SOFT MATTER FOR SUSTAINABLE FOODS

PARTICLE-WATER INTERACTIONS AND THEIR ROLE IN ORAL PROCESSING

Lawrence Harris

Mondelēz International
SNACKING MADE RIGHT

Mondelēz International

SNACKING MADE RIGHT

Mondelēz International
SNACKING MADE RIGHT

ATTRACTIVE PORTFOLIO OF LEADING BRANDS IN PRIORITY CATEGORIES

Global biscuit brands

- **#1** cookie in the world
- **#1** breakfast biscuit in the world

Global chocolate brands

- **#1** in UK, India, Australia, Ireland
- **#1** in France, Germany, Austria
- **#1** in Duty Free & Travel Retail

Local Jewels, including…

- **#1** savory cracker manufacturer globally
- **#1** cookie in France
- **#2** cookie in the US behind Oreo

Local Jewels, including…

- **#1** in Brazil
- **#1** in Russia
- **#1** in Sweden
- **#1** in Norway
- **#1** in Belgium

Rankings from available Nielsen Global Data for branded manufacturers as of January 15, 2021 for measured channels in key markets where the company competes, with the exception of Toblerone ranking.
Toblerone is the number one chocolate brand in duty free and travel retail based on the latest available retail sales value report, TRAQ (Travel Retail Audit Quarterly), by Generation Research as of January 15, 2021

Mondelēz International
SNACKING MADE RIGHT

WE HAVE A SNACK FOR EVERY OCCASION

SNACKING MADE RIGHT – WE ARE LEADING THE FUTURE OF SNACKING BY OFFERING THE RIGHT SNACK, FOR THE RIGHT MOMENT, MADE THE RIGHT WAY

INDULGENT

WHOLESOME

Mondelēz International
SNACKING MADE RIGHT

SOFT MATTER FOR SUSTAINABLE FOODS

- How do consumers experience soft matter physics and why does this matter to sustainable foods?

- **Context** – reformulation and reengineering of established products towards sustainability

- Two significant challenge areas for sustainable food reformulation are **Cost** and **Consumer Acceptance**
  - Can manufacturers overcome cost hurdles to achieve the margins to enable production, distribution and a great consumer experience?
  - Will consumers accept the potential cost and sensory experience of more sustainable foods?
  - Can more sustainable foods present equal or better consumer liking?
  - Will consumers buy them again? Will they enjoy them? Could they replace the “norm”?

- The economics, technical functionality and consumer experience all need to work together to make “sustainable foods” as compelling a proposition as the current product landscape

- **A case study** – Fibre particles in low moisture comestible products

Mondelēz International
SNACKING MADE RIGHT

FIBRE PARTICLES

- Cereal and fruit/vegetable derived, fibre powders represent comparatively low cost, nutritionally compelling bulk and functional ingredients

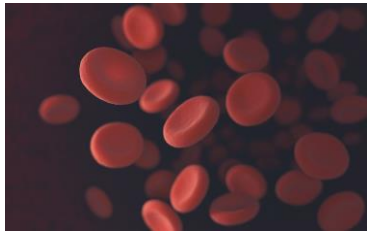
- Depending on the ingredient(s) they replace they can often represent environmentally sound choices for manufacturers
  - The botanical source itself can offer environmental advantages
  - When derived from waste streams (e.g. apple pomace from juice production) they can represent a link in a circular economy

- However such ingredients are typically high in plant cell wall material
  - High insoluble fibre content
  - Challenging particle morphologies

- When present in particle form and/or low moisture products these properties can lead to challenging rheology and textures

A LOW MOISTURE COMESTIBLE PRODUCT.....CHOCOLATE






Chocolate is a highly concentrated suspension of particles with a high degree of particle size and morphology heterogeneity

