim Milk
- Cream

**Cream Separator**

- Skim Milk 1.4 µm MF Permeate
- 1.4 µm Ceramic MF

**Casein MF Retentate**

- Skim Milk 1.4 µm MF Permeate
- 0.08 µm Organic MF

**Native Whey MF Permeate**

- Native Whey MF Permeate
- 10 kDa Organic UF

**Milk Permeate**

- RO Water for Diafiltration

**Reverse Osmosis**

- UF Permeate

**Reverse Osmosis**

- UF Retentate

**Cheese Process**

- De-wheyed
- Filter sterilised
- Recombined milk

**Cheese**

- Unpasteurised
- Reduced fat, Improved structure function,

**Spray Dryer**

- WPC80

**Native WPC80 Powder**

- Glyco-Macropedptide Powder

**Milk Permeate Powder**

**CMP Isolate**

**WPC80**

**Native WPC80 Powder**

Innovative Food Product Development Cycle: Frame for Stepping Up Research Excellence of FINS
What Areas in Dairy Recovery are hot right now!

- Removal of bacteria and recovery of filtration retentates
- Phospholipid recovery – milk and oil processing
- Enrichment of milk oligosaccharides
- Recovery of targeted enzymes
- Renovation – where can waste streams be recombined in existing products – legislation and regulation - EMP for certain markets
- Retention of higher bioavailability milk salts through selective partition of minerals in demineralization process
- Retention of higher levels of trace minerals and vitamins in demineralization and lactose processing
THANK YOU FOR YOUR ATTENTION
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