Reduced calorie foods
Sensorial shortcomings and emerging solutions

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NIZO food research
What Services and deliverables

- New processes
- New formulations recipes
- Test productions
- Tolling (for small volume high value ingredients)

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

Working Together to deliver:

Pilot plant: business as unusual!

Together to the next level
from Ingredient to Reward

**Flavour & Texture**

**Ingredients**
- Molecular characterisation
- Settings
- Parameters
- Interactions

**Food**
- Rheology
- Tribology
- Particle size
- Flavour

**Bolus**
- Consistency
- Particle size
- Coating
- Acoustic tribology
- Jaw tracking
- Muscle activity
- Articulography
- Flavour release

**Nutrients**
- Hormones
- Peptides
- Simphyd

**Sensory perception**
- QDA
- TDS
- Consumer data

**Reward**
- Heart beat
- Temperature
- Face recognition
- Conductivity
- Interviews

**Satiety, satiation**
- Heart beat
- Temperature
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- Conductivity
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Together to the next level
Reduced calorie foods

Significant impact on perceived product quality and rewarding value from foods!
Optimisation needed to overcome sensorial shortcomings

- Fat-replacement
- High protein food taste
- Sweetness optimization
- Taste (bitterness) masking
- Rich texture in low-cal foods
- Low viscous protein foods

Optimising aroma, taste, texture and mouth feel for excellent hedonic appreciation and reward
from Ingredient to Reward
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Together to the next level
Perception
*a multisensory integration process*

Taste
Smell
Vision
Hearing
Touch

orbitofrontal cortex

integrated response to all stimuli

Together to the next level
Compensation strategies
Flavour perception

Sugar, fat (and salt) reduction by cross-modal sensory enhancement
Effect of fat on aroma release

Difference in intensity of aroma release

Adjust aroma concentration

Off flavours: Very strong in lingering

High fat: significantly more lingering

Together to the next level
Dynamic Sensory: TDS

**Stevia drinks**

Full sugar reference

- Sugar gives early sweetness

First generation Stevia

- Delayed sweet with Stevia
- Lingering liquorice/stevia aftertaste
Stevia drinks

Full sugar reference
- Swallow
- Yoghurt aftertaste
- Sugar gives early sweetness

Optimized Stevia
- Swallow
- Improved aftertaste
- Still lacking early sweetness

Together to the next level
Aroma release profile requires modification
Superimposing aroma profiles on a product

De Kok et al. in Dev in Food Science 43 Bredie & Petersen (ed) Elsevier (2006) 585-588
First build a virtual product to prepare prototypes and test the desired reformulation

Delivering aroma separately from texture, taste, touch, sound.....

Brain response
Sensory perception

Together to the next level
Aromas enhance sweetness

- Consumers look for less calories with the same taste
- Clean-label is often a requirement

Natural apple aromas increase sweetness by 20%

- Cross-modal interactions make use of learned associations
- Ripeness-associated esters in apples trigger sweetness response
- Olfactoscan technology enables screening of taste-enhancing aromas
- Often, non-label methods to enhance these flavours are possible via raw material selection, processing, or fermentation
Screen for taste active molecules

- Taste enhancing ingredients like MSG of yeast extracts used widely
- Preference from consumer for clean label

**Taste enhancers from your raw materials with no label change**

- Isolate taste active compounds from natural foods
- Food grade taste fractionation (ÄKTA) coupled with sensory assessment of sweetness induction in your applications
- Proven success with salt and umami enhancing fractions from dairy food, sweetness from fruits and vegetables
More sweet, less sugar

- Health-conscious consumers look for lower calories but don’t compromise on taste

Pulsation of tastants leads to 15% increase in perception

- Humans are more attuned to changes than constant signals
- Tastants delivered at a varying (pulsed) concentration are perceived more intense
- The effect has been proven for sweetness and salty taste

Lingering aromas for creaminess

- Health-conscious consumers opt for low-fat products
- Creaminess-enhancing flavors are found in many low-fat products

