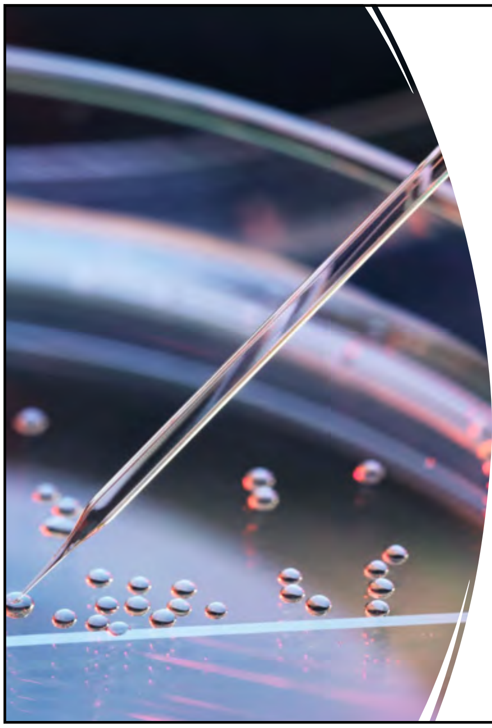


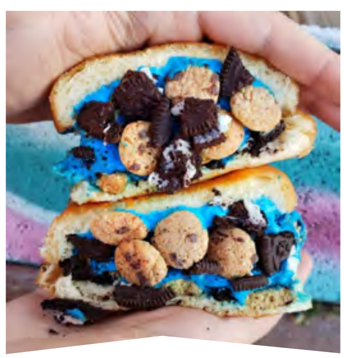
Microstructure and Flavor Release; some novel approaches

S.A. Rankin, Ph.D.

Oct, 2023

Frozen Dessert Center Conference

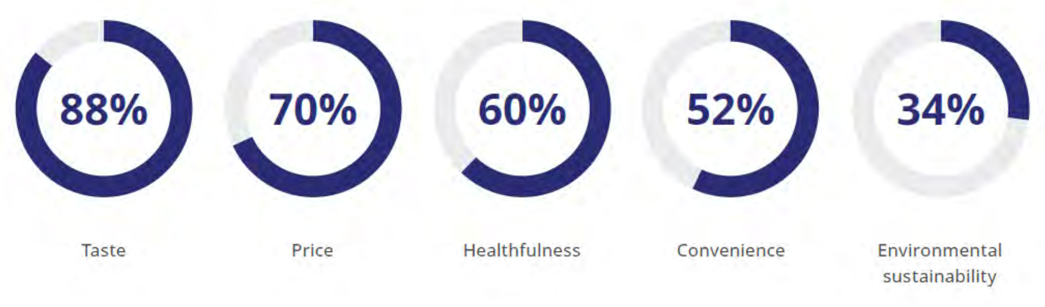
1



Relevance?

2

Relevance?



https://www.taste-institute.com/en/resources/blog/importance-of-taste-in-product-development

3

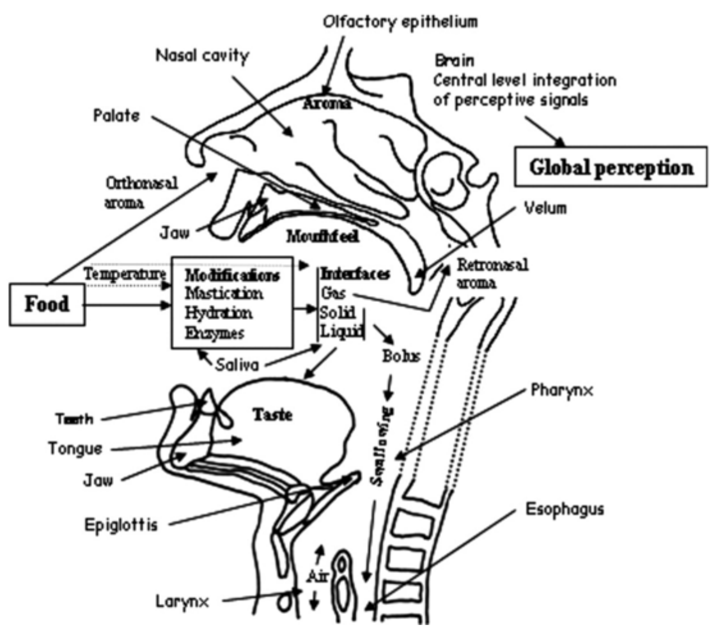
Relevance?

The release of flavor compounds from food, and their delivery to the receptors located in the mouth and nose (Fig. 1), is acknowledged as one of the ***key factors determining the perceived flavor quality*** *of foods.*

Salles et al, 2011

4

Fig 1

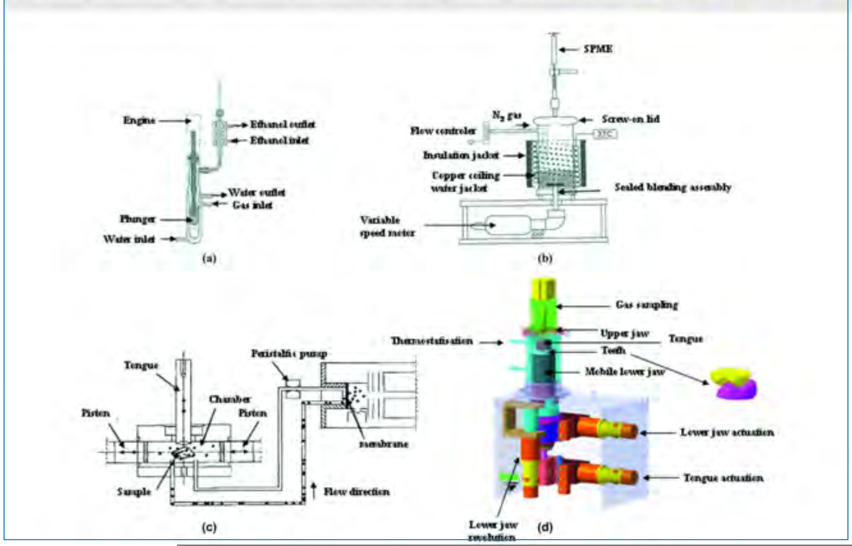


5

Relationship between flavor release and perception…has been extensively studied but is very difficult to establish.

Figure 2 of 2

Figure 2 Examples of devices developed to reproduce human mouth functions. (a): van Ruth and Roozen (2000); (b): Deibler et al. (2001); (c): Jensen et al. (2003); (d): Salles et al. (2007).



Salles et al., 2011

6

Flavor defined

The flavor perception we derive from eating a food product is determined by the ***nature and quantity*** *of the* ***flavor components****, the* ***availability*** *of these components to the sensory system as a function of time, and the mechanisms and* ***strategies of perception*** *and scaling which determine the flavor quality and intensity over time ….*

Overbosch et at., 1991

7

Strong sense of convention

Flavor
- Vanilla
- Chocolate
- Strawberry
- Dairy

- Texture/mouthfeel
- Melt
- Composition
- Color
- Etc.

