Reformulating ice cream: from structure to sensory perception

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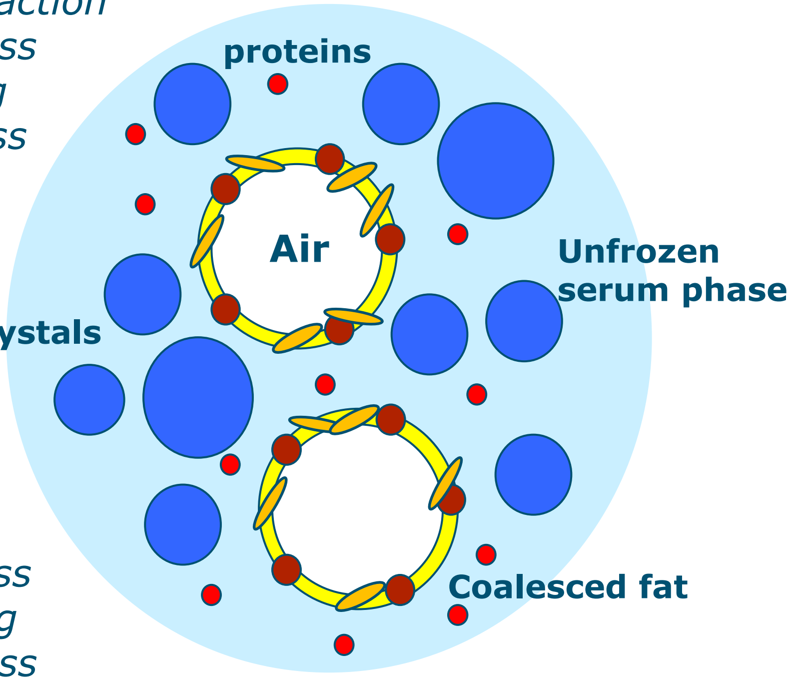
WAGENINGEN UR
For quality of life

Structure

Role of structural elements

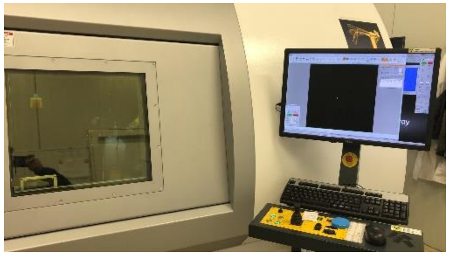
Ice: *solid fraction*
hardness
melting
coldness



Air: *softness*
melting
coldness

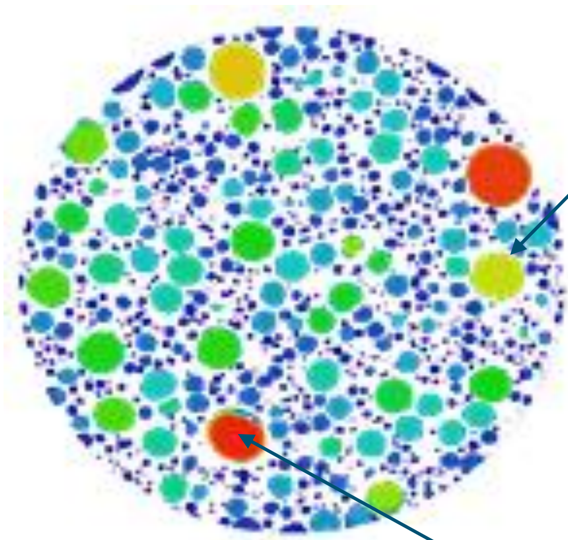
Serum phase: *"glue" for structure*
hardness / scoopability
smoothness

Structure




XRT: X-Ray Tomography

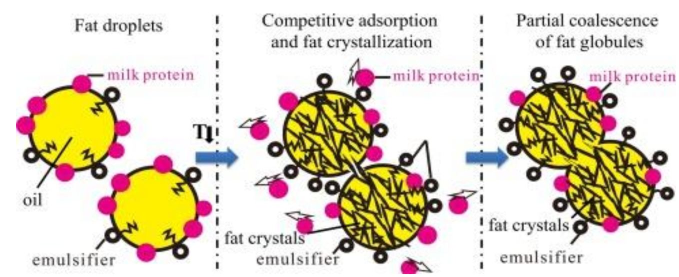
Fat crystals



Air cells

XRT image

Homogenizing (20 °C) | Aging (4 °C) | Freezing (-20 °C)



Jinju et al. (2020)

↓

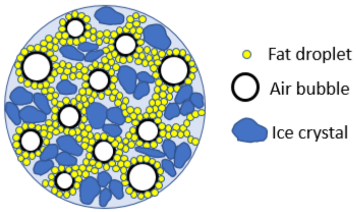
Overrun
Ice crystal size
Viscosity
Network in serum phase

↓

Rheological properties
Melting properties

Effect of structural elements?

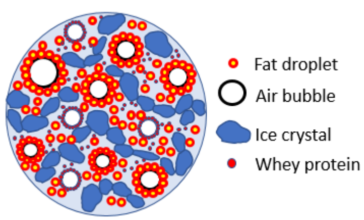
Fat network-dominated structure



To vary degree of fat destabilization

- Same fat content: 10%
- Different surfactants
    - Whey protein → limited fat destabilization
    - Tween 80 → high fat destabilization

Ice crystal-dominated structure



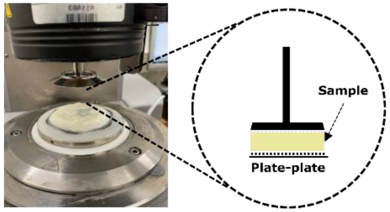
To vary overrun

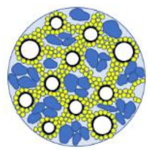
- 'Liquid nitrogen freezing'
- Different freezing times
    - 8 min: 90% overrun
    - 25 min: 30% overrun

To vary ice crystal size

- Different freezing methods
    - Batch freezer: 20 μm
    - 'Liquid nitrogen freezing': 50 μm

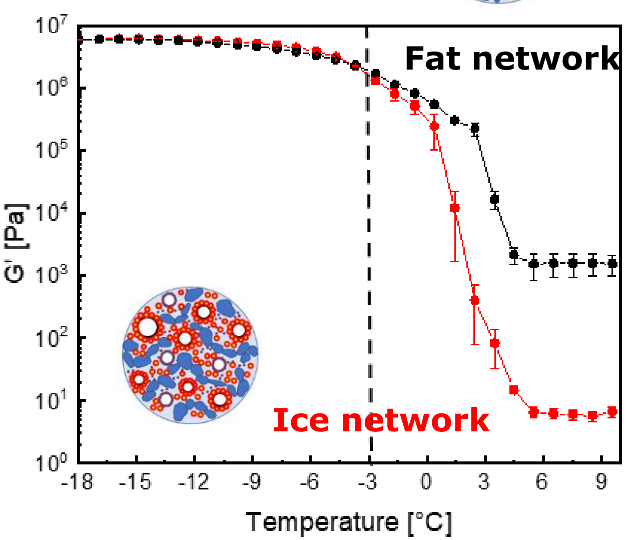
Effect of structure on viscoelastic properties