**Time-release of creaminess boosters determines efficacy**

- Creaminess-enhancing flavors take advantage of learned associations
- Hydrophobic flavours are released more slowly in higher fat products
- Creaminess boosters are:
  - more effective in thicker systems
  - only effective when released after the product is in the mouth
  - most effective when latest released

Retro-nasal aroma release affects appetite

- High demand for rewarding weight management (+ AND -) products
- Search for tasteful foods with a high rebuy and compliance, which incorporate triggers to promote balanced nutrition

A drink which leads to a retro-nasal aroma release profile that is similar to a solid food is perceived as more satiating than the original drink

- Approach
  - Identify sensory triggers which regulate food intake behavior by using e.g. the olfactometer, a unique tool which mimics the release of flavor during food consumption
  - Opposite mechanism for promoting intake and drinkability

Ruijschop et al., 2008

* sign, effect type of aroma stimulation on Δ satiation VAS rating (p < 0.05)
Compensation strategies
Texture perception

Mouthfeel engineering
Breakdown during oral processing
Measuring oral processing
Mouth feel is the sensation created by food or beverages in the mouth.

- **flavour**
  - full of flavour
  - lingering
  - natural
  - creamy
  - fatty
  - smooth
  - melting
  - coating
- **friction**
- **breakdown**
  - chewable
  - palatable
  - homogeneous
  - full
  - creamy
  - satisfying
- **viscosity & texture**

**Toxicology**
**rheology**
**particle analysis**
**tongue adhered layer analysis**
**artificial throat**
**olfactometer PTR-MS**
Mouth feel engineering

Benefits:
- High protein
- Low calorie
- Low carbohydrates
- Indulgent
- Oral freshness
- Body
- Natural
- Multisensory

Understanding:
- dynamic reward
- *in-vivo* structure breakdown
- *in-vivo* aroma release
- perception mechanisms
- cross modality

Solutions:
- Ingredient interactions
- Ingredient modification
- Emulsion technology
- Matrix structuring
Perception is a dynamic process
oral processing, structure breakdown and lubrication

Understanding the changes in the product
during oral processing is key for NPD
Two emulsions with different emulsifiers → stable on the shelf → different response to oral processing → different sensory perception

Dresselhuis, de Hoog et al.  
Food Hydrocolloids 22 (2008) 1170
Mouth feel engineering tools

• Handling saliva

• Subjects performing oral processing

• Unique techniques
  tribology, rheo-microscopy, Articulography, TDS, EMG, FES

• Broad range of traditional techniques
  rheology, microscopy, light scattering, chromatography, spectroscopy, calorimetry

• Statistics and interpretation
Tribology

- Relates to friction sensed by the tongue surface (roughness, smoothness, creaminess, astringency)

Commercial tribometers:
- Accurate
- Reproducible
- Artificial surfaces

Optical Tribological Configuration:
- Accurate
- Reproducible
- Allows (pig) tongue surfaces
- Allows CLSM observation
- Ex vivo
- Non human, preserved tongue

Acoustic tribology:
- Reproducible
- Human in vivo measurement
- Sensitive to time and individual variations

van de Velde & de Hoog (2014) in Food Texture Design and Optimization p. 308-320
Oral lubrication effects

- Smoothness, roughness, astringency, and silky, smooth, creamy mouthfeel are difficult to characterize.
- These attributes are lubrication properties of foods, and are sensed by the tongue rubbing against the palate.

Acoustic tribometer captures tonguefeel

- A microphone collects an acoustic signal from the tongue surface.
- Astringent products like coffee increase the signal.
- Smoothing/creamy products like creamer decrease the signal.
- Correlation to sensory response better than traditional tribology for astringency and protein systems.
Friction measurements
the link with sensory perception

Friction decreases with increasing fat content
Measuring oral coating components adhered to the mucous layer

- Sensitive methods to measure oral coatings and their decay
  - Amount of oral coating
    - Impact of product formulation
  - Decay of the material in time
  - Correlate with sensory attributes

- Food grade fluorescent dye (curcumin), Tongue swab analysis, Spectroscopy, Microscopy, Chromatography, ….