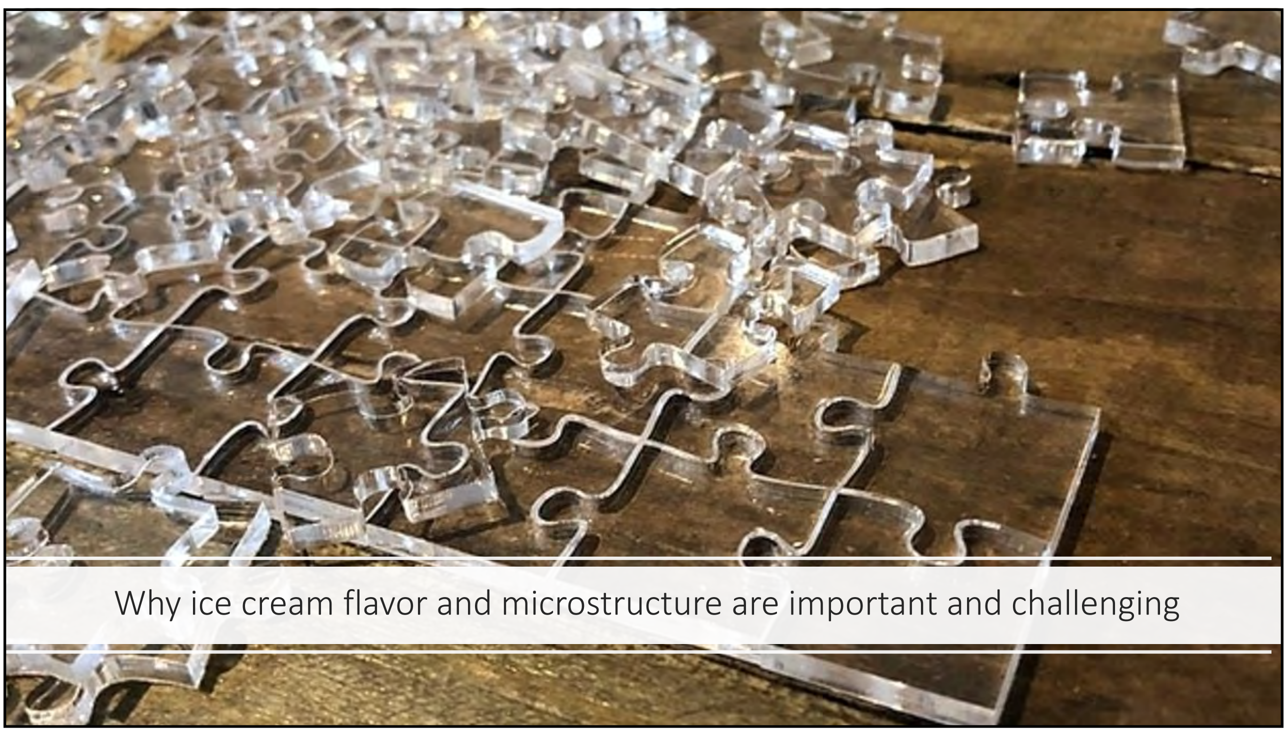
8

A few key points

IC structure is complex, so are flavors – this is trouble

Some practical principles –> novel approaches

9



Why ice cream flavor and microstructure are important and challenging

10

Complex Ingredients

Ice Cream And Frozen Dairy Dessert Application Monograph, USDEC

Nutrition Facts
Serving Size 1/2 Cup (69g)
Servings Per Container 16

Amount Per Serving	
Calories 140	Calories from Fat 60
	% Daily Value*
Total Fat 7g	**11%**
Saturated Fat 4.5g	**23%**
Trans Fat 0g	
Cholesterol 30mg	**10%**
Sodium 65mg	**3%**
Total Carbohydrate 17g	**6%**
Dietary Fiber 0g	**0%**
Sugars 14g	
Protein 2g	
Vitamin A 2%	• Vitamin C 0%
Calcium 8%	• Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

		2,000	2,500
	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

INGREDIENTS: MILK, CREAM, SUGAR, CORN SYRUP, DESSERT SOLIDS (WHEY, WHEY SOLIDS, NONFAT DRY MILK, AND EDIBLE SALTS (SODIUM CARBONATE, SODIUM CITRATE, DIPOTASSIUM PHOSPHATE)), STABILIZER (MONO & DIGLYCERIDES, CELLULOSE GUM, GUAR GUM, LOCUST BEAN GUM, POLYSORBATE 80, CARRAGEENAN, DISODIUM PHOSPHATE, CALCIUM SULFATE), NATURAL AND/OR ARTIFICIAL FLAVORS AND ANNATTO.

U.S. DAIRY INGREDIENTS: COMPOSITIONS AND ADVANTAGES IN FROZEN DESSERTS

INGREDIENT	PROTEIN (%)	LACTOSE (%)	FAT (%)	ASH (%)	MOISTURE (%)	APPLICATION ADVANTAGE
Skim Milk Powder	34 to 37	49 to 52	0 to 1	8 to 9	3 to 4	Stable source of dairy solids; cost-effective
Evaporated, Condensed Skim Milk	7	11	0	1	80	Cost-effective source of dairy solids
Milk Protein Concentrate	42 to 85	8 to 50	1 to 2	8 to 10	< 5	Common source for milk protein fortification
Milk Protein Isolate	> 90	0.5	< 2	< 8	5	Source of highly concentrated milk protein
Casein*	80 to 85	0.5	1	4 to 8	5	Concentrated casein protein with various functional properties
Sweet Whey Powder	10	>70	1	9	5	Cost-effective source of milk solids
Whey Protein Concentrate	34 to 80	10 to 50	4 to 6	3 to 7	4	Highly functional, nutritional protein
Whey Protein Isolate	> 90	<1	<1	3	4	Concentrated source of highly functional, nutritional protein
Whey Permeate	2 to 6	70 to 85	<1	10	4	Cost-effective source of milk solids
Lactose	< 1	95+	< 0.1	< 0.5	5	Source of milk sugar: Contributes total solids and freezing point
Whey Protein Phospholipid Concentrate	> 50	1 to 5	> 12	< 8	< 6	Source of protein and milk phospholipid for emulsification and foaming

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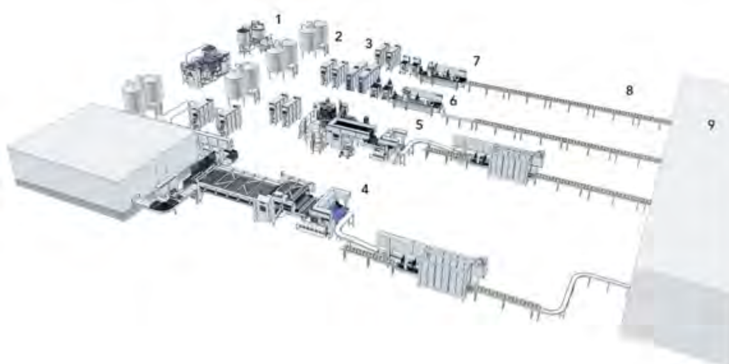
Complex processing

Fig.19.10

Ice cream plant for production of 5.000-10.000 l/h of various types of ice cream.

1. Mix preparation
2. Ageing tanks
3. Continuous freezers
4. Bulk filling
5. Cone filling
6. Moulding
7. Extrusion
8. Cartoning



TetraPak, 2023

12

Complex Material

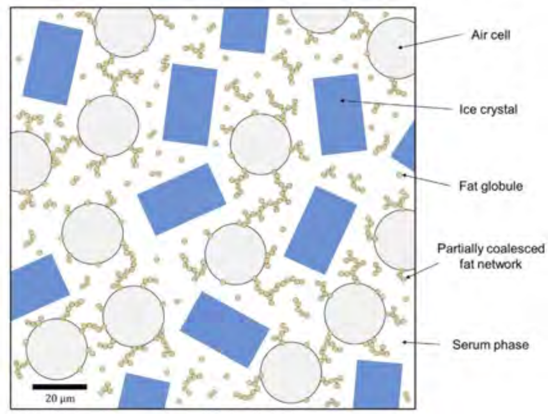


FIGURE 2 Schematic illustration of typical ice cream microstructure

VanWees et al., 2021

13

Variation in finished products - survey

United States commercial ice cream products . . .

