Improving creaminess of yoghurt and fermented products by understanding the role of ingredients and processing routes

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Your presenter

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NIZO food research
65 proud years of open innovation

Why:
• Good food needs good science

How:
• Science Hub for projects in a global food network:

What:
• Flavor, Texture or Health.
• Process improvement
• From lab to pilot plant

Where:
• HQ in the Dutch Food Valley
• Sales offices in USA, France & Japan

Who:
• 180 professionals
What

Services and deliverables

An open innovation network for:
- Research
- Consultancy
- Product & Process Development
- (test) Productions

Working Together to deliver:
- New processes
- New formulations recipes
- Test productions
- Tolling (for small volume high value ingredients)

Pilot plant: business as unusual!
Consumers prefer yoghurt with a creamy and rich texture.
High protein, low fat
- Effect on satiety
- Effect on building/maintaining muscle mass
Greek-style yoghurt products

Clear differences

Traditional Greek strained yogurts are numbers in bold. Greek style yogurts are underlined numbers and Plain non fat yogurts are numbers.

repository.lib.ncsu.edu/ir/bitstream/1840.16/.../etd.pdf
Greek-style yoghurt products
Clear differences

FIGURE 2: TEXTURE MAP OF EIGHT GREEK-STYLE YOGURT PRODUCTS

Sensory attributes reflect subsequent stages

First bite
- hardness
- temperature

Masticatory
- crunchy
- cooling
- thick
- elastic
- cohesive
- tough
- sticky
- tacky
- slimy
- slippery
- creamy viscosity

After taste
- coating
- fatty
- creamy coating
- grainy, gritty
- rough, astringent
- taste, aroma

swallow

time
Creamy low fat yoghurt
Factors playing a role in creaminess

• Texture/mouthfeel
  • Thickness (viscosity) 😊
  • Smoothness 😊
  • Astringency (rough, dry) 😞
  • Chalkiness, powdery 😞

• Flavour
  • Acid 😊
  • Creamy flavour 😊
  • Clean flavour 😊

The choice of processing and ingredients plays a major role in achieving final consumer acceptance and shelf-life of the product.
By understanding the effect of the applied shear and the functionality of milk proteins these factors can be optimised resulting in an increased viscosity of Greek-style yogurt while maintaining a smooth and creamy texture.
Processing routes

- Heat treatment
- Fortification of milk solids
- Homogenisation
- Milk reception, handling, storage, standardisation of fat content in milk

Fermentation/incubation of milk

- Cooling
- Filling

Initial viscosity

Fruit mixing

Final viscosity

Structure and shear sensitivity of fermented milks
Use of powders in fermented products

Protein type / formulation approach

• MPC powder
• MPC/WPC mixture
• Milk concentrate (UF)
  • Liquid condensed milk

Choice affect functionality and flavour
- Solubility
- Clean flavour
- No graininess or chalky mouthfeel

SMP (high MSNF) in a formulation can lead to a very sweet taste and high solids formulation
32 commercial MPC’s
The extremes

- Extremely large differences in composition and properties between MPCs
- Differences attributable to:
  - Desired composition
  - Tailored processing
  - Sub-optimal processing
- Control of composition and process will allow optimized and tailored functionality
Sensory analysis
Low heat MPC

Mouthfeel

Cooked milk O
Popcorn - rice cookies O
Chlorine O
Sperm O
Sulphury O
Dry M
Astringent M
Cardboard T
Bland T
Detergent - wet woolen socks T
Sulphury T
Popcorn - rice cookies T

Odour

Salt T
Sweet T
Sulphury O
Sperm O
Chlorine O
Popcorn - rice cookies O
Cooked milk O

Taste

Mouthfeel

Taste

Together to the next level

Together to the next level
Sensory analysis
Effect of heat treatment

Mouthfeel

Odour

Taste

Cooked milk O
Popcorn - rice cookie O
Chlorine O
Sperm O
Sulphury O

Dry M
Astringent M
Cardboard T
Bland T
Detergent - wet woolen socks T
Sulphury T
Popcorn - rice cookies T
Cooked milk T
Salt T
Sweet T

MPC80LH
MPC80MH
Role of WPC on yoghurt texture
Effect of casein micelle to whey protein ratio on viscosity and particle size of stirred yoghurt

Conclusion:
To obtain a viscosity enhancing effect, an optimal amount of whey proteins should be present, as a non-optimal amount decreased the viscosity. The required amount was dependent on the protein composition of the final milk.