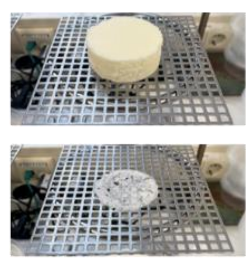
0 hour

3 hours



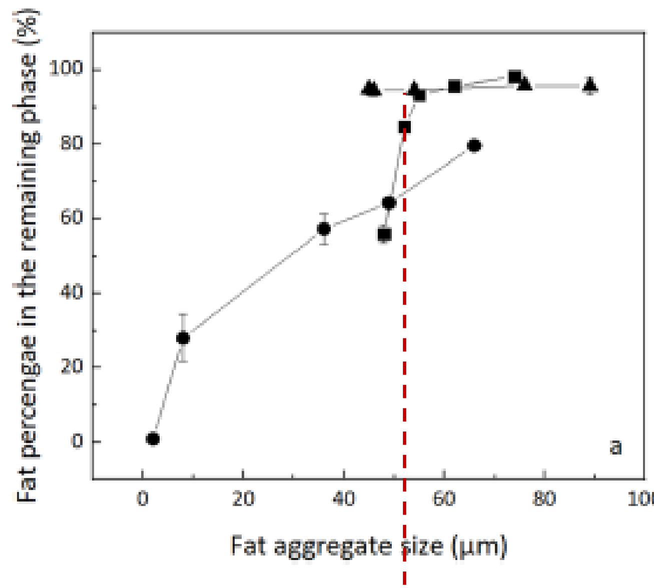
0 hour

3 hours



The fat network delays melting

Different series differing in:
- Fat aggregate size
- Fat aggregate percentage

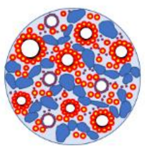


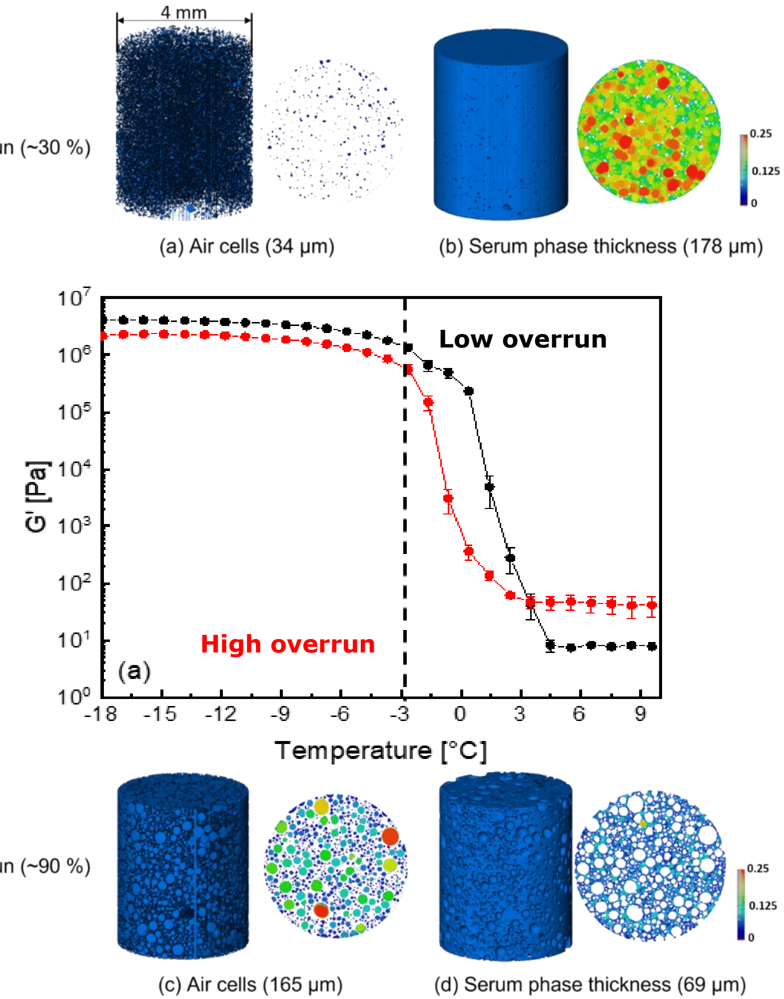
Critical size: 45 micron

Liu et. al, Food Hydrocolloids, 2023, 138, 108466

Effect of overrun on viscoelastic properties

Fat-free sample





Low overrun: 30%

Small air cells and
a dense structure
(thick lamellae)

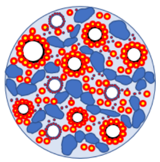
High overrun leads to **faster melting** in early stage and delays melting at later stage

High overrun: 90%

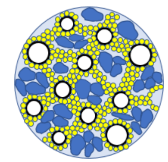
Large air cells and
a loose structure
(thin lamellae)

Liu et. al, Food Hydrocolloids, 2023, 138, 108466

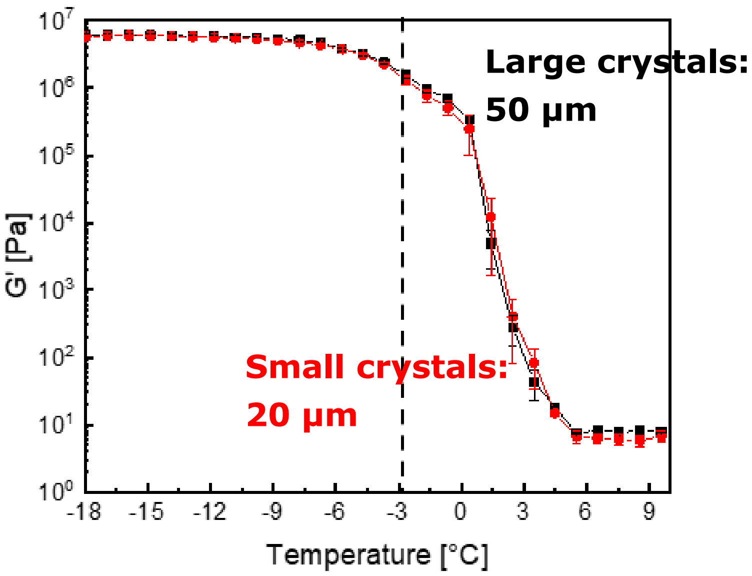
Effect of ice crystal size on viscoelastic properties

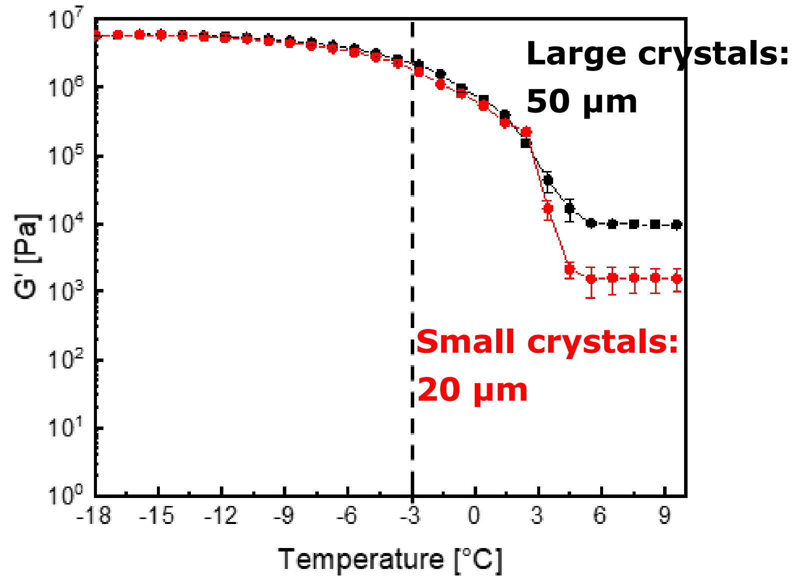


Ice crystal-dominated structure



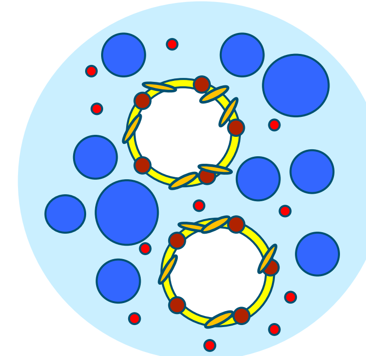
Fat network-dominated structure





Ice crystal size has limited effect on the melting properties of both types of ice cream

Structure - Perception

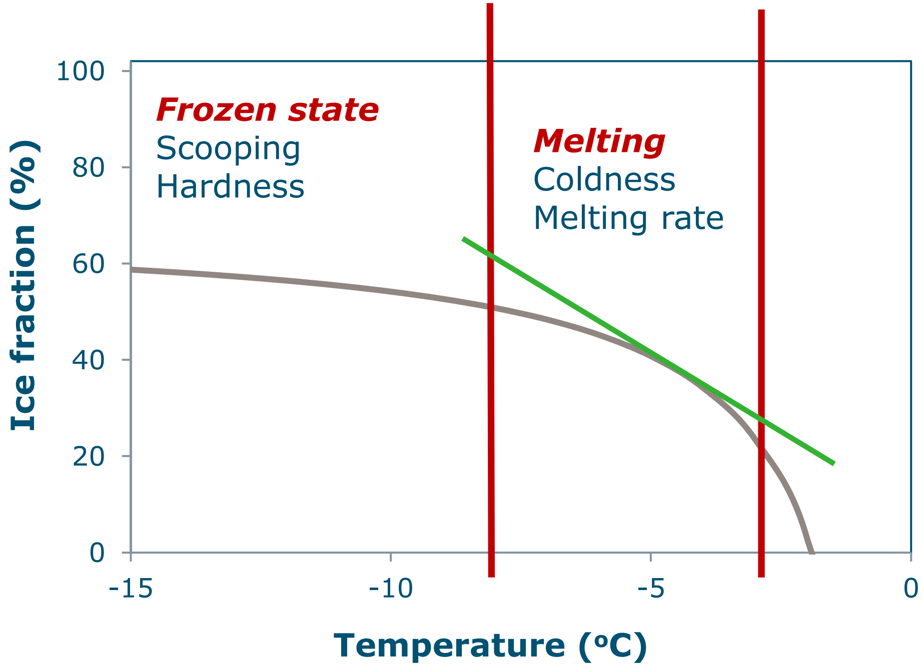


Hardness:
- Ice content
- Serum viscosity
- Air cells
- Ice crystal size

Iciness/coarseness/ roughness:
- Ice crystal size
- Serum viscosity
- Fat destabilization

Smoothness:
- Ice crystal size
- Overrun
- Fat

Softness
- Ice crystal size
- Serum viscosity
- Overrun



Molten state
Creamy?
Flavor

Mouthcoating
- Fat content
- Fat destabilization (fat layer on the tongue)
- Thickeners (viscosity)

Coldness
- Ice content
- Ice crystal size
- Serum phase viscosity
- Overrun
- Fat content

Creaminess
- Serum phase viscosity
- Fat content
- Overrun

Sensory perception

Table 1–Mean values of ice cream structural and physical attributes from instrumental analyses and the corresponding Tukey HSD test for significant differences at $P < 0.05$.

Draw temperature (°C)	Emulsifier[a] level (%)	Mean ice crystal size (μm)	Mean air cell size (μm)	Fat destabilization (%)	Drip-through rate (g/min)	Hardness (N)
−3	0	69.6 ± 1.2a	30.7 ± 1.5a	0f	1.2 ± 0.04a	88.4 ± 4.2c
−3	0.1	69.8 ± 1.5a	30.6 ± 1.1a	6.6 ± 1.3e	1.0 ± 0.03c	101.4 ± 1.9b
−3	0.2	69.4 ± 1.0a	28.4 ± 1.5ab	15.5 ± 2.6c	0.68 ± 0.08d	112.9 ± 5.4a
−5	0	40.7 ± 1.3b	26.5 ± 1.3bc	7.6 ± 1.9e	1.5 ± 0.02b	52.3 ± 4.1f
−5	0.1	41.6 ± 1.9b	23.7 ± 0.7d	14.3 ± 3.0d	0.46 ± 0.07e	62.7 ± 4.7e
−5	0.2	42.2 ± 1.7b	24.1 ± 1.3cd	25.4 ± 2.5b	0.41 ± 0.04e	72.7 ± 6.6d
−7.5	0	21.6 ± 1.8c	24.7 ± 1.4cd	22.3 ± 3.9d	1.1 ± 0.09c	35.8 ± 3.6g
−7.5	0.1	20.3 ± 1.1c	23.4 ± 1.2d	36.0 ± 4.2b	0.28 ± 0.01f	47.3 ± 2.8f
−7.5	0.2	20.1 ± 1.6c	22.7 ± 1.7d	54.7 ± 5.9a	0.21 ± 0.01f	61.9 ± 4.4e

Table 2–Sensory panel scores on a 15-point numeric scale for iciness, denseness, melt rate, and greasiness in ice creams with varying draw temperatures and emulsifier levels ($n = 12$).