Table 2–Compositional and structural attributes of commercial ice cream samples.

Components	Mean and standard error	Range
Mean ice crystal size (μm)	48.1 ± 2.3	26.3–67.1
Mean air cell size (μm)	29.9 ± 1.5	17.1–39.5
Percent total fat (%)	8.6 ± 1.0	0.01–14.3
Percent fat destabilization (%)	21.9 ± 3.88	2.60–55.3
Overrun (%)	75.0 ± 6.5	21.7–119
Density of ice cream (g/L)	$649 \pm .03$	509–904
Density of ice cream mix (kg/L)	$1.10 \pm .01$	1.07–1.16
Drip-through rate (g/min)	1.07 ± 0.15	0.13–1.88
Total solids (%)	38.3 ± 0.67	31.1–42.6

Table 3–Mean values of compositional and structural analyses and the corresponding Student's *t*-test of significant differences at $P < 0.05$ for the 18 samples analyzed.

Sample code	Mean ice crystal size (μm)	Mean air cell size (μm)	Total fat (%)	Fat destabilization (%)	Overrun (%)	Ice cream mix density (kg/L)*	Drip-through rate (g/min)	Total Solids (%)
106	46.3 ± 5.0^{cde}	30.4 ± 2.0^{bcde}	10.3 ± 0.1^{def}	15.1 ± 1.7^{gh}	95.1 ± 1.1^{bc}	1.10^{ef}	1.20 ± 0.14^{d}	40.2 ± 0.6^{bc}
159	26.3 ± 1.6^{h}	22.2 ± 1.1^{fgh}	0.1 ± 0.1^{j}	11.0 ± 4.1^{hi}	96.0 ± 2.9^{b}	1.16^{a}	1.85 ± 0.11^{a}	36.9 ± 0.2^{fg}
171	53.0 ± 2.3^{b}	30.1 ± 4.1^{cde}	13.1 ± 0.3^{b}	20.4 ± 1.6^{fg}	67.0 ± 2.4^{g}	1.09^{g}	0.33 ± 0.05^{gh}	39.1 ± 0.3^{cd}
215	53.5 ± 1.3^{b}	24.6 ± 0.5^{defg}	9.0 ± 0.5^{g}	7.8 ± 1.0^{ijk}	91.8 ± 2.6^{cd}	1.09^{g}	0.67 ± 0.06^{e}	36.4 ± 0.1^{g}
286	40.0 ± 5.1^{fg}	28.0 ± 5.2^{defg}	0.2 ± 0.1^{j}	26.0 ± 2.7^{ef}	68.4 ± 2.7^{g}	1.16^{a}	1.72 ± 0.13^{ab}	34.6 ± 0.1^{h}
293	50.8 ± 1.4^{bcd}	26.4 ± 1.3^{efg}	9.4 ± 0.4^{fg}	55.3 ± 5.9^{a}	83.4 ± 4.3^{ef}	1.13^{b}	0.24 ± 0.04^{gh}	42.6 ± 3.2^{a}
313	61.9 ± 4.9^{a}	27.1 ± 2.8^{efg}	14.3 ± 0.6^{a}	6.0 ± 1.6^{ijk}	26.9 ± 1.1^{i}	1.09^{g}	1.40 ± 0.32^{cd}	40.9 ± 0.4^{b}
423	51.7 ± 1.9^{bc}	36.5 ± 1.7^{abc}	7.6 ± 1.0^{h}	2.6 ± 0.2^{k}	51.0 ± 1.5^{h}	1.09^{g}	1.69 ± 0.08^{ab}	35.9 ± 0.2^{gh}
472	41.3 ± 1.1^{efg}	38.2 ± 1.7^{a}	5.7 ± 0.4^{i}	30.6 ± 1.0^{de}	119 ± 4.0^{a}	1.12^{c}	1.26 ± 0.09^{d}	35.8 ± 0.3^{gh}
559	42.8 ± 0.6^{efg}	37.4 ± 3.7^{a}	$*11.5^{c}$	45.0 ± 3.4^{bc}	21.7 ± 1.1^{j}	1.10^{e}	0.20 ± 0.20^{h}	40.7 ± 0.6^{b}
603	53.6 ± 1.2^{b}	26.0 ± 1.2^{efg}	11.0 ± 0.1^{cd}	21.9 ± 7.5^{f}	80.3 ± 1.9^{f}	1.11^{ef}	0.26 ± 0.03^{gh}	38.6 ± 0.2^{de}
638	40.9 ± 2.6^{egh}	36.6 ± 2.3^{ab}	9.9 ± 0.2^{efg}	5.0 ± 0.8^{jk}	97.5 ± 1.7^{b}	1.11^{d}	1.72 ± 0.07^{ab}	40.9 ± 0.4^{b}
652	45.8 ± 3.2^{de}	21.9 ± 1.8^{gh}	10.8 ± 1.7^{cde}	7.9 ± 2.3^{ijk}	72.2 ± 2.2^{g}	1.10^{e}	0.44 ± 0.05^{fg}	39.2 ± 0.1^{cd}
727	43.9 ± 2.6^{ef}	28.5 ± 1.6^{def}	5.5 ± 0.2^{i}	32.3 ± 2.8^{d}	89.6 ± 3.2^{d}	1.11^{c}	0.64 ± 0.07^{ef}	37.8 ± 0.3^{ef}
824	45.7 ± 2.9^{de}	34.2 ± 4.9^{abcd}	5.9 ± 0.2^{i}	47.0 ± 1.7^{b}	95.4 ± 0.7^{bc}	1.09^{f}	0.89 ± 0.16^{e}	$*38.0^{def}$
880	67.1 ± 3.9^{a}	39.5 ± 1.8^{a}	14.0 ± 0.6^{ab}	40.4 ± 7.3^{c}	23.7 ± 0.6^{ij}	1.10^{ef}	0.13 ± 0.02^{h}	40.6 ± 0.2^{b}
913	66.3 ± 3.1^{a}	30.1 ± 3.6^{cde}	5.2 ± 0.6^{i}	10.0 ± 0.6^{hij}	85.7 ± 2.1^{e}	1.07^{h}	1.53 ± 0.07^{bc}	31.1 ± 0.1^{i}
957	37.9 ± 2.5^{g}	17.1 ± 1.6^{h}	11.5 ± 0.5^{c}	9.0 ± 3.6^{ij}	83.3 ± 1.6^{ef}	1.11^{d}	1.86 ± 0.31^{a}	41.0 ± 0.3^{b}

[*] Denotes significant differences within ± 0.04.
[a,b,c,d,e,f,g,h,i,j,] Means not sharing the same letter are significantly different ($\alpha = 0.05$).