Kanning (2014). Routes to tailor the structure of mildly acidified stirred yoghurt using whey protein denaturation and interactions. IDF Microstructure
Yoghurt milk characterisation
Effect of casein micelle to whey protein ratio on total whey distribution in yoghurt milk after pasteurisation (4% protein)

Conclusion:
Increased formation of soluble whey protein aggregates
Yoghurt milk characterisation
Effect of casein micelle to whey protein ratio on distribution of β-lg and α-lac in yoghurt milk after pasteurisation (4% protein)

Conclusion:
Heterogeneous aggregates were formed

β-lg was more easily involved in the incorporation of aggregates than it was involved in the coating of micelles, particularly at higher whey protein levels.
Role of WPC on yoghurt texture

• Role of whey proteins in yoghurt texture

- Increased viscosity of the yoghurt
- Soluble whey protein aggregates
- Native β-lactoglobulin and the amount of free thiol groups

• Type of whey protein powder
  - Degree of denaturation. Minimizing the heat treatment during whey processing maximized the functional properties of WPC to be used in yoghurt.
  - Composition (ratio β-lactoglobulin/α-lactalbumin)

Kanning (2014). Routes to tailor the structure of mildly acidified stirred yoghurt using whey protein denaturation and interactions. IDF Microstructure
Concentration before fermentation
Effect of MPC/WPC mixture (functional blend)

- Optimum pH for pre-heating strongly dependent on:
  - Milk solids concentration
  - Casein:whey protein ratio
  - Minerals
Concentration after fermentation
Greek-style yoghurt

• Cloth straining

• Ultrafiltration (UF)
  • Spiral wound
  • Ceramic

• Centrifugation

Choice affect texture and flavour
- Shear
- Process temperature
All remove acid

Choice affect texture and flavour
- Shear
- Process temperature
All remove acid

Tetra Pak

Fig. 7.5 Flow chart for the manufacture of concentrated yoghurt by ultrafiltration (Reproduced by permission of Tetra Pak, Lund Sweden)
Processing routes

Milk reception, handling, storage, standardisation of fat content in milk

Fortification of milk solids

Homogenisation

Heat treatment

Fermentation/incubation of milk

Cooling

Filling

Storage

Initial viscosity

Fruit mixing

Final viscosity

Structure and shear sensitivity of fermented milks

Together to the next level
Yoghurt texture
Functionality of ingredients

Stirred yoghurt

Picture size 160 μm x 160 μm

Yoghurt can be regarded as a concentrated dispersion of particles in serum

Viscosity yoghurt =
Viscosity serum phase x particles (volume, properties and interactions)

\[ \eta = \eta_s \times f(\phi) \]
Structure breakdown of starch-containing yoghurt

The shear rate at which aggregates breakup varies with yogurt composition (ref at 0.75 s\(^{-1}\); tapioca at 1.5 s\(^{-1}\) and rice at 2.25 s\(^{-1}\)). This suggests a variation in the breakup of the protein network as a function of the presence and size of starch granules.
Thickness of product

1. Gel build-up during fermentation
2. Structure break-down (concentration, cooling, structuring, filling)
3. Structure build-up (rebodying)

Resulting in different initial viscosities

Final viscosity (lowest)
Dependent on the applied shear rate during processing (Cooling, Buffer tank, Filling machine)
Shearing/smoothening

This occurs during pumping/filling

\[ \dot{\gamma} < 10 \text{ s}^{-1} \]

\[ 10 \text{ s}^{-1} < \dot{\gamma} < 447 \text{ s}^{-1} \]

\[ \dot{\gamma} >>> 447 \text{ s}^{-1} \]

- M. E. van Marle et al.
Shearing/smoothening devices

• Smoothening valve (back-pressure valve)
• Sieves
• Smoothening homogenisers or pumps
• High-shear devices
• Low velocity in system

• High velocity in system

VELOCITY (Yellow is highest velocity)