Quantification of the coating obtained from different products and its decay
Rheo-microscopy set-ups
rheology combined with in-situ direct observation with CLSM

Continuous Shear Cell

Oscillating Shear Cell

Compression Cell

Optical Tribological Cell
CLSM and rheo-microscopy facility

Information on:
- Spatial distribution of ingredients
- Interaction between ingredients
- Dynamics of ingredients
- Structure deformation under shear

"Together to the next level"

standard imaging
define new protocol
design new equipment

development time

applications
Microstructure

Ice cream

Red: fat
Black: air
Green: protein phase
Protein for fat replacement

- Fat plays a crucial role in the structure and texture of foods
- Proteins are promising candidates to replace fat
- Structuring of proteins is required

**NIZO developed special caseins that are excellent fat replacers**

- Understanding of casein micelles
- Swollen micelles with enhanced water binding
- Scaling up from lab to factory
- Application testing
  - Soft serve ice cream

Slow melting low-fat ice cream

- Consumer desires low-fat products, but needs 100% taste
- Low-fat ice creams are especially difficult since they lack mouthfeel and show fast melting behavior

Enhanced mouthfeel and melt down resistance by high pressure treatment of ice mix

- Understanding casein micelle behavior under high pressure treatment allows to create a protein network that enhances mouthfeel and reduces melt down.

Huppertz et al. Int. Dairy J. 2011
Enhanced sweetness perception

*serum release in gels boosts taste intensity*

- Increase of serum release by 5x allows sugar reduction by 30%
- Principle also works for salt.

*Sala, Stieger, van de Velde (2010) Food Hydrocolloids*
Salt release from sausage

• Health-conscious consumers look for lower sodium intake but don’t compromise on taste

Up to 40% sodium reduced sausages with same salty taste

• Salt and other tastants are perceived better in liquids than in solids
• By creating juicy sausages which release salt in the serum (juice) salty perception was increased
• Lean pork sausages with gellan gum release more serum due to microphase separation

van de Velde & Adamse, New Food (2013, issue 2), 25
van de Velde & Adamse, VMT (2013, issue 8/9), 17
Protein fortification of foods

• Simply increasing protein content of products leads to texture and sensory defects

• Drinkables
  • High protein content can lead to aggregation, gelation and separation during processing and storage
  • Sensory defects: sandy / inhomogeneous / gelled

• Semi-solids and solids
  • Strong protein networks results in undesirable texture
  • Sensory defects: tough / rubbery / sticky / mealy / crumbly

Tailored protein ingredients can provide the solution!
Drinkables: modulating viscosity of caseinates

- Caseinates can be easily tailored to provide readily dispersible ingredients which give extremely low viscosity at very high concentration
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Together to the next level
Assessing consumer experience

Analytical sensory methods
Implicit measures
Food Experience Simulator

• Consumers do not always accurately report their own behaviour
• Some target groups are not able to self-report
• In some cultures “negative” feedback is difficult to give

Measure consumer liking and buying intent by physiology

• NIZO is part of a 4-year consortium building a ‘Food Simulator’
• All sensory aspects of the food buying and consumption experience can be presented in a controlled lab setting
• Physiological measures are taken
• Taylor-made software translates the response to liking and buying intent
The Food Experience Simulator

1. Dedicated setup delivers multi-sensory exposure to food

Screen:
Package or product appearance

Olfactometer:
Aroma

Gustometer:
Taste
Caloric value
The Food Experience Simulator

Cameras:
- Eye tracking
- Pupil dilation
- Facial recognition

Cap:
- NIRS

Wrist sensor:
- Skin conductivity

Joystick:
- Response time

2. Many-factor response measured
3. Taylor-made software interprets response and converts to reward value or buying intent

The Food Experience Simulator
Tasty reduced calorie foods for weight management

1. Selection of health concept and ingredient
2. Preparation of health ingredient
3. Preparation of health products
4. Building health claims

Pilot-scale production of final product

Processing of health ingredient

Product application: From raw material to consumer use

End product

Choose strategy and technologies

Testing

Concept

Together to the next level
Co-creation

Together to the next level