Warren and Hartel, 2014

14

United States commercial

Table 2–Compositional and [cut off]

Components	Range
Mean ice crystal size (μm)	26.3–67.1
Mean air cell size (μm)	17.1–39.5
Percent total fat (%)	0.01–14.3
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Total solids (%)	31.1–42.6

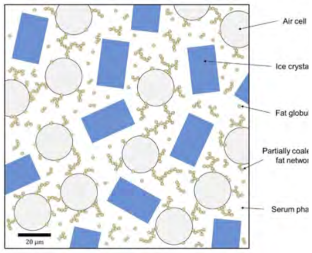
Warren and Hartel, 2014

15

Ice cream complexity II

https://tarateaspoon.com/24-exciting-ice-cream-flavors-you-can-make-tara-teaspoon/

16

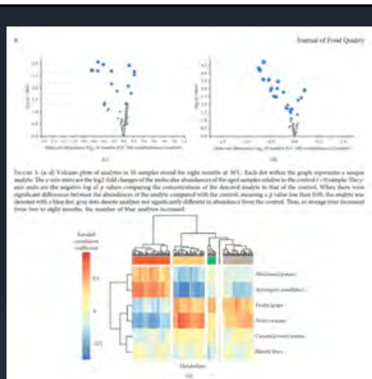


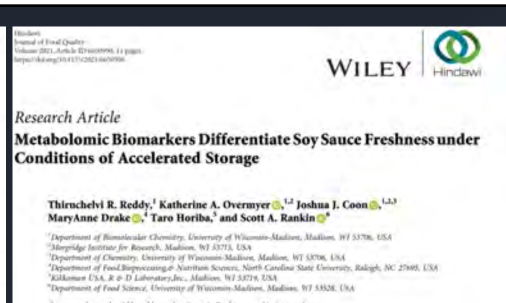
URE 2 Schematic illustration of typical ice cream microstructure

During consumption?

In the case of semi-solids, the main change in food properties is the reduction of viscosity due to shearing forces, temperature change, and dilution or chemical breakdown induced by saliva.

17





Journal of Food Quality

WILEY | Hindawi

Research Article

Metabolomic Biomarkers Differentiate Soy Sauce Freshness under Conditions of Accelerated Storage

Thiruchelvi R. Reddy,[1] Katherine A. Overmyer,[1,2] Joshua J. Coon,[1,2,3] MaryAnne Drake,[4] Taro Horiba,[5] and Scott A. Rankin[6]

Correspondence should be addressed to Scott A. Rankin

Linking chemical, flavor responses

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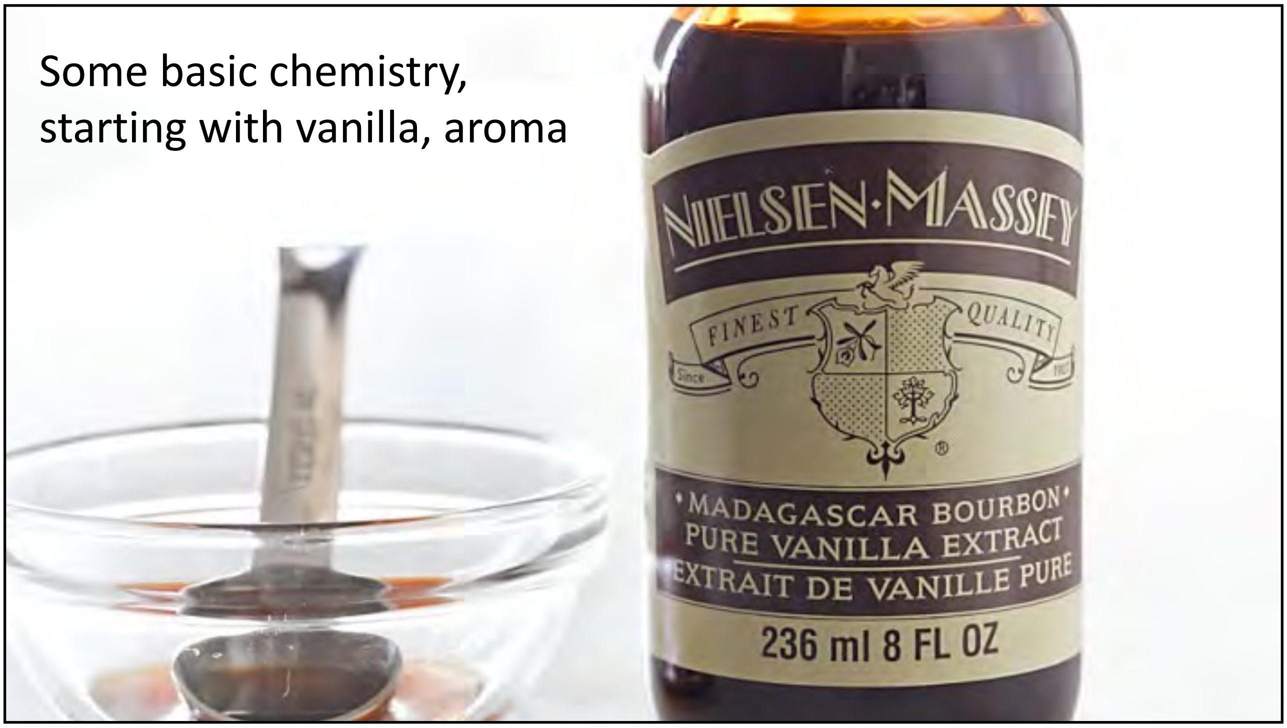
Some basic chemistry, starting with vanilla, aroma



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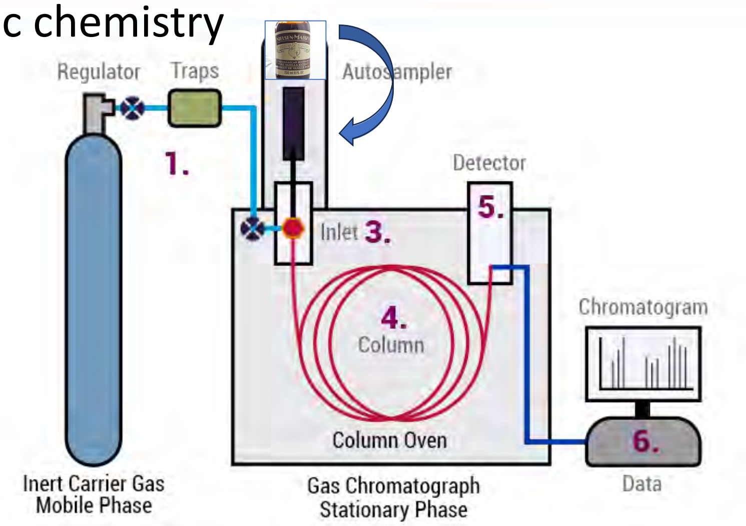
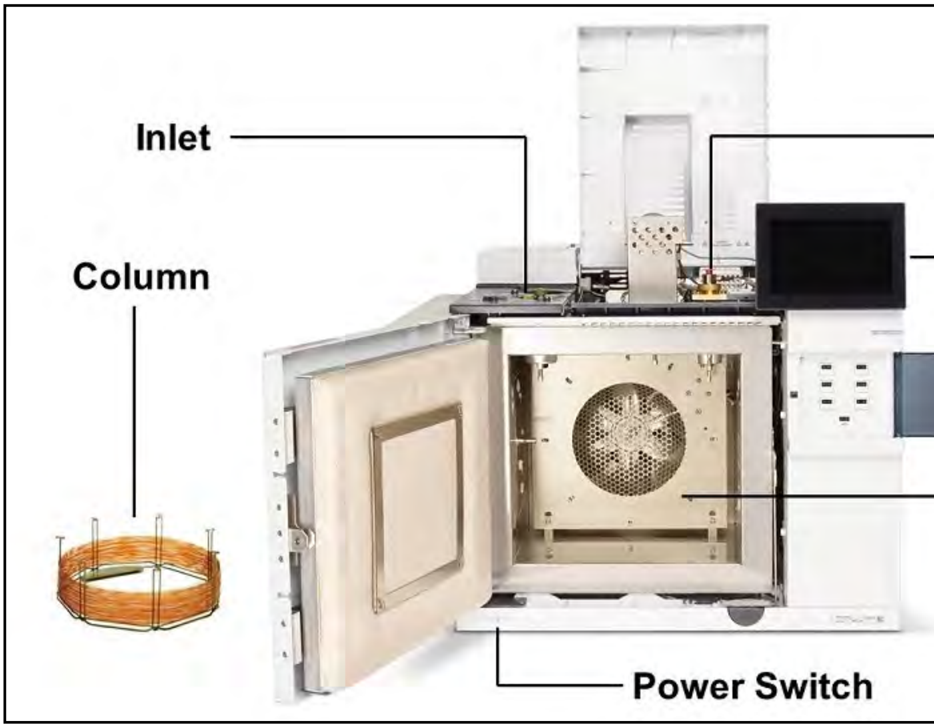
Some basic chemistry