Draw temperature (°C)	Emulsifier level (%)[a]	Sensory iciness	Sensory denseness	Sensory melt rate	Sensory greasiness
−3	0	9.9 ± 1.0a	5.7 ± 0.9bc	5.0 ± 1.0ab	2.4 ± 0.8e
−3	0.1	8.5 ± 0.9b	6.0 ± 0.9b	4.5 ± 1.3bc	3.0 ± 0.9de
−3	0.2	6.4 ± 0.9c	6.7 ± 0.8a	5.0 ± 1.1b	3.6 ± 0.7cd
−5	0	4.5 ± 0.8d	4.9 ± 0.7d	4.2 ± 1.1c	2.7 ± 0.7e
−5	0.1	4.1 ± 0.9d	5.4 ± 0.7cd	4.4 ± 1.0bc	4.3 ± 1.0bc
−5	0.2	3.2 ± 1.2e	6.1 ± 1.1b	4.6 ± 0.8bc	4.9 ± 1.0b
−7.5	0	2.4 ± 0.6f	4.2 ± 0.9e	4.7 ± 1.0bc	4.0 ± 1.1c
−7.5	0.1	2.0 ± 0.9f	4.9 ± 0.8d	4.9 ± 1.3b	4.9 ± 0.9ab
−7.5	0.2	1.0 ± 0.5g	5.1 ± 0.9cd	5.6 ± 0.9a	5.6 ± 0.5a

Amador et.al, Journal of Food Science, 2017, 82, 1851

Fat destabilization
- Decrease ice crystal size
- Decrease iciness

Fat destabilization
- Increase greasiness

→ Fat provides a lubrication layer

Sensory perception

Table 3–Ice cream structural attributes in ice creams collected at −3 °C draw temperature with varying stabilizer levels.

Stabilizer[a] level (%)	Mix viscosity[b] (Pa·s)	Ice crystal size (μm)	Air cell size (μm)	Fat destabilization (%)	Drip-through rate (g/min)	Hardness (N)
0	0.0229 ± 0.001c	69.1 ± 1.8a	32.8 ± 0.9a	0b	1.28 ± 0.042a	87.8 ± 1.9b
0.2	0.204 ± 0.005b	68.9 ± 1.3a	27.9 ± 1.0b	0b	1.05 ± 0.043b	88.9 ± 3.2b
0.4	0.906 ± 0.003a	70.3 ± 1.5a	25.2 ± 1.1c	3.1 ± 0.7a	0.93 ± 0.042c	106.2 ± 2.8a

Same size

Iciness (particle detection)

- Related to mix viscosity (for same crystal size)
- Reduced with fat destabilization

→ Fat and thickeners can be used to mask ice crystals

Table 4–Sensory panel scores on a 15-point numeric scale for iciness, deneseness, melt rate, and greasiness for ice creams drawn at −3 °C with varying stabilizer levels.

Stabilizer level (%)	Sensory iciness	Sensory deneness	Sensory melt rate	Sensory greasiness
0	10.1 ± 0.8a	5.5 ± 0.8c	4.6 ± 0.6b	2.0 ± 1.1c
0.2	7.5 ± 0.6b	6.3 ± 0.7b	4.7 ± 0.7b	3.8 ± 0.6b
0.4	4.5 ± 0.6c	7.3 ± 0.8a	5.8 ± 0.8a	5.2 ± 0.6a

Amador et. al, Journal of Food Science, 2017, 82, 1851

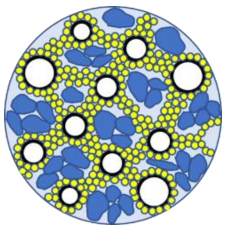
Sensory perception still not completely understood

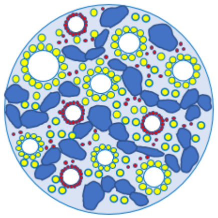
Low fat ice cream?

Full fat ice cream:
- Fat content: 10-16%

Reduction of fat

Low-fat ice cream:
- Fat content: < 3%





Microstructural changes:
- Loss fat network
- Higher ice connectivity
- Lower viscosity
- …

Property changes:
- Higher melting rate
- No shape retention
- Lower lubrication
- …

Polysaccharides:
Polysaccharide addition to increase viscosity

What is the role of the structure of polysaccharides and its specific rheological behavior?

Sensory perception of reformulated ice creams

Different thickeners

Fat reduced samples:
- High coldness
- High coarseness
- High hardness

Thickener addition
- Reduced coldness
- Reduced coarseness

→ Hardness increased

Table 6
Sensory characteristic of ice creams as affected by fat content, fat replacer type & concentration.

Sample codes		Flavor	Coldness	Creaminess	Coarseness	Hardness	Acceptance
CG[a]	**Full fat**	6.93[d] ± 0.82	4.51[abc] ± 1.00	4.83[de] ± 1.65	3.51[ab] ± 0.51	4.32[ab] ± 1.24	6.52[b] ± 1.03
0.35 GG[b]		5.17[c] ± 1.03	8.24[e] ± 2.06	3.81[bc] ± 0.98	8.13[ab] ± 0.51	6.54[c] ± 1.85	4.77[a] ± 2.07
0.45 GG		4.33[abc] ± 1.32	6.12[d] ± 1.32	2.80[cd] ± 0.65	7.10[ef] ± 1.98	6.82[cd] ± 1.36	5.51[ab] ± 1.69
0.50 GG		4.54[abc] ± 1.54	5.47[cd] ± 1.02	4.41[cd] ± 0.89	4.07[bc] ± 0.68	8.45[ef] ± 2.65	6.12[b] ± 2.36
0.55 GG		4.18[abc] ± 1.78	5.42[cd] ± 0.79	5.27[fgh] ± 1.84	4.92[cd] ± 0.63	8.83[f] ± 2.03	5.34[ab] ± 1.78
CB[a]	**Full fat**	6.51[d] ± 1.23	4.53[abc] ± 0.94	5.33[ef] ± 1.25	2.71[a] ± 0.32	4.83[b] ± 1.02	6.21[b] ± 1.30
0.35 BSG[b]		3.37[a] ± 1.25	7.47[e] ± 1.23	3.29[ab] ± 1.02	6.83[e] ± 1.57	5.83[c] ± 1.06	5.35[ab] ± 1.06
0.45 BSG		4.83[bc] ± 1.48	6.15[d] ± 1.49	4.73[cd] ± 1.65	4.51[bc] ± 1.12	6.55[c] ± 2.04	5.37[ab] ± 1.02
0.50 BSG		3.94[abc] ± 0.08	4.82[abc] ± 1.34	7.12[h] ± 2.35	4.12[bc] ± 0.98	8.36[ef] ± 2.07	6.14[b] ± 2.03
0.55 BSG		3.44[a] ± 0.48	4.02[a] ± 1.39	6.71[fgh] ± 1.98	3.89[bc] ± 0.83	7.53[de] ± 1.05	5.34[ab] ± 1.78
CM[a]	**Full fat**	7.13[d] ± 0.35	4.13[ab] ± 1.48	4.92[de] ± 1.05	3.95[bc] ± 0.65	3.75[a] ± 0.88	6.24[b] ± 1.36
0.35 MGB[b]		3.64[ab] ± 0.12	7.17[e] ± 2.65	2.53[a] ± 0.85	7.63[ef] ± 2.02	4.67[ab] ± 0.86	5.26[ab] ± 0.78
0.45 MGB		4.15[abc] ± 0.87	5.27[bcd] ± 1.25	3.97[cd] ± 1.07	5.71[d] ± 1.39	6.32[c] ± 1.26	5.63[ab] ± 1.08
0.50 MGB		4.83[bc] ± 0.63	4.93[abc] ± 1.65	5.93[fg] ± 1.65	4.72[bcd] ± 1.07	6.95[cd] ± 2.30	5.67[ab] ± 1.07
0.55 MGB		4.04[abc] ± 0.32	4.57[abc] ± 1.78	6.25[gh] ± 1.16	4.27[bc] ± 1.06	7.61[de] ± 2.01	5.64[ab] ± 0.98

Javidi et. al, Food Hydrocolloids, 2016, 52, 625

What is the role of the structure of polysaccharides and its specific rheological behavior?

Effect of polysaccharides in ice cream structure

Two types of polysaccharides (based on persistence length)

- **Flexible**: locust bean gum and guar gum ( )
- **Rigid:** xanthan gum and iota carrageenan ( )

Ice cream formulations of the studied samples (LBG: locust bean gum; GG: guar gum, XG: xanthan gum; IC: iota carrageenan).