VISCOSITY (Yellow is highest viscosity)
## Ingredient functionality – multiple functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Plants</th>
<th>Seaweeds</th>
<th>Micro-organisms</th>
<th>Proteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase bulk volume</td>
<td>Starch</td>
<td></td>
<td></td>
<td>Milk proteins and their derivates (MWP, WPC)</td>
</tr>
<tr>
<td>Viscosifier continuous phase / viscosity builders</td>
<td>Inulin</td>
<td>λ-Carrageenan (E407)</td>
<td>Xanthan gum (E415), EPS from LAB</td>
<td>Milk proteins and their derivates (MWP, WPC)</td>
</tr>
<tr>
<td></td>
<td>Maltodextrin</td>
<td>Agar</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Galactomannans (guar gum E412, lbg E410)</td>
<td>Alginate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gum tragacanth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle interactions</td>
<td>Pectins (E440)</td>
<td></td>
<td></td>
<td>Gelatin</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Pectins" /></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syneresis prevention / gelation / gelling agents</td>
<td>Pectins (LM) (E440) – calcium induced gel</td>
<td>κ- / ι-Carrageenan (E407) Agar, Alginate</td>
<td></td>
<td>MWP = microparticulated whey protein</td>
</tr>
</tbody>
</table>

*Ingredients in green = used as fat replacer*
Structure and shear sensitivity of fermented milks – set-up

- The influence of EPS properties and their location in the protein network on shear sensitivity of fermented milks was investigated.

- Six LAB strains with known chemical structure of the repeating unit of EPS were used to acidify milk at 32°C and 42°C.

- The role of EPS on milk gel structure breakdown was analyzed using:
  - Rheological measurements
  - Localization of EPS in the gel structure during acidification

\[
\begin{align*}
\beta-D-Ga \rightarrow (1\rightarrow 6) \alpha-D-Ga \rightarrow (1\rightarrow 4) \beta-D-Ga \rightarrow (1\rightarrow 6) \alpha-D-Ga & \rightarrow (1\rightarrow 3) \alpha-L-Rha \rightarrow (1\rightarrow 2) \alpha-D-Ga \rightarrow (1\rightarrow 3) \beta-D-Gal \rightarrow (1\rightarrow 3) \alpha-L-Rha \rightarrow (1\rightarrow 2) \beta-D-Gal \rightarrow (1\rightarrow 3) \alpha-D-Gal \rightarrow (1\rightarrow 3) \beta-D-Gal \rightarrow (1\rightarrow 3) \\
S. thermophilus Rs / Sts & S. thermophilus S3 & S. thermophilus S4 & L. bulgaricus 1B & L. helveticus 766
\end{align*}
\]
Flexibility of EPS polymer

The relation between molar mass and radius of gyration provides information of the flexibility of a polymer.
EPS flexibility

*L. lactis* subsp. *cremoris* in fermented milks

Fig. 3. Relation between Posthumus viscosity of stirred fermented milks made at 25°C and some molecular characteristics of EPS produced by strains of *L. lactis* subsp. *cremoris*: Posthumus vs. EPS Kuhn length (a), Posthumus vs. EPS intrinsic viscosity (b) and Posthumus vs. EPS thickening efficiency (c).

Effect culture
Role of EPS

EPS functionality is determined by:
- EPS amount, characteristics (Mw, Rg)
- Distribution in the yoghurt

Smoothness of yoghurt is affected by EPS

EPS = Exopolysaccharides
LAB = Lactic acid bacteria
Use of stabilisers

Thickeners/Stabilizers, Yogurt, USA Compared to Europe 2010-2011

Ingredients vs Region

- North America 1.244
- West Europe 2.516

Ingredients:
- Guar Gum
- Modified Corn Starch
- Pectin
- Sodium Octyl Sulfate
- Trisodium Citrate

Together to the next level
Amylomaltase treated starch (ATS)

Mechanism

Potato starch:

Amylose

Amylomaltase

Amylopectin

Enzyme is an amylomaltase or (α1,4)-(α1,4) glucosyltransferase, E.C. 2.4.1.25

• Declared as starch or potato starch in Europe
• Sold under trade name ETENIA™, by AVEBE
Amylomaltase treated starch (ATS)

Mechanism

ATS did not affect the fermentation process (pH and microstructure)
Amylomaltase treated starch (ATS)

Mechanism

*Fig.* CLSM image of stirred yoghurt (3.5% protein; 0.5% fat) with 0.8% ATS. Image size 62 µm × 62 µm. Orange/red are protein aggregates; micro-organisms are bright green and ATS domains are green.
Amylomaltase-treated starch (ATS)

Mechanism

Milk → Yoghurt gel → Yoghurt during stirring → Yoghurt after storage

Fermentation → Breaking of the gel → Cold storage (1-3 days)

= Dispersed / dissolved ATS

= Gelled ATS domains

= Protein aggregate
**Amylomaltase-treated starch (ATS)**

Effect on yoghurt properties

ATS in low-fat, stirred-style yoghurt results in thick, smooth product.
Excellent creaminess enhancer

Low-fat, stirred-style yoghurt (0.5%) having the perception of full-fat yoghurt (3%)

ATS domains in complex foods, behaving like fat globules

Reduction in fat-related energy value from 27 to 4.5 kcal/100 g product.