https://blog.perkinelmer.com/posts/gas-chromatography-explained-what-it-is-and-how-it-works/

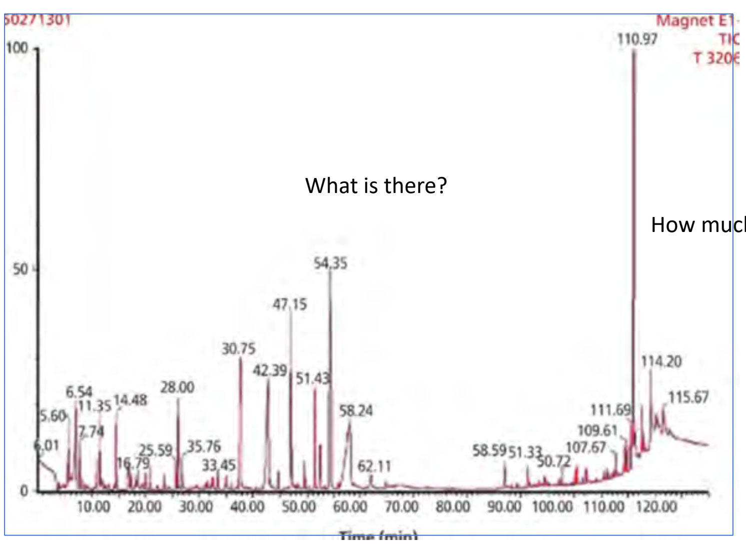
20



https://www.agilent.com/en/product/gas-chromatography/what-is-gas-chromatography

21

Chemical basis of flavor (aroma)



What is there?

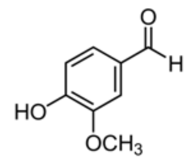
How much is there?

https://www.chromatographyonline.com/view/flavour-and-fragrance-analysis-wondrous-vanilla

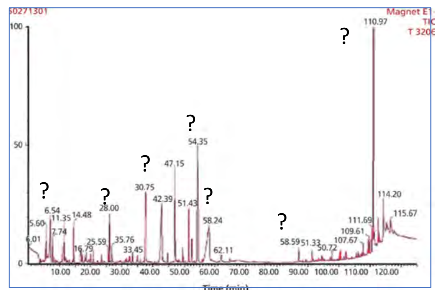
22

What do we know, don't know at this point?

- Compound ID, e.g., 4-hydroxy-3-methoxybenzaldehyde
- Quantity, e.g., 100 mg/kg



- Is there enough to make an *impact*?