Ingredients (%)	10% fat	1% fat	LBG	GG	XG		IC	
Cream	30	3.0	2.98	2.99	2.99	2.99	2.99	2.98
Skimmed milk	56.2	81.9	81.47	81.67	81.75	81.59	81.75	81.47
Sucrose	13.8	15.0	14.90	14.94	14.96	14.93	14.96	14.90
Vanillin	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Polysaccharide (similar mix viscosity)	0	0	0.55	0.3	0.2	0	0.2	0
Polysaccharide (similar serum phase viscosity)	0	0	0.55	0.3	0	0.4	0	0.55

Similar mix viscosity
→ related to the structure formation

Similar serum phase viscosity
→ related to sensory perception

Lui et. al, Current research in Food Science, 2023, 7, 100531

Effect of polysaccharides in ice cream structure

Two types of polysaccharides (based on persistence length)

- **Flexible**: locust bean gum and guar gum ( )
- **Rigid:** xanthan gum and iota carrageenan ( )

Ice cream properties

Viscoelastic properties

	Overrun	Melting rate	Hardness
Mix viscosity	-0.416	0.598	0.025
Mix consistency coefficient	-0.563	0.565	0.230
Mix flow behavior index	0.476	-0.266	-0.164
Mix loss factor	0.816	-0.041	-0.610
Mix G'	-0.891	0.397	0.843
Serum phase viscosity	0.478	0.818	-0.749
Network formation	-0.585	0.490	0.404

Overrun determined by viscous-like behavior: **Flexible** polysaccharides → higher overrun

Leads to **softer products**

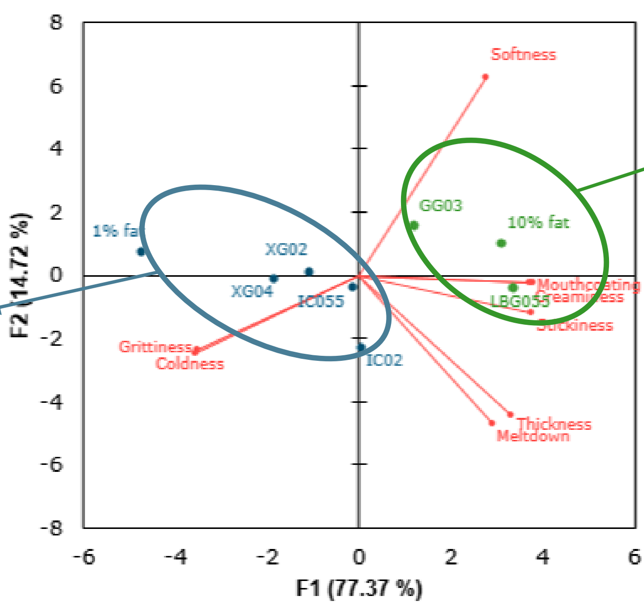
Ice cream melting is mainly related to the serum phase viscosity (**not** dependent on **polysaccharide type)**

Lui et. al, Current research in Food Science, 2023, 7, 100531

Link between structure and sensory attributes?

Rate-All-That-Applies: 80 participants

Attributes	1% fat	10% fat	LBG055	GG03	XG02	IC02	XG04	IC055
Creaminess	3.3 ± 1.9^{d}	4.7 ± 1.9^{ab}	5.2 ± 1.8^{a}	4.3 ± 2.0^{bc}	4.2 ± 2.2^{bc}	4.1 ± 2.2^{bc}	3.8 ± 2.0^{cd}	4.1 ± 1.9^{bc}
Softness	3.1 ± 1.8^{cd}	4.8 ± 2.2^{a}	4.1 ± 2.2^{bc}	4.5 ± 1.9^{ab}	3.5 ± 2.1^{bc}	2.7 ± 1.9^{d}	3.4 ± 2.0^{bc}	3.6 ± 1.9^{bc}
Coldness	6.6 ± 1.7^{a}	5.3 ± 1.9^{d}	5.5 ± 1.8^{cd}	5.2 ± 1.5^{d}	5.9 ± 1.9^{bc}	5.9 ± 1.6^{bc}	6.3 ± 1.5^{ab}	6.0 ± 1.9^{bc}
Grittiness	5.1 ± 2.3^{a}	3.0 ± 2.3^{c}	3.6 ± 2.3^{bc}	3.5 ± 2.3^{bc}	4.3 ± 2.6^{ab}	4.3 ± 2.3^{ab}	4.1 ± 2.5^{ab}	4.0 ± 2.5^{ab}
Thickness	3.3 ± 1.9^{c}	4.2 ± 1.9^{b}	4.6 ± 1.9^{a}	4.0 ± 1.9^{bc}	3.8 ± 2.0^{c}	4.5 ± 2.3^{ab}	3.7 ± 2.0^{c}	4.0 ± 1.9^{bc}
Stickiness	2.1 ± 1.6^{d}	3.4 ± 2.2^{ab}	3.6 ± 2.2^{a}	2.8 ± 2.0^{bc}	2.6 ± 2.1^{cd}	2.9 ± 2.3^{bc}	2.4 ± 2.0^{cd}	2.9 ± 1.8^{bc}
Mouth coating	3.3 ± 1.9^{c}	4.5 ± 2.0^{ab}	4.9 ± 2.0^{a}	4.2 ± 2.1^{ab}	3.7 ± 2.0^{bc}	4.0 ± 2.1^{bc}	3.6 ± 2.0^{bc}	4.0 ± 1.9^{bc}
Meltdown	3.9 ± 2.2^{b}	4.7 ± 2.1^{a}	4.6 ± 1.8^{a}	4.4 ± 1.9^{ab}	4.4 ± 2.1^{ab}	4.8 ± 2.3^{a}	4.5 ± 2.2^{ab}	4.6 ± 2.0^{a}
Off-flavor	1.3 ± 1.8^{b}	1.7 ± 1.9^{b}	1.4 ± 1.8^{b}	4.0 ± 3.0^{a}	1.6 ± 2.0^{b}	1.6 ± 2.1^{b}	1.4 ± 1.9^{b}	1.3 ± 1.7^{b}
Overall liking	4.6 ± 1.8^{ab}	5.2 ± 2.0^{a}	5.3 ± 2.0^{a}	3.5 ± 2.1^{c}	4.7 ± 1.9^{ab}	4.5 ± 1.9^{ab}	4.6 ± 1.8^{ab}	5.0 ± 1.8^{a}



Flexible polysaccharides provide higher mouth coating, creaminess and stickiness

Rigid polysaccharides provide higher grittiness and coldness

Development of low-fat ice cream:

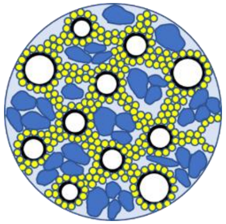
→ Use polysaccharides with a flexible structure

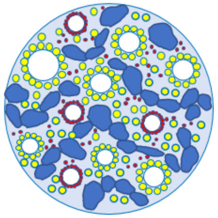
Low fat ice cream?

Full fat ice cream:
- Fat content: 10-16%

Reduction of fat

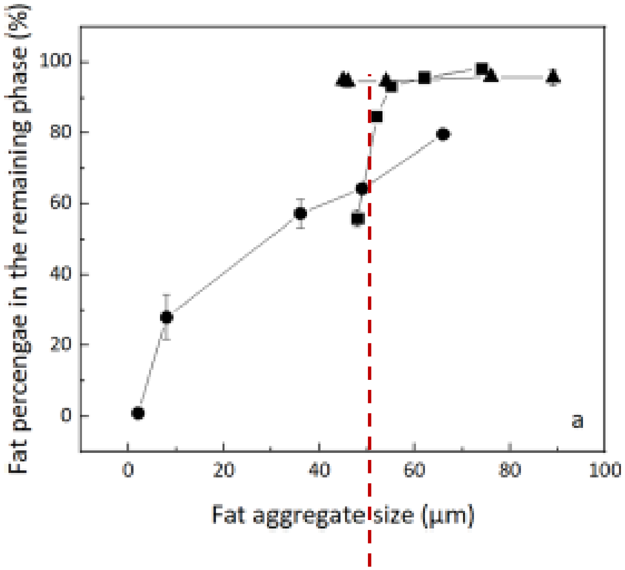
Low-fat ice cream:
- Fat content: < 3%





0 hour

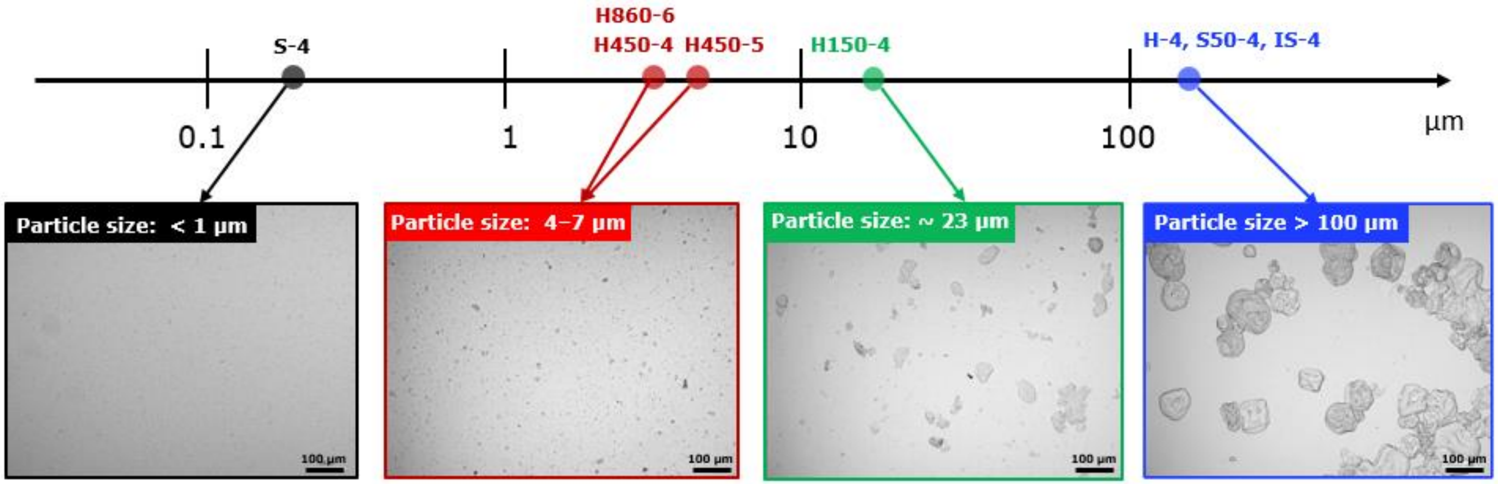
3 hours

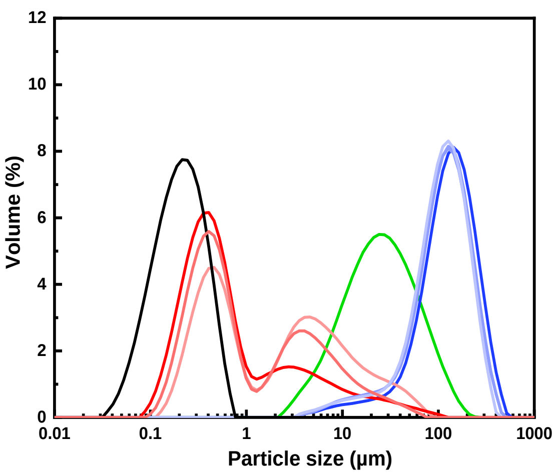


Critical size: 45 micron

Can fat particles / fat network be replaced by other particles?