It shares many features in common with industrial and biological materials

But it has the additional requirement to be a pleasant eating experience



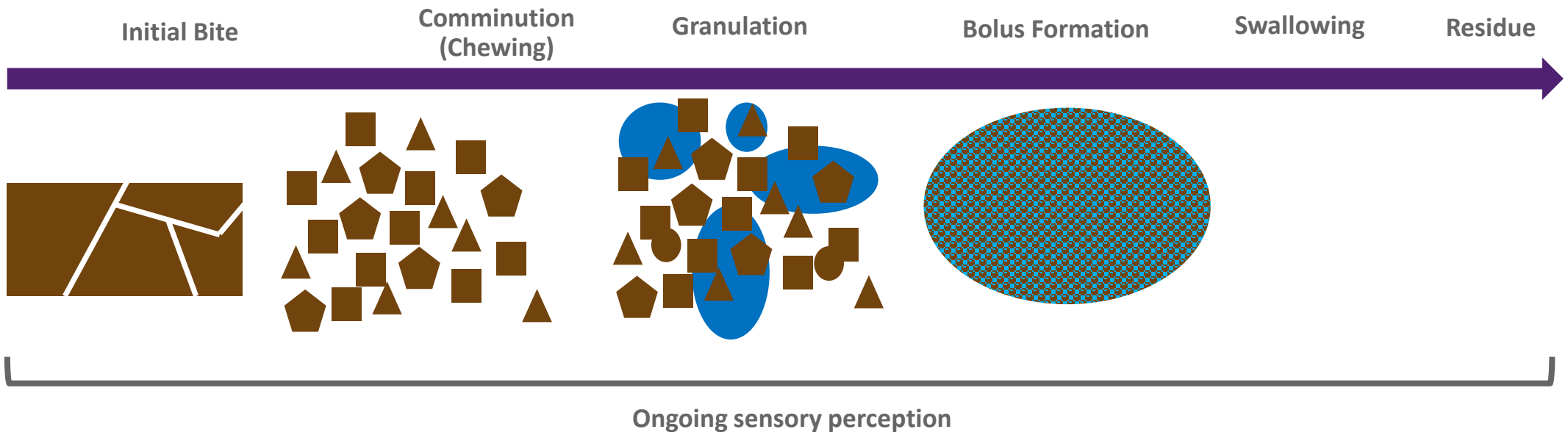
- Highly concentrated, **solid-in-liquid suspension**
- Needs to flow in a controlled and predictable way under a range of shear regimes
- Needs to solidify when cooled, achieving a specific crystal structure
- Heavily influenced by **particle properties** & **interactions** and fat chemistry & **crystallisation**

- Highly concentrated, **solid-in-solid suspension**
- Needs to posses certain **mechanical** & chemical properties
  - In process and transit robustness
- With the consumer
  - **Appearance** – gloss, bloom
  - **Texture** – snap, bite, chew, melt

Mondelēz International
SNACKING MADE RIGHT

ORAL PROCESSING – A SIMPLIFICATION

What happens in the mouth?



- Product size/length scale decrease
- Introduction of saliva
- Temperature change
- Residence time
- Evolution of the product microstructure. Concurrent:
  - Melting
  - Dilution
  - Dissolution
  - Hydration
  - Dispersion
  - Agglomeration
  - Emulsification

Mondelēz International
SNACKING MADE RIGHT

ORAL PROCESSING OF CHOCOLATE

- The main structural change occurring during chocolate consumption is broadly defined as a phase inversion from a:
- Fat continuous, solid-in-solid dispersion => an oil-in-water emulsion (He et. al 2018)

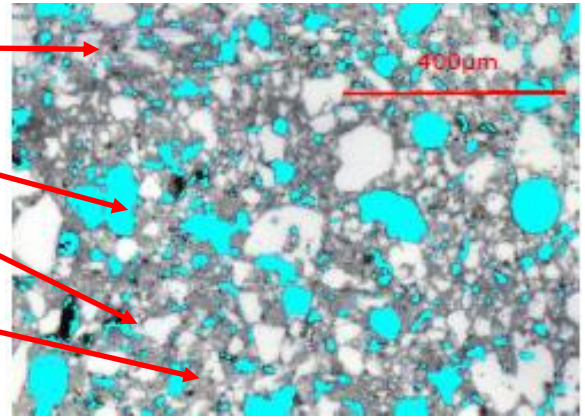
Solid chocolate

Sugar

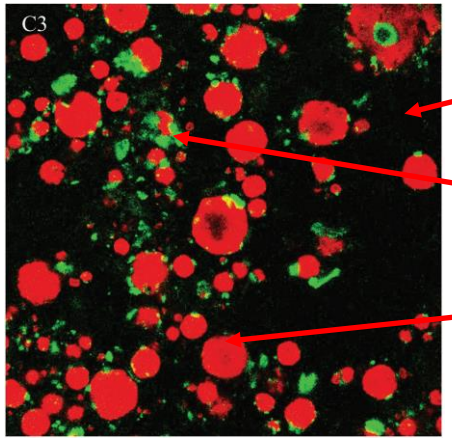
Milk Powders

Cocoa Powder

Continuous fat phase



Chocolate Bolus



Continuous saliva based phase

Cocoa Powder

Dispersed fat phase

He Q, Bramante F, Davies A, Elleman C, Fourtouni K, Wolf, B 2018, 'Material properties of ex vivo milk chocolate boluses examined in relation to texture perception', *Food and FUnction*, 9, pp. 3532