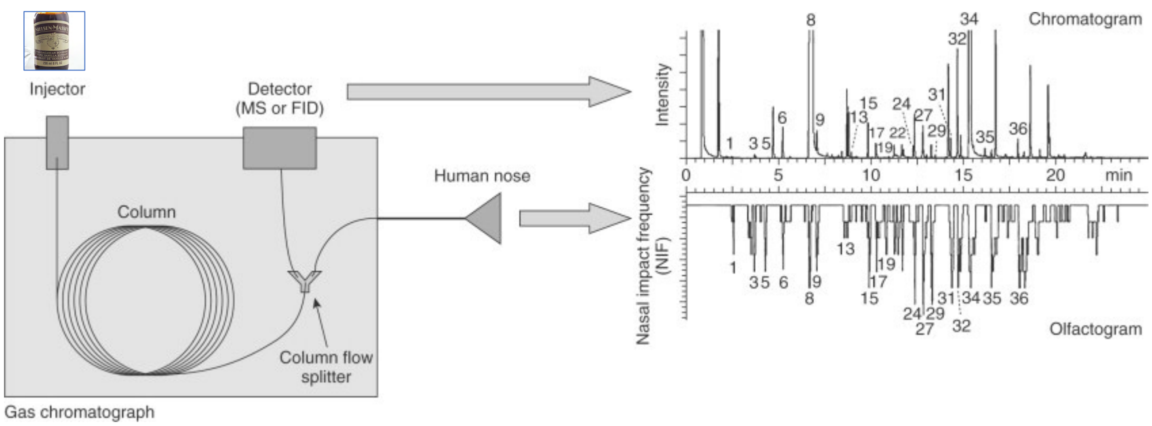


23

https://odourobservatory.org/measuring-odour/gas-chromatography-olfactometry/

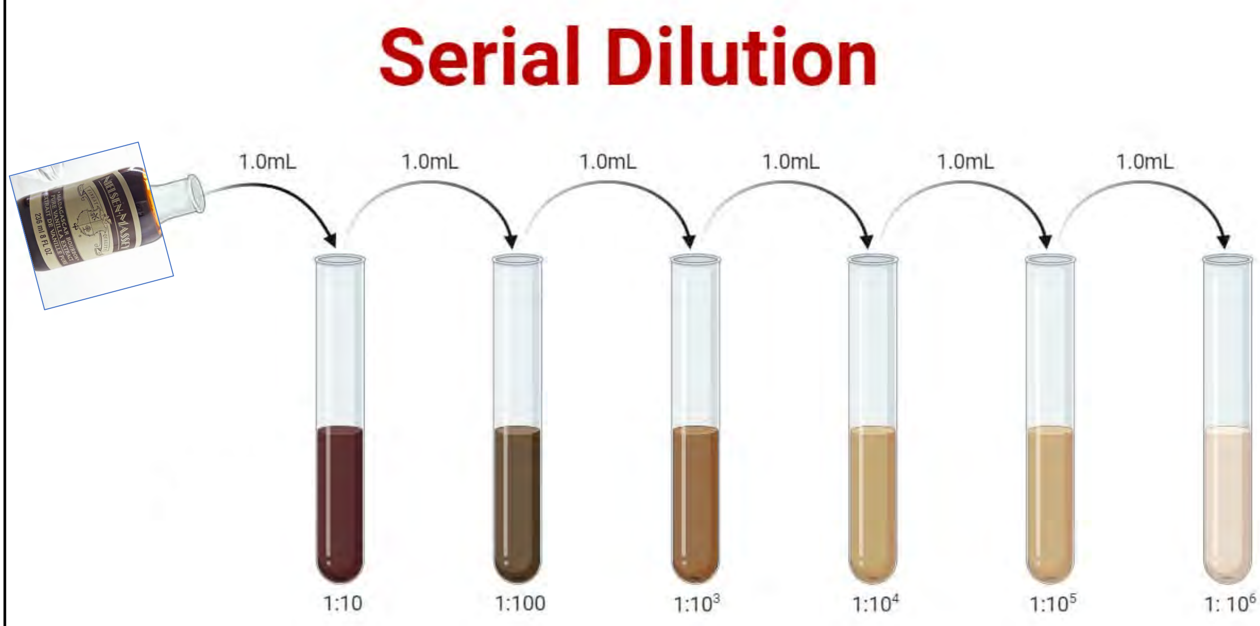
24

Human detector



https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/olfactometry

25



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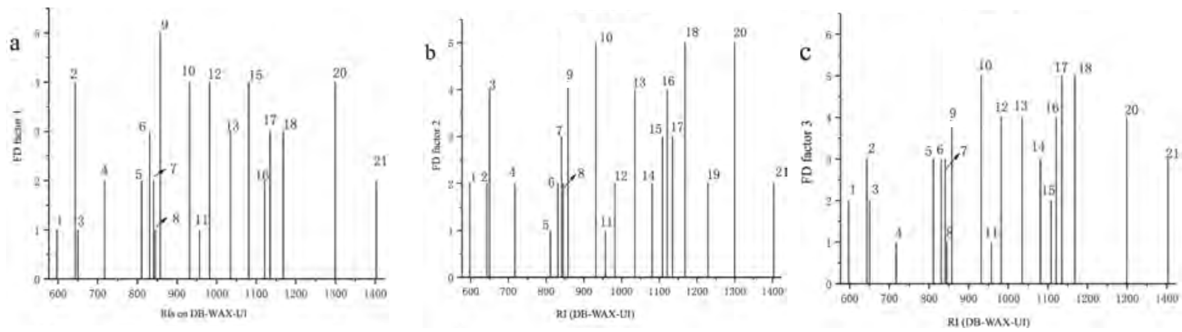
1/10 1/100 1/1000



Lin et al., 2019

27

Flavor Impact compound: distinct aroma recognition

604 M. TAKAHASHI *et al.*

Table 2. Odor-Active (FD ≧ 25) Volatiles in Tahitian Cured Vanilla Beans

Odorant[a]	Odor quality[b]	RI	FD factor	Identification mode[c]
Acetic acid	acidic, sour	1430	625	MS, RI, GC-O
2-Methylbutanoic acid	buttery, cheese-like	1691	25	MS, RI, GC-O
3-Methylbutanoic acid	buttery, cheese-like	1693	25	MS, RI, GC-O
3-Methylnonane-2,4-dione[d]	floral, medicinal	1739	25	RI, GC-O
(2*E*,4*E*)-deca-2,4-dienal[d]	oily	1816	25	RI, GC-O
β-Damascenone	raisin-like, fruity	1826	25	MS, RI, GC-O
Guaiacol	phenolic, medicinal	1863	125	MS, RI, GC-O
Anisaldehyde	anise-like, raspberry-like	2052	1953125	MS, RI, GC-O
Methyl (*E*)-cinnamate	fruity, cinnamon-like	2083	125	MS, RI, GC-O
p-Cresol	fecal	2084	125	MS, RI, GC-O
Anisyl acetate	floral, raisin-like	2132	15625	MS, RI, GC-O
Ethyl (*E*)-cinnamate	cinnamon-like, fruity	2145	125	MS, RI, GC-O
Unknown	cooked, meaty	2167	25	GC-O
Eugenol	clove-like, spicy	2169	125	MS, RI, GC-O
4-Vinylguaiacol	phenolic, spicy	2207	25	MS, RI, GC-O
Anisyl alcohol	floral, anise-like	2276	390625	MS, RI, GC-O
Phenylacetic acid	buttery, honey-like	2512	125	MS, RI, GC-O
Vanillin	sweet, vanilla-like	2604	1953125	MS, RI, GC-O
3-Phenylpropanoic acid	metallic, buttery	2672	125	MS, RI, GC-O
Isovanillin	phenolic, medicinal	2718	125	MS, RI, GC-O

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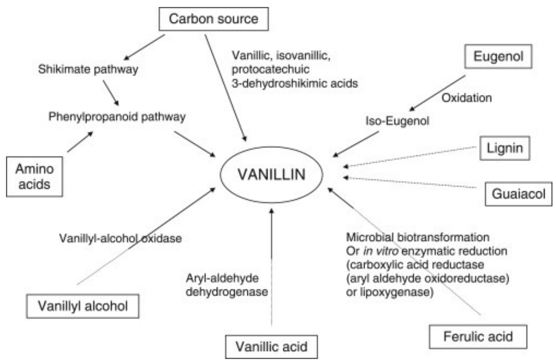
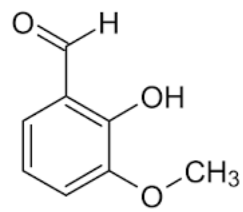
Flavor Chemistry reveals

- What chemicals exist
- How much is there (concentration)
- Most impactful compounds (in extract)





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Flavor Release

…is the process whereby flavor molecules move out of a particular molecular environment within a food and into the surrounding saliva or vapor phase (McNulty, 1987; Overbosch et al., 1991)

The most important aspect of …is that aroma molecules leave the bolus and arrive at the olfactory epithelium in the nose where they can be sensed (R. Linforth, A. Taylor, in Flavour in Food, 2006).

Flavor release (or lack thereof) is also the basis of some masking agents/technologies that prevent or slow the release of aroma compounds thus decreasing their perception (Rankin, 2023)

30

Thermodynamic and kinetic parameters control the flavour release from foods. They depend not only on the composition but also on the physical state of the matrix: liquid systems (water or lipids) are relatively simple to study and are useful to understand physical partitioning and release; when moving to viscous or solid systems, more parameters are involved such as diffusion; ***real foods are often even more complex****, with* ***heterogeneous composition and structure*** *and must be studied at different levels (Voilley and Souchon, 2006)*

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Mass Transfer

…operations are concerned with the transfer of matter from one stream to another. In many processes a change in phase may also be involved.

Table 13.1. Some mass transfer process involved in food processing.

Operation	Material transferred	Phase change	Examples and comments
Dehydration	Water	From liquid or solid to vapour	Many drying methods are available. Quality is improved by minimizing the loss of volatile components
Solvent extraction	Oil	From solid matrix to organic liquid	Extraction of oils and fats from animal plant or microbial sources
Leaching Sulphiting	Soluble components Sulphur dioxide	From solid matrix to aqueous solvent From gas to solid or liquid media	Tea, coffee, sugar extraction; plant protein Sulphiting may also be done using solutions of sodium bisulphite or metabisulphite
Smoking	Phenolic components	From vapour to solid matrix	Preservation of foods by use of antimicrobial agents
Distillation	Alcohol and other volatile components	From liquid to vapour	Recovery of alcohol from a fermentation broth
Packaging	Gases and vapours	From the external environment into the package	Prevention of microbial and oxidation reactions
Membrane processing	Water, and dissolved solutes	From liquid to liquid through a semipermeable membrane	Reverse osmosis for concentrating liquids. Ultrafiltration for concentrating proteins
Oxygen transfer	Oxygen	From gas to liquid	Aerobic fermentation processes in which oxygen is consumed from the solution by micro-organisms
Ion exchange	Metal ions, proteins	From solution to a solid phase	Elution involves the reversal of the adsorption process