Protein particle size and morphology

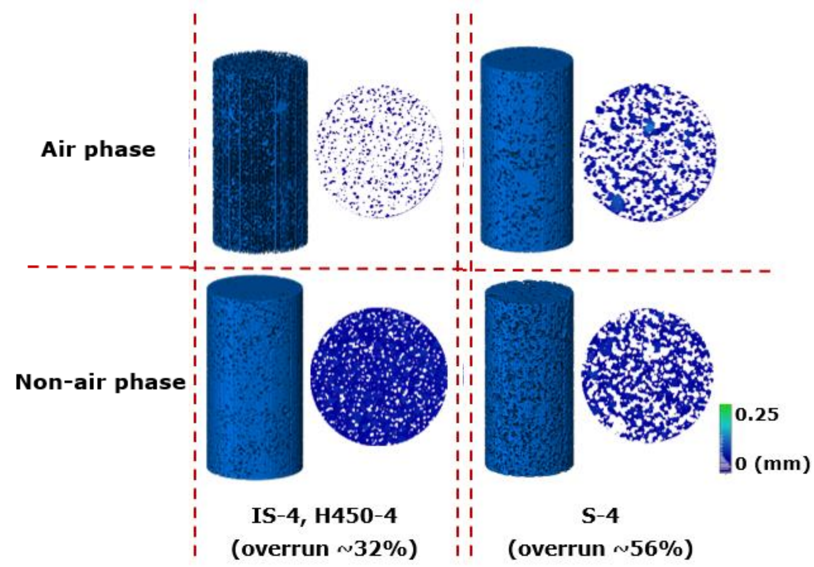




Series	Sample code	$D_{4,3}$ (µm)	Percentage of soluble fraction (%)	Mix viscosity (mPa·s)
Reference	Fat-10	16.0 ± 0.2^{c}	-	20.1 ± 0.1^{d}
Homogenization series	H-4	145 ± 5^{a}	74	31.2 ± 1.1^{b}
	H150-4	23.2 ± 0.5^{c}	79	26.8 ± 0.3^{c}
	H450-4	4.1 ± 0.1^{de}	90	17.1 ± 0.1^{e}
Fraction series	S-4	0.25 ± 0.01^{e}	100	11.4 ± 0.2f
	S50-4	139 ± 5^{ab}	50	31.7 ± 2.1^{b}
	IS-4	137 ± 6^{ab}	0	199 ± 2^{a}
Concentration series	H-4	145 ± 5^{a}	74	31.2 ± 1.1^{b}
	H450-5	6.9 ± 0.2^{d}	82	30.8 ± 0.4^{b}
	H860-6	3.8 ± 0.1^{e}	88	32.1 ± 0.9^{b}

Microstructure

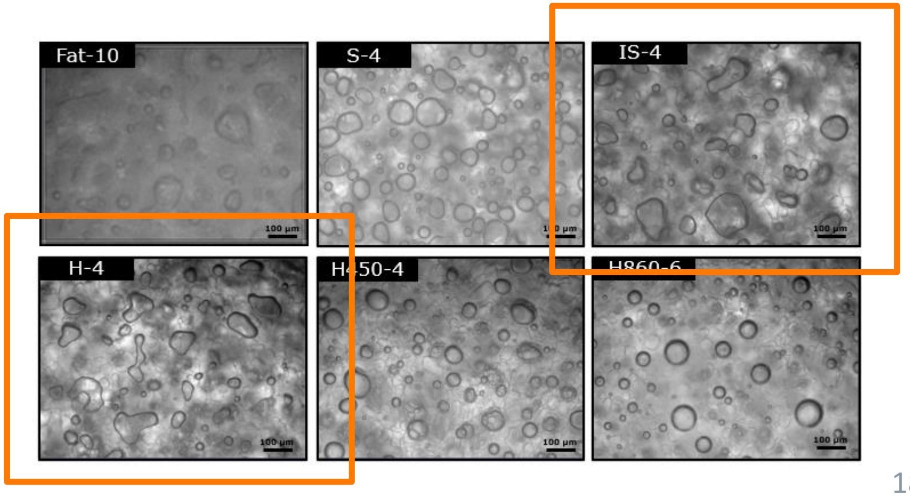
Series	Sample code	Overrun (%)	Air cell size (µm)	Ice crystal size (µm)
Reference	Fat-10	32 ± 2[f]	35 ± 13[a]	50 ± 14[a]
Homogenization series	H-4	55 ± 1[c]	29 ± 13[a]	50 ± 12[a]
	H150-4	50 ± 2[cd]	26 ± 11[a]	52 ± 11[a]
	H450-4	44 ± 3[de]	33 ± 16[a]	51 ± 15[a]
Fraction series	S-4	71 ± 4[a]	28 ± 16[a]	47 ± 13[a]
	S50-4	63 ± 2[b]	33 ± 7[a]	54 ± 15[a]
	IS-4	43 ± 2[e]	30 ± 13[a]	43 ± 12[a]
Concentration series	H-4	55 ± 1[c]	29 ± 13[a]	50 ± 12[a]
	H450-5	52 ± 4[c]	30 ± 16[a]	48 ± 13[a]
	H860-6	53 ± 4[c]	25 ± 9[a]	48 ± 15[a]



Soluble proteins showed higher ability to adsorb at the air cell interface → **higher overrun**

Insoluble particles are in the **serum phase** → Hinder air cells to acquire spherical shape

Air cell morphology



Textural and melting properties of ice cream

Textural properties **Melting properties**

Series	Sample code	Hardness (MPa)	Scooping energy (N · mm)	Lag time (min)	Melting rate (%/min)
Reference	Fat-10	8.0 ± 0.2[b]	454 ± 69[b]	35 ± 1.8[b]	0.76 ± 0.03[e]
Homogenization series	H-4	5.2 ± 0.3[cd]	388 ± 22[bc]	28 ± 0.2[cd]	2.16 ± 0.04[b]
	H150-4	4.4 ± 0.9[de]	356 ± 25[c]	19 ± 0.3[ef]	2.17 ± 0.01[b]
	H450-4	3.6 ± 0.4[ef]	309 ± 18[cd]	16 ± 0.4[f]	2.11 ± 0.03[b]
Fraction series	S-4	1.0 ± 0.3[g]	108 ± 24[e]	20 ± 0.9[ef]	2.72 ± 0.01[a]
	S50-4	2.9 ± 0.5[f]	257 ± 15[d]	33 ± 0.5[bc]	1.86 ± 0.07[c]
	IS-4	9.5 ± 0.4[a]	572 ± 43[a]	48 ± 3.3[a]	1.07 ± 0.10[d]
Concentration series	H-4	5.2 ± 0.3[cd]	388 ± 22[bc]	28 ± 0.2[cd]	2.16 ± 0.04[b]
	H450-5	5.6± 0.2[cd]	395 ± 33[bc]	23 ± 0.3[de]	2.22 ± 0.03[b]
	H860-6	5.3 ± 0.2[cd]	359 ± 65[c]	18 ± 0.1[ef]	2.25 ± 0.05[b]

Small soluble protein particles lead to lower hardness and higher scoopability due to their contribution to overrun

Insoluble particles contribute more to the melting resistance due to their positive effect on mix viscosity and their greater ability in network formation

Texture - Sensory

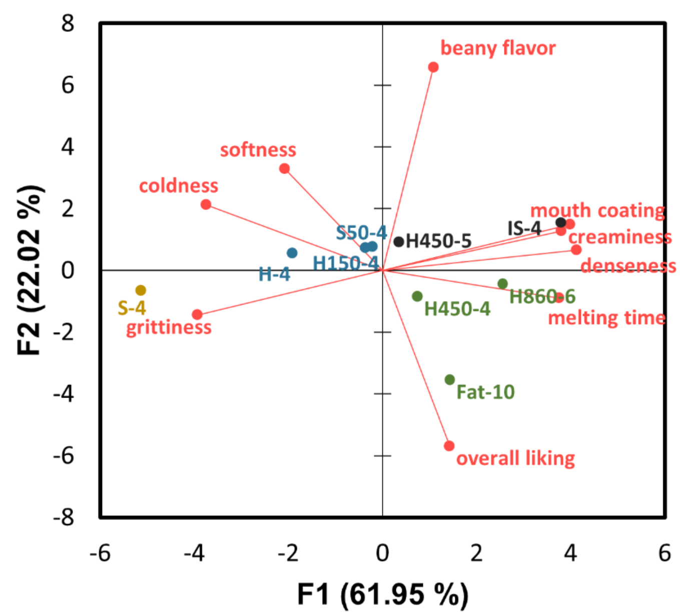
Variables	Creaminess	Softness	Coldness	Grittiness	Denseness	Mouth coating	Melting
Hardness	**0.848**	-0.197	**-0.869**	**-0.717**	**0.855**	**0.838**	0.61
Scooping energy	**0.800**	-0.319	**-0.830**	**-0.742**	**0.869**	**0.814**	0.68
Lag time	0.541	-0.139	-0.431	-0.272	0.512	0.452	0.31
Melting rate	**-0.761**	0.467	**0.719**	0.656	**-0.798**	**-0.746**	-0.69
G'_{-15}	**0.856**	-0.048	**-0.846**	-0.699	**0.827**	**0.822**	0.52
SZII	**-0.735**	-0.235	0.619	0.449	-0.658	-0.662	-0.30
G'_{5}	0.682	-0.121	-0.656	-0.415	0.587	0.624	0.38
FCB	**-0.885**	0.286	**0.882**	**0.940**	**-0.913**	**-0.926**	**-0.76**
SMR	0.612	-0.027	-0.610	-0.664	0.678	0.647	0.49