- The individual material properties within this composite bolus combine to give an overall system
- It is the properties of this "bolus system" which are key drivers of sensory perception and consumer liking.
- The behaviours of insoluble fibre rich particulates – both their final "soft state" and their transition to the "soft state" - are a major source of technical challenges to their adoption

Mondelēz International
SNACKING MADE RIGHT

ORAL PROCESSING OF CHOCOLATE – INTRODUCING FIBRE PARTICLES

The contents of the mouth leading up to, during and following bolus formation interact with the oral surfaces to provide the sensory experience

The standard set of particles (sucrose, milk powder, whey powder, cocoa powder) , result in the coarse, saliva based emulsion structure

The continuous saliva phase is also loaded with insoluble and partially solubilised particles.

This **particle containing, coarse emulsion** is what the consumer experiences and accept for a “normal” chocolate

Introducing insoluble fibre rich particles perturbs this system

Fat droplet

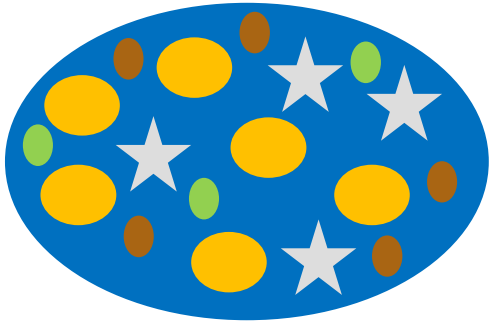
Dairy powder
(native/partially dissolved/hydrated)

Sucrose particle
(native/partially dissolved)

Cocoa powder particle
(native/partially dissolved/hydrated)

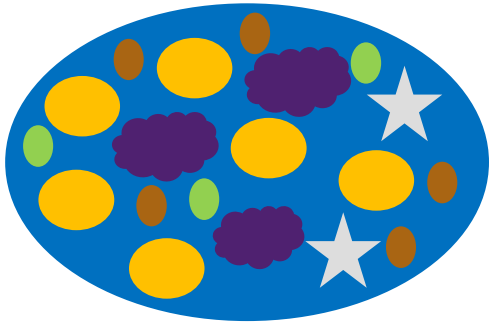
Saliva based phase
Contains dissolved components from sucrose, dairy powders, cocoa powder

Bolus of standard chocolate



Vs.

Bolus of chocolate with insoluble fibre replacing fat and/or sugar



Fibre particle

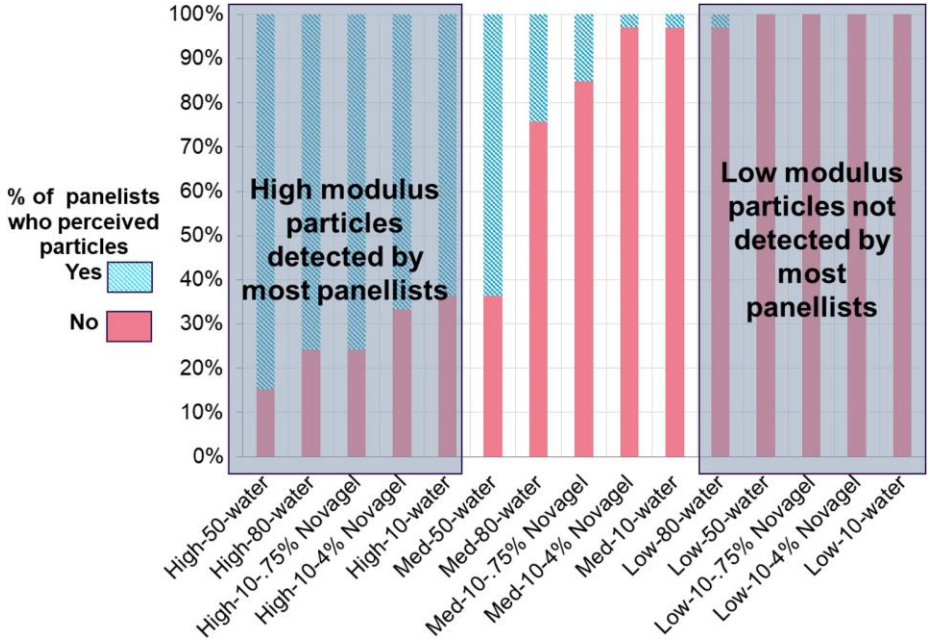
- (Partially)Hydrated
- Swollen
- Soft particle properties
- ????