Lewis, 1996

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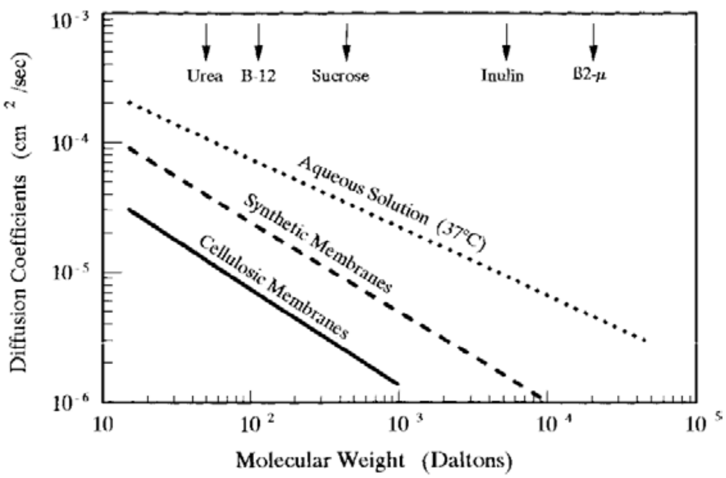
Diffusivity



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Effect of lipid type, phase

TABLE 1
Comparison of Dynamically Released Quantities of Flavor (μg, after 30 s) from Emulsions Comprising Different Lipid Phases[a]

		Lipids used in emulsions					
		Liquid lipids[b]				Solid lipids[b]	
	Water[c]	Triacetin	Tributyrin	Miglyol[d]	Butter oil[d]	Trimyristin[d]	Tripalmitin
Diacetyl	$1.22^{a} \pm 0.06$	$2.02^{b} \pm 0.01$	$2.28^{c} \pm 0.14$	$1.50^{d} \pm 0.11$	$5.95^{e} \pm 0.07$	$2.26^{c} \pm 0.17$	$1.75^{f} \pm 0.15$
Isobutyl acetate	$0.81^{a} \pm 0.01$	$0.70^{b} \pm 0.03$	$0.20^{c} \pm 0.00$	$0.25^{d} \pm 0.00$	$0.33^{e} \pm 0.02$	$0.31^{e} \pm 0.01$	$0.31^{e} \pm 0.03$
Ethyl 2-methylbutyrate	$1.22^{a} \pm 0.01$	$0.91^{b} \pm 0.04$	$0.15^{c} \pm 0.01$	$0.17^{c} \pm 0.01$	$0.25^{d} \pm 0.01$	$0.21^{c,d} \pm 0.01$	$0.35^{e} \pm 0.04$
(*Z*)-3-Hexenyl acetate	$6.22^{a} \pm 0.22$	$3.25^{b} \pm 0.15$	$0.33^{c} \pm 0.02$	$0.48^{c} \pm 0.01$	$0.69^{d} \pm 0.01$	$0.68^{d} \pm 0.02$	$1.48^{e} \pm 0.11$
2,3-Dimethylpyrazine	$0.28^{a} \pm 0.00$	$0.23^{b} \pm 0.03$	$0.30^{a,c} \pm 0.05$	$0.27^{a,b} \pm 0.01$	$0.31^{a,c} \pm 0.00$	$0.34^{c} \pm 0.01$	$0.24^{b} \pm 0.00$
(*Z*)-3-Hexenol	$0.74^{a,b} \pm 0.01$	$0.73^{a} \pm 0.06$	$0.58^{c} \pm 0.07$	$0.60^{c} \pm 0.00$	$0.80^{b,d} \pm 0.01$	$0.82^{d} \pm 0.01$	$0.61^{c} \pm 0.01$
2-Isobutylthiazole	$4.50^{a} \pm 0.05$	$2.80^{b} \pm 0.21$	$0.58^{c} \pm 0.05$	$0.67^{c} \pm 0.00$	$0.95^{d} \pm 0.02$	$0.93^{d} \pm 0.03$	$1.93^{e} \pm 0.14$
Furfuryl acetate	$1.23^{a} \pm 0.07$	$0.98^{b} \pm 0.10$	$0.35^{c} \pm 0.05$	$0.52^{d} \pm 0.01$	$0.71^{e} \pm 0.03$	$0.69^{e} \pm 0.02$	$0.79^{e} \pm 0.05$
Linalool	$1.98^{a} \pm 0.10$	$1.13^{b} \pm 0.15$	$0.15^{c} \pm 0.02$	$0.18^{c} \pm 0.00$	$0.26^{c} \pm 0.01$	$0.27^{c} \pm 0.01$	$0.42^{d} \pm 0.01$
2-Pentylpyridine	$2.36^{a} \pm 0.14$	$0.75^{b} \pm 0.28$	$0.21^{c} \pm 0.06$	$0.24^{c} \pm 0.09$	$0.22^{c} \pm 0.03$	$0.19^{c} \pm 0.02$	$0.30^{c} \pm 0.04$
D-Carvone	$1.31^{a} \pm 0.01$	$0.64^{b} \pm 0.13$	$0.11^{c} \pm 0.02$	$0.14^{c} \pm 0.01$	$0.17^{c} \pm 0.01$	$0.18^{c} \pm 0.01$	$0.46^{d} \pm 0.04$
β-Damascenone	$4.79^{a} \pm 0.43$	$0.89^{b} \pm 0.28$	$0.20^{c} \pm 0.06$	$0.13^{c} \pm 0.04$	$0.11^{c} \pm 0.01$	$0.13^{c} \pm 0.02$	$0.34^{c} \pm 004$
γ-Nonalactone	$0.11^{a} \pm 0.02$	$0.07^{b} \pm 0.03$	$0.05^{b} \pm 0.01$	$0.04^{b} \pm 0.00$	$0.05^{b} \pm 0.00$	$0.07^{b} \pm 0.01$	$0.05^{b} \pm 0.01$
CV[e] (%)	4.2	15.1	13.8	8.3	4.7	6.0	8.0
Log*P*[f]		0.36	3.31	10.7[g]		18.0	20.9
Molarity (mol L^{-1})		0.27	0.17	0.09	0.06	0.06	0.05

[a]Values with different roman letters within a line are significantly different [ANOVA and Duncan's multiple range (DMR) test, $P < 0.05$].
[b]At 22°C.
[c]Adapted from Reference 13.
[d]Adapted from Reference 4.
[e]Average CV.

Rabe et al., 2003

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Effect of lipid type, phase

TABLE 1
Comparison of Dynamically Released Quantities of Flavor (µg, after 30 s) from Emulsions Comprising Different Lipid Phases[a]

		Lipids used in emulsions					
		Liquid lipids[b]				Solid lipids[b]	
	Water[c]	Triacetin	Tributyrin	Miglyol[d]	Butter oil[d]	Trimyristin[d]	Tripalmitin
Diacetyl	$1.22^a \pm 0.06$	$2.02^b \pm 0.01$	$2.28^c \pm 0.14$	$1.50^d \pm 0.11$	$5.95^e \pm 0.07$	$2.26^c \pm 0.17$	$1.75^f \pm 0.15$

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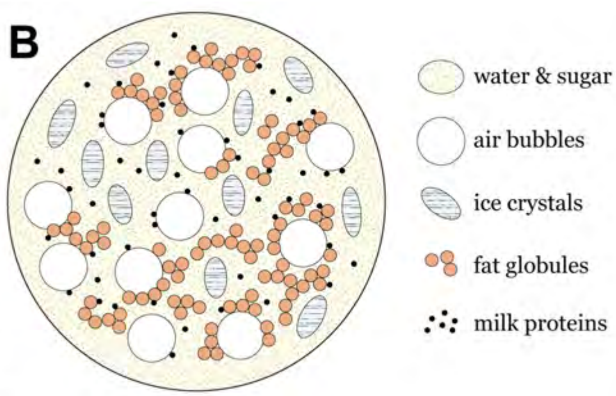
Unraveling flavorant/microstructure physics