Rheological properties (Hardness, Scooping energy)

Melting properties (Melting rate, G'_{-15})

Lubrication properties (FCB)

Ice cream with medium-sized particles (4 micron) have properties similar to fat sample



Role of fat and protein on aroma release

code in water	code in saliva	fat type	fat level	Protein level
WAH1	SAH1	A	High	1
WAH2	SAH2	A	High	2
WBH1	SBH1	B	High	1
WBH2	SBH2	B	High	2
WAL1	SAL1	A	Low	1
WAL2	SAL2	A	Low	2
WBL1	SBL1	B	Low	1
WBL2	SBL2	B	Low	2

- **Fat content:** 3 and 9%
- **Protein level**: 4% and 8%

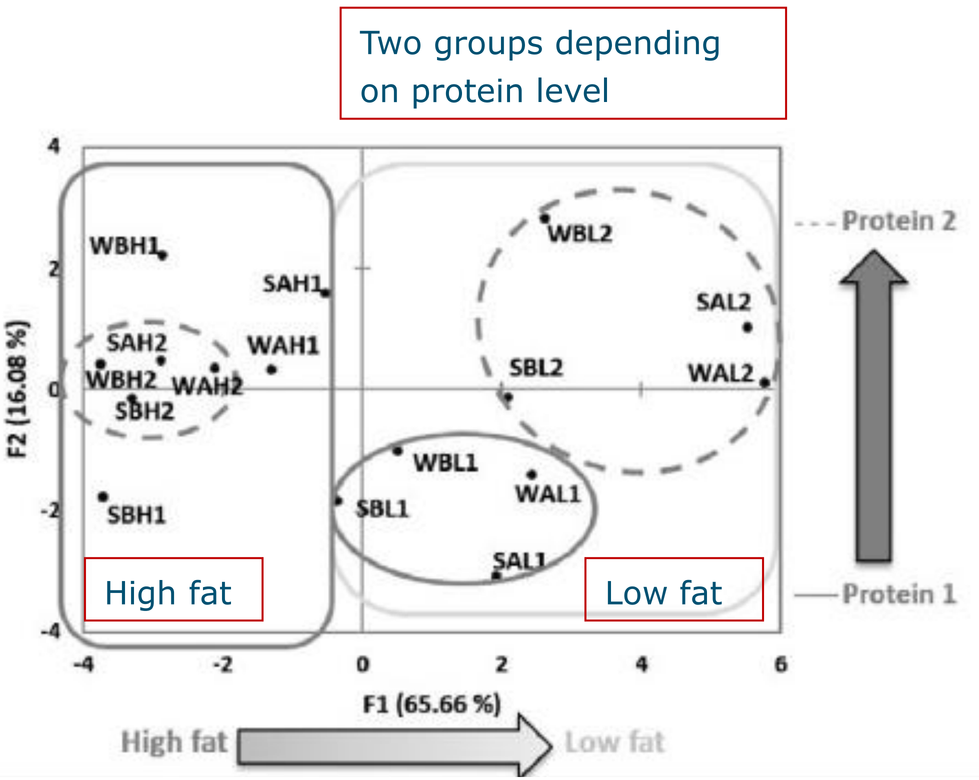
14 aroma compounds with different lop P values:

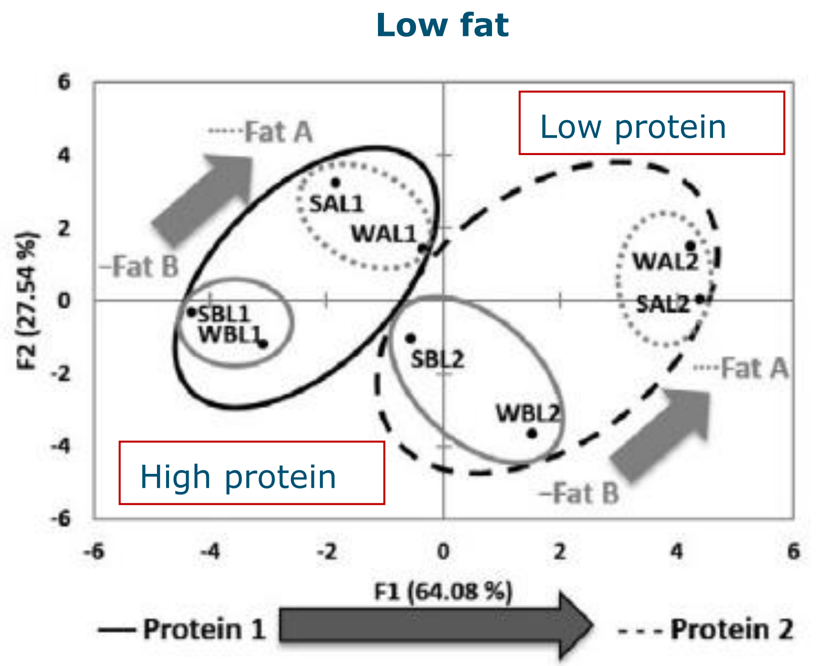
Acetoin, 2,5-dimethylpyrazine, vanillin,
2-methoxy phenol, benzaldehyde, phenyl ethyl alcohol,
2-ethyl-3,5-dimethylpyrazine, 2-methoxy-4-methylphenol,
hexanal, p-anisaldehyde, ethyl butyrate, butyl propionate,
cis-3-hexenyl acetate, ethyl octanoate.

Ayed et. al, Food Chemistry 2018, 267, 132

Role of fat and protein content on aroma release

Ice cream with **low fat level** release more **hydrophobic compounds** than high fat level



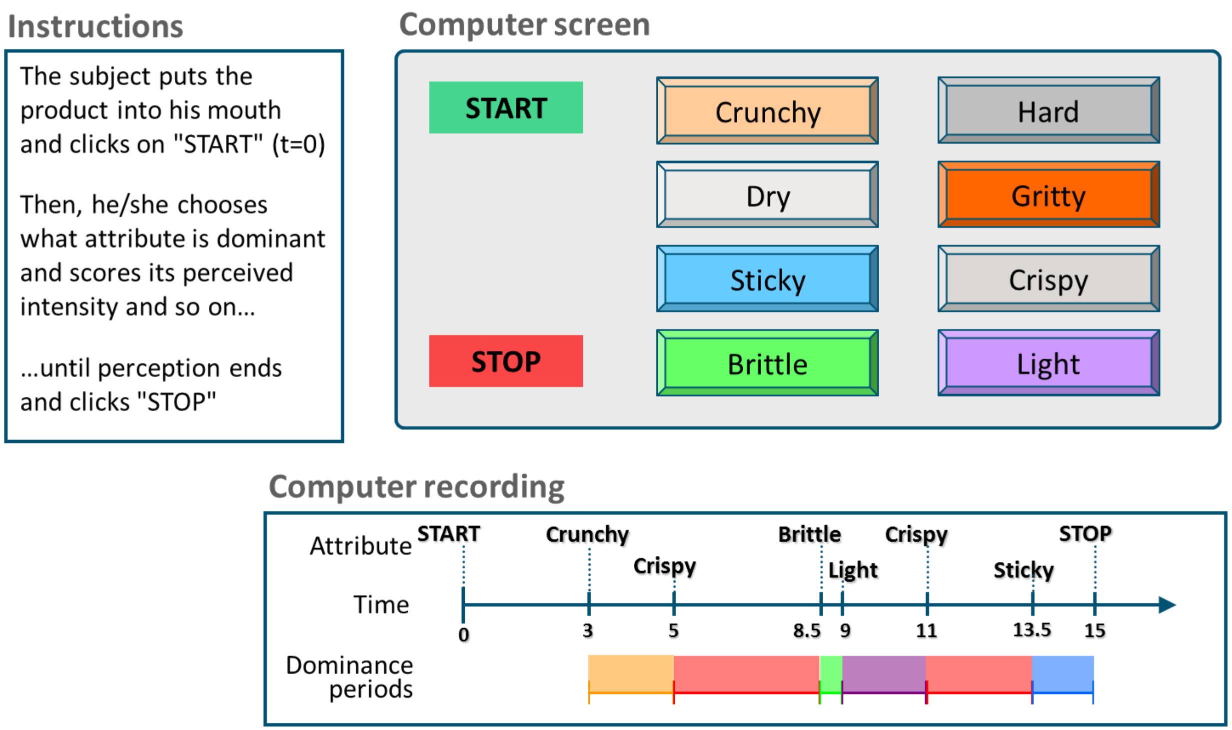


hydrophobic compounds less released for **higher protein content**:

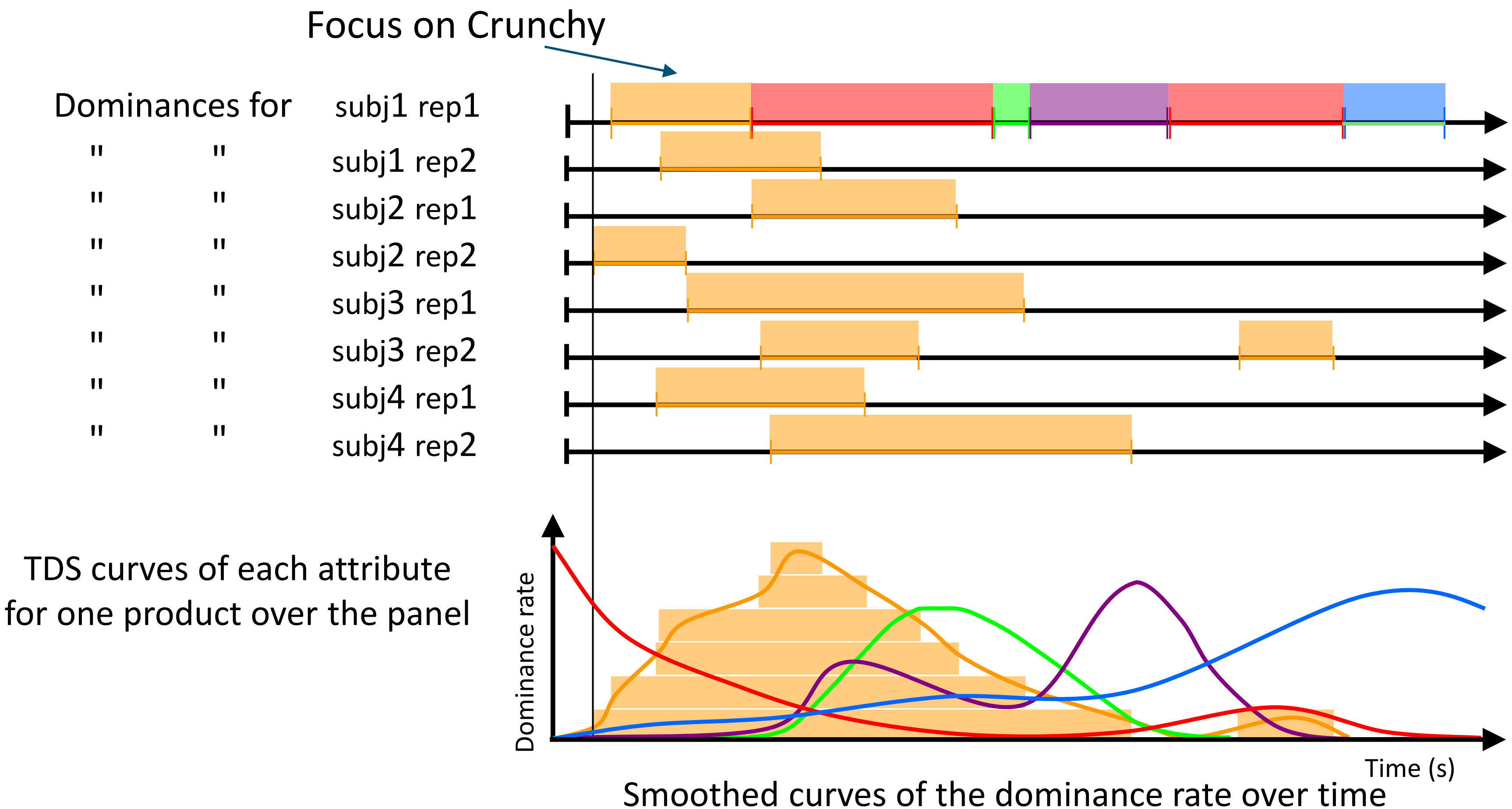
Dynamic perception

Temporal dominance of sensation (TDS)

- Presentation of all attributes simultaneously
- Selection of dominant attribute until another attribute becomes dominant (attracts most attention)



Dynamic perception



Dynamic sensory perception

6 ice creams:
- Milk (M)
- Cream (C)
- Egg (E)
- Hydrocolloids (H)

6 sensory attributes:

iciness

coldness

creaminess

roughness

gumminess

mouth coating

Table 1
Formulations of the mixes used for ice cream manufacture. Milk (M), diary cream (C), egg yolk (E), hydrocolloids (H) and sugar (S).

Sample	M (% w/w)	C (% w/w)	E (% w/w)	H (% w/w)	S (% w/w)
MECH	36	36	14	0.5	13.5
MEH	72	0	14	0.5	13.5
MCE	36.5	36	14	0	13.5
MCH	50	36	0	0.5	13.5
MH	86	0	0	0.5	13.5
M	86.5	0	0	0	13.5

Varela et. al, Food Hydrocolloids 2014, 36, 220

Dynamic sensory perception

6 ice creams:
- Milk (M)
- Cream (C)
- Egg (E)
- Hydrocolloids (H)

Milk (MH)
- Also icy
- Masks coldness

→ Hydrocolloids can mask early sensation of icy and cold

Milk (M)
- High Iciness in beginning
- High coldness

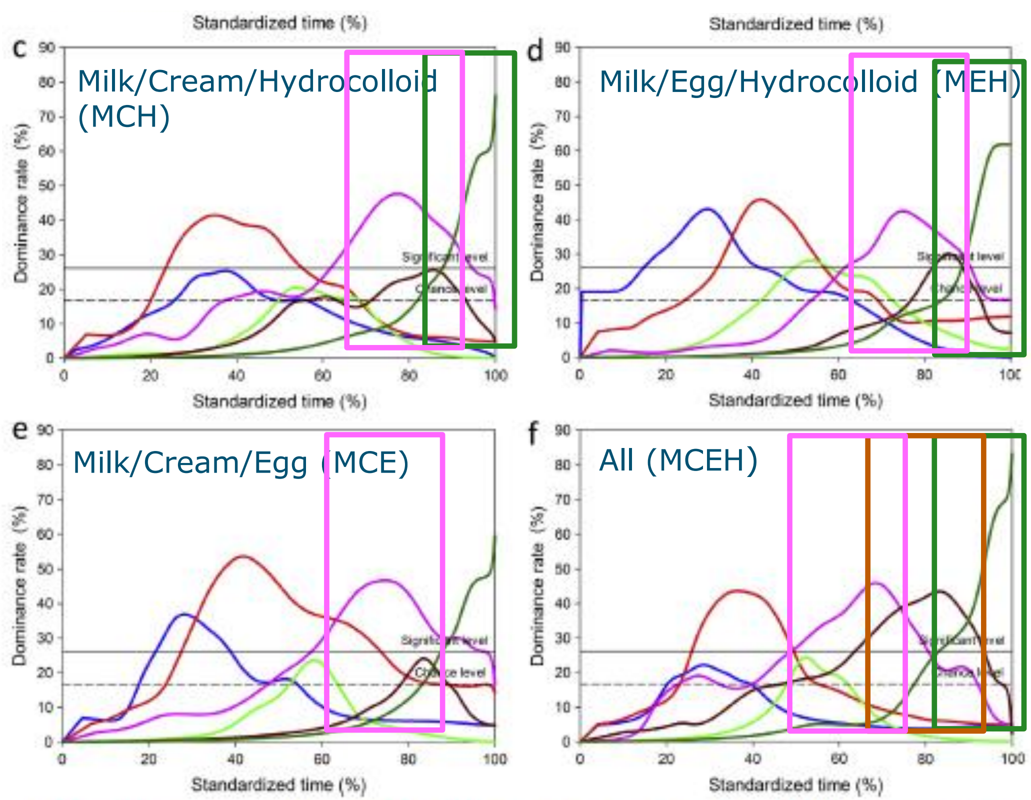
(related to large ice crystals)

Mouthcoating
Samples with:
- Cream
- Hydrocolloids

Cream / hydrocolloids
- High gumminess

Creaminess
- Difficult to asses
- Perceived later

→ The ones that were liked most had early creaminess



iciness
coldness
creaminess
roughness
gumminess
mouth coating

Varela et. al, Food Hydrocolloids 2014, 36, 220

Effect of eating behaviour?

Does the way people consume ice cream influence perception?

Tonguers: move the jaw in a horizontal plane (from left to right)

Chewers: move the jaw in a vertical direction (up and down)

Melters: no clear movement

Suckers: can not be distinguished from melters (only self-reporting)

Oral behaviour classification	Self-reporting (%)	Video recording (%)
Combined behaviour	27.2	39.8
Tonguers	49.5	36.9
Chewers	13.6	21.4
Melters	6.8	1.9
Suckers	2.9	0.0

Almost 40% use their tongue

Doyenette et. al, Food Quality and preference 2019, 78, 103721

Effect of eating behaviour?

Does the way people consume ice cream influence perception?

Two different ice creams:
- Soft
- Hard

Ice cream hardness level	Consumption time (s)	Oral behaviour	Consumption time (s)
Low	20.6 ± 1.0[a]	Chewing	17.1 ± 0.8[A]
		Natural	22.6 ± 1.4[B]
High	29.1 ± 1.3[b]	Melting	34.9 ± 2.4[C]

Consumption time of harder ice cream is 50% longer

Melting takes twice the time as chewing

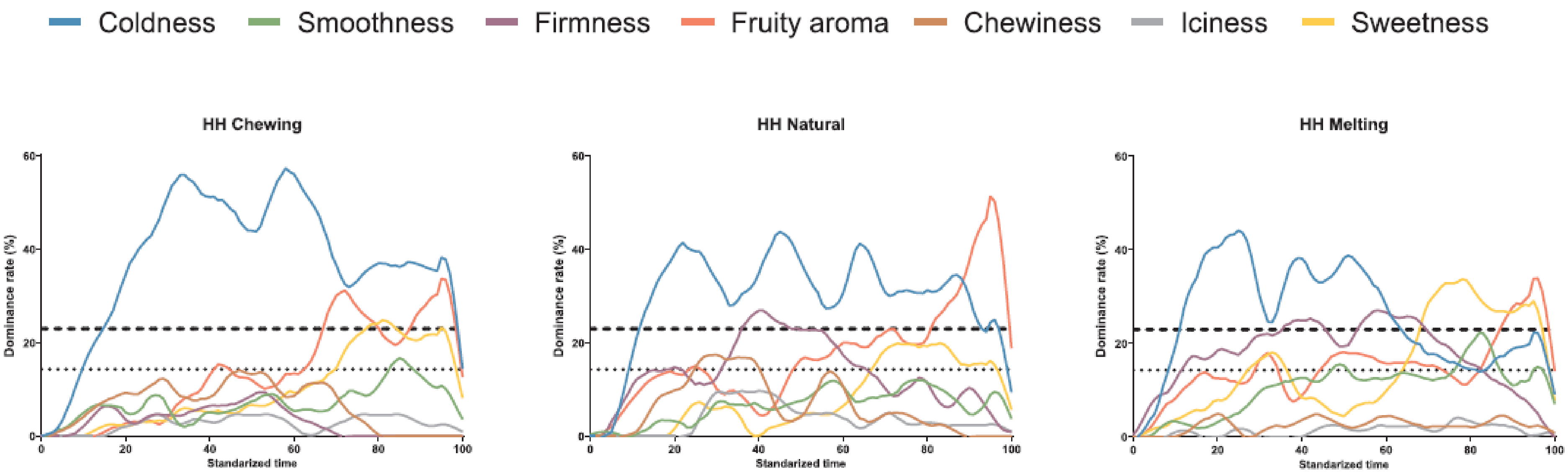
Influence of eating procedure on perception?