How can we approach the native to hydrated state of insoluble fibre particles as a soft matter problem to better predict and tune their properties?

Mondelēz International
SNACKING MADE RIGHT

ORAL PROCESSING OF CHOCOLATE – INTRODUCING FIBRE PARTICLES

- Links between particle mechanical properties and textural/sensory perception have been demonstrated
- For examples, Shewan et. al 2020 have shown the link between the modulus (softness) and concentration of particles in a liquid suspension and the perception of smoothness
- Their work was based on a model system of spherical, hydrocolloid gel particles of pre-set moduli in an aqueous phase, but clearly demonstrates the link between modulating discrete particle properties and overall system properties and perception
- The correlation between the bulk rheological & tribological properties of food & bolus systems have also been widely reported in other studies e.g. Krop et. al 2019
- The discrete soft particle properties of the individual ingredients are known to contribute to the bulk system rheology, tribology and sensory perception



Shewan H, Stokes J, Smyth H, 2020, 'Influence of particle modulus (softness) and matrix rheology on the sensory
experience of 'grittiness' and 'smoothness', *Food Hydrocolloids*, 101, 105662

		Smooth	Firm	Elastic	Chewy	Cohesive	Pasty	Slippery	Salivating	Melting	Fracture stress	Fracture strain	Fracture Energy	Viscosity at 50 s^{-1} shear rate	μ at 50 mm/s	μ at 3 mm/s	μ at 50 mm/s	μ at 3 mm/s
Sensory	Smooth																	
	Firm	0.40																
	Elastic	0.44	0.98															
	Chewy	0.41	0.99	0.98														
	Cohesive	0.53	0.96	0.94	0.98													
	Pasty	-0.43	-0.92	-0.95	-0.91	-0.84												
	Slippery	0.66	0.68	0.77	0.64	0.63	-0.84											
	Salivating	0.25	0.94	0.94	0.91	0.82	-0.95	0.71										
	Melting	-0.38	-0.97	-0.99	-0.97	-0.91	0.97	-0.73	-0.96									
Texture analysis	Fracture stress	0.59	0.96	0.96	0.95	0.95	-0.94	0.80	0.91	-0.94								
	Fracture strain	0.36	0.87	0.90	0.87	0.80	-0.98	0.80	0.92	-0.92	0.91							
	Fracture Energy	0.55	0.89	0.87	0.87	0.84	-0.88	0.72	0.90	-0.87	0.94	0.82						
Rheology	Viscosity at 50 s^{-1} shear rate	0.30	0.91	0.89	0.88	0.80	-0.90	0.67	0.98	-0.91	0.80	0.86	0.95					
Tribology, gel bolus filtrate	μ at 50 mm/s	0.56	0.68	0.71	0.63	0.57	-0.80	0.82	0.79	-0.72	0.79	0.74	0.90	0.85				
	μ at 3 mm/s	-0.30	-0.11	-0.11	-0.16	-0.30	-0.15	0.14	0.22	0.04	-0.03	0.25	0.14	0.24	0.39			
Tribology, gel bolus fragments	μ at 50 mm/s	0.47	0.06	0.19	0.05	0.00	-0.31	0.48	0.16	-0.24	0.18	0.22	0.25	0.16	0.56	0.15		
	μ at 3 mm/s	0.42	-0.44	-0.31	-0.45	-0.42	0.22	0.17	-0.40	0.31	-0.28	-0.30	-0.23	-0.37	0.18	0.34	0.81	

Krop E, Hetherington M, Holmes M, Miquel S, Sarkar A 2019, 'On relating rheology and oral tribology to sensory properties in hydrogels', *Food Hydrocolloids*, 88, pp. 101 - 113

SUMMARY

- Broadly speaking when insoluble fibre particles are introduced in to a product such as chocolate, sensory descriptors such as rough, powdery, chalky, sticky become a challenge that limits dosage %

- The ability to understand the **dynamic** in-mouth transition of native, dry insoluble fibre particles to “hydrated”, soft particles and their contribution to complex bolus properties presents the opportunity to define and tune the properties necessary to keep sensory experiences close to a “standard” product

- Chocolate is one example where lack of understanding around insoluble fibre particle-water interaction in-mouth can limit applications, others include
  - Meat alternatives
  - Extruded cereals
  - Protein bars

- All possess a similar challenge. Insoluble fibre may not always be present as discrete, native particles, but the dry food matter will still present composite particle that will undergo a transition from dry/hard to wet/soft in-mouth

THANK YOU

Mondelēz International
SNACKING MADE RIGHT