O = yoghurt with 0.5% fat
● = yoghurt with 1.5% fat

Alting, van de Velde, Kanning et al. (2009) Food Hydrocolloids 23 980
Processing routes

Milk
9% DM

- Evaporation
- UF

Milk protein powder (MPC) and/or WPC

Concentrated milk

Set yoghurt

Concentrated yoghurt

- Concentrated stirred Yoghurt

Concentrated yoghurt

Set yoghurt

Straining

UF/centrifugation

Concentrated yoghurt

Greek yoghurt

Concentrated yoghurt 18%

Acid whey

From ~10% MSNF
14-16% MSNF

Lactose

Together to the next level
Whey Too Much: Greek Yogurt’s Dark Side

Greek yogurt is a booming $2 billion a year industry — and it’s producing millions of pounds of waste that industry insiders are scrambling to figure out what to do with.

By Justin Elliott on May 22, 2013

Twice a day, seven days a week, a tractor trailer carrying 8,000 gallons of watery, cloudy slop rolls past bucolic countryside, finally arriving at Neil Rajman’s dairy farm in upstate New York. The trucks are coming from the Chobani plant two hours east of Rajman’s Sunnyside Farms, and they’re hauling a distinctive byproduct of the Greek yogurt making process—acid whey.

http://modernfarmer.com/2013/05/whey-too-much-greek-yogurts-dark-side/
Routes to apply acid whey

- Composition
  - High in lactose, Ca and P

<table>
<thead>
<tr>
<th>Component</th>
<th>Unit</th>
<th>Sweet whey (rennet precipitation)</th>
<th>Sour whey (biol. precipitation)</th>
<th>Technical whey* (HCL precipitation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>%</td>
<td>93–94</td>
<td>94–95</td>
<td>93–94</td>
</tr>
<tr>
<td>Lactose</td>
<td>%</td>
<td>4.5–5.0</td>
<td>3.8–4.2</td>
<td>4.4–4.6</td>
</tr>
<tr>
<td>Protein (N x 6.38)</td>
<td>%</td>
<td>0.8–1.0</td>
<td>0.8–1.0</td>
<td>0.8–0.9</td>
</tr>
<tr>
<td>Fat</td>
<td>%</td>
<td>0.2–0.8</td>
<td>Traces</td>
<td>Traces</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>0.5–0.8</td>
<td>0.7–0.9</td>
<td>0.7–0.8</td>
</tr>
<tr>
<td>pH value</td>
<td></td>
<td>6.2–6.6</td>
<td>4.5–4.7</td>
<td>4.4–4.55</td>
</tr>
<tr>
<td>Cheese fines**</td>
<td>Vol.-%</td>
<td>0.05–0.3</td>
<td>0.05–0.3</td>
<td>0.05–0.3</td>
</tr>
</tbody>
</table>

* Aggregated figures are independent of the type of protein precipitant used
  ** The percentage figures refer to “removable” cheese fines

- Flavour profile
- Protein functionality

High protein fermented beverages
Whey smoothies
Fermented desserts

Tracking oral behaviour

• The “amount of work” to orally process a food product is an important quality marker
• EMA is a new technique to track the oral behaviour during consumption

Measure consumer response to your products

• ElectroMagnetic Articulography (EMA) has been used for many years in speech therapy
• Up to 8 sensors are attached to oral surfaces
• Position of the sensors is tracked in time and time-linked to consumption
• NIZO developed proprietary software for data analysis
Creamy low fat yoghurt

Conclusions

• Increase in protein content provides an improved texture

• Route to formulate the product affects the flavour and texture

• Consumer decides!
Improving creaminess of yoghurt and fermented products by understanding the role of ingredients and processing routes

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Acknowledgements

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