Three protocols:
- Natural
- Melting (without any tongue movements)
- Chewing (masticating between the teeth)

Doyenette et. al, Food Quality and preference 2019, 78, 103721

Effect of eating behaviour?

Hard ice creams



coldness becomes more dominant

coldness dominant independent on eating habit

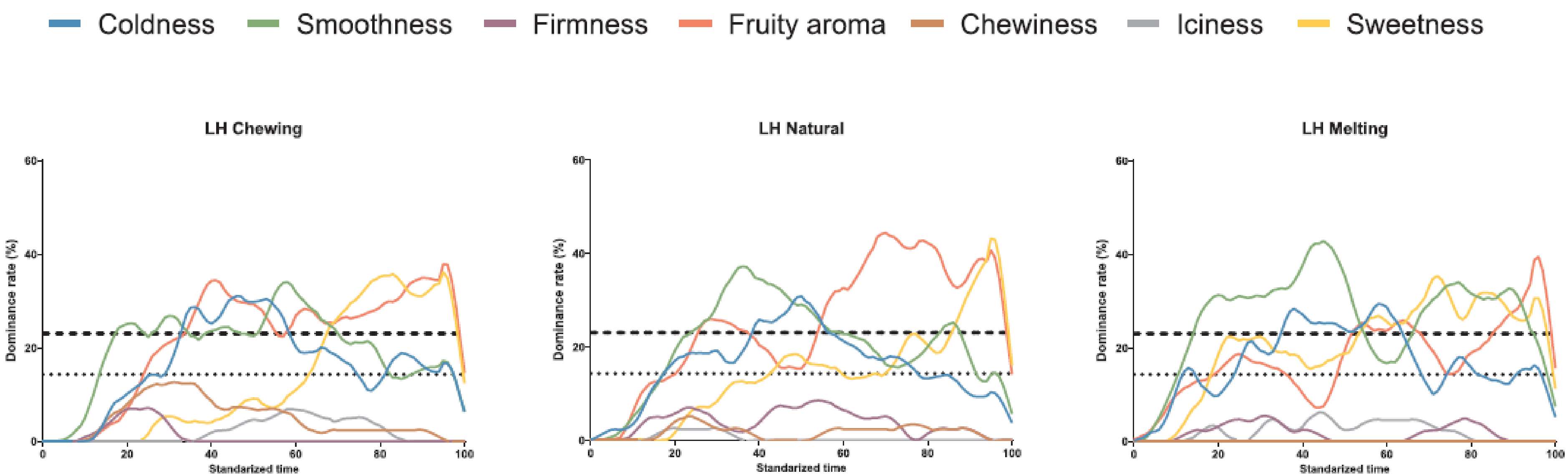
Firmness and **smoothness** becomes more dominant ***(more contact with palate)***

Texture perceived early since no tongue movements are needed

Taste and aroma (**fruity** and **sweet)** in later stage as some tongue movement is required

Effect of eating behaviour?

Soft ice creams



Fruity perceived earlier and more dominant

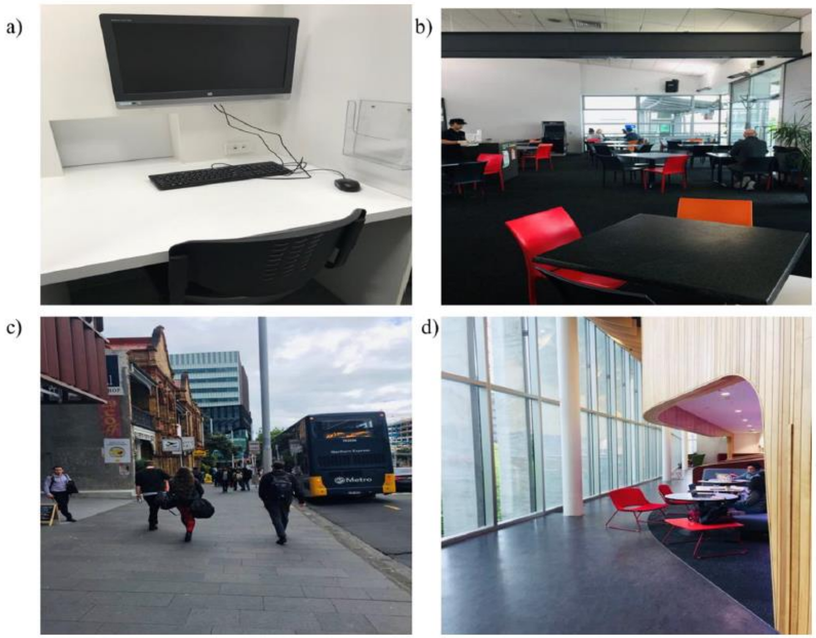
- larger surface area due to chewing
- Perceived earlier as aroma is released earlier in softer products

Sweetness less dominant

Smoothness becomes more dominant

coldness becomes dominant only in second half

Effect of eating environment?



a) Laboratory

b) Cafe

c) Bus stop

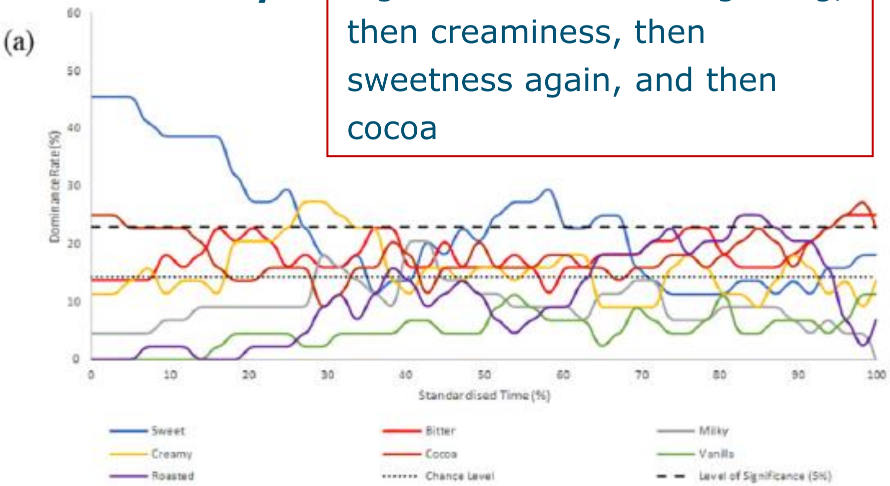
d) University study area

Xu et. al, Food Quality and preference 2019, 77, 191

Effect of eating environment?

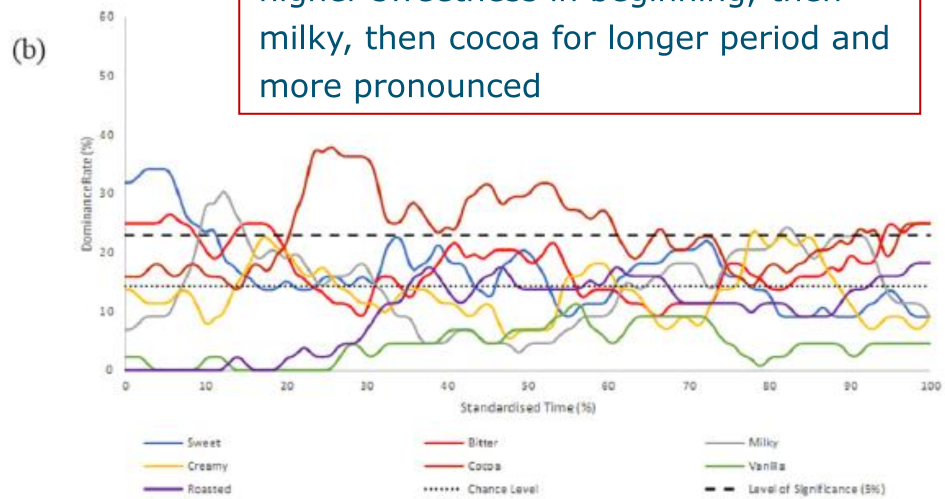
laboratory

higher sweetness in beginning, then creaminess, then sweetness again, and then cocoa



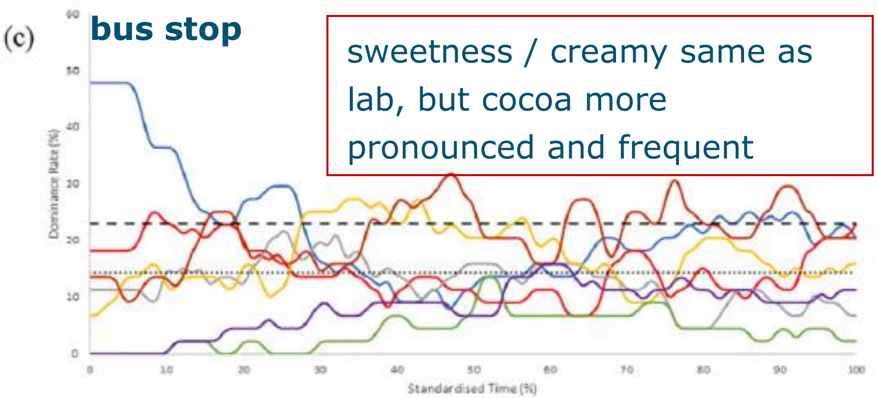
cafe

higher sweetness in beginning, then milky, then cocoa for longer period and more pronounced



bus stop

sweetness / creamy same as lab, but cocoa more pronounced and frequent



study area

sweetness at beginning, but bitter took over quite soon

Xu et. al, Food Quality and preference 2019, 77, 191

Thank you for your attention!

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Physics and Physical Chemistry of Foods

WAGENINGEN UR
For quality of life