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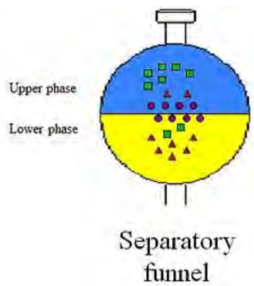
Partitioning



■ $K_D > 1$

● $K_D = 1$

▲ $K_D < 1$

$$K_D = \frac{[A]_{upper}}{[A]_{lower}}$$

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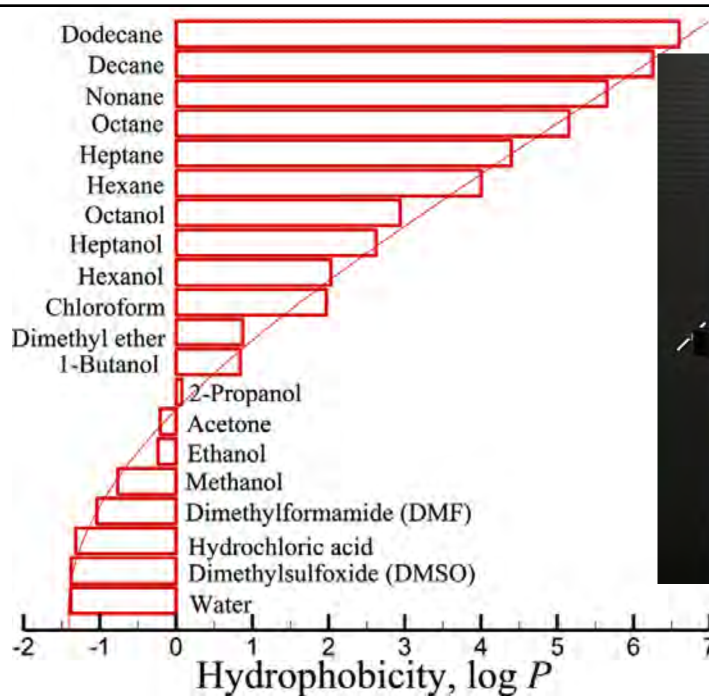

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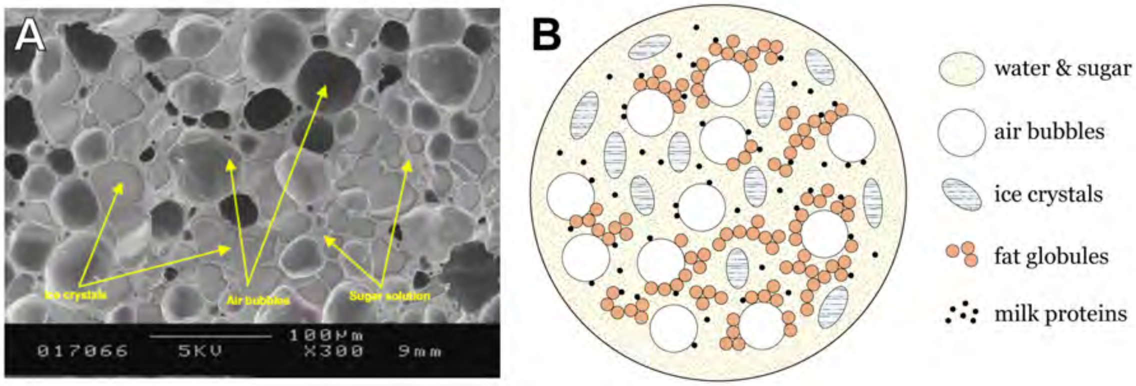
Matrix/structure effects



https://scienceandfooducla.wordpress.com/2013/03/05/homemade-ice-cream/

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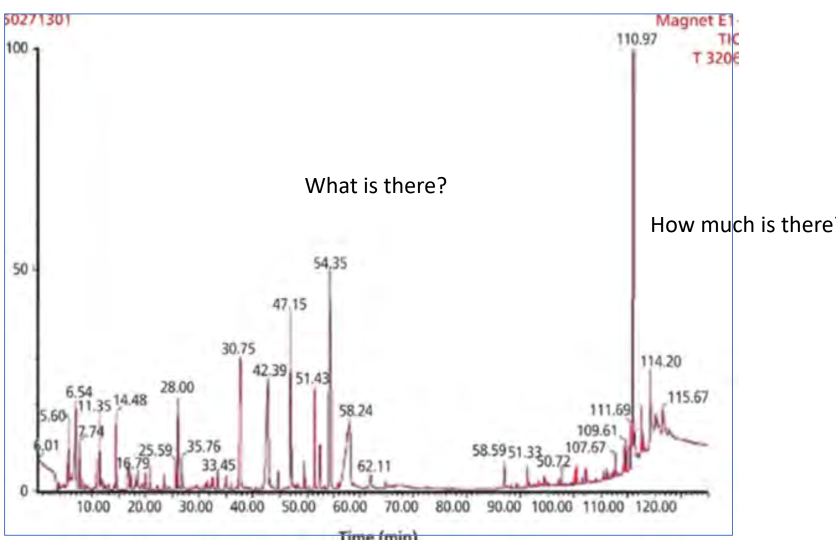
Chemical basis of flavor (aroma)



https://www.chromatographyonline.com/view/flavour-and-fragrance-analysis-wondrous-vanilla

40

Flavor Impact compound: not so distinct aroma

604 M. TAKAHASHI *et al.*

Table 2. Odor-Active (FD ≧ 25) Volatiles in Tahitian Cured Vanilla Beans

Odorant[a]	Odor quality[b]	RI	FD factor	Identification mode[c]
Acetic acid	acidic, sour	1430	625	MS, RI, GC-O
2-Methylbutanoic acid	buttery, cheese-like	1691	25	MS, RI, GC-O
3-Methylbutanoic acid	buttery, cheese-like	1693	25	MS, RI, GC-O
3-Methylnonane-2,4-dione[d]	floral, medicinal	1739	25	RI, GC-O
(2*E*,4*E*)-deca-2,4-dienal[d]	oily	1816	25	RI, GC-O
β-Damascenone	raisin-like, fruity	1826	25	MS, RI, GC-O
Guaiacol	phenolic, medicinal	1863	125	MS, RI, GC-O
Anisaldehyde	anise-like, raspberry-like	2052	1953125	MS, RI, GC-O
Methyl (*E*)-cinnamate	fruity, cinnamon-like	2083	125	MS, RI, GC-O
p-Cresol	fecal	2084	125	MS, RI, GC-O
Anisyl acetate	floral, raisin-like	2132	15625	MS, RI, GC-O
Ethyl (*E*)-cinnamate	cinnamon-like, fruity	2145	125	MS, RI, GC-O
Unknown	cooked, meaty	2167	25	GC-O
Eugenol	clove-like, spicy	2169	125	MS, RI, GC-O
4-Vinylguaiacol	phenolic, spicy	2207	25	MS, RI, GC-O
Anisyl alcohol	floral, anise-like	2276	390625	MS, RI, GC-O
Phenylacetic acid	buttery, honey-like	2512	125	MS, RI, GC-O
Vanillin	sweet, vanilla-like	2604	1953125	MS, RI, GC-O
3-Phenylpropanoic acid	metallic, buttery	2672	125	MS, RI, GC-O
Isovanillin	phenolic, medicinal	2718	125	MS, RI, GC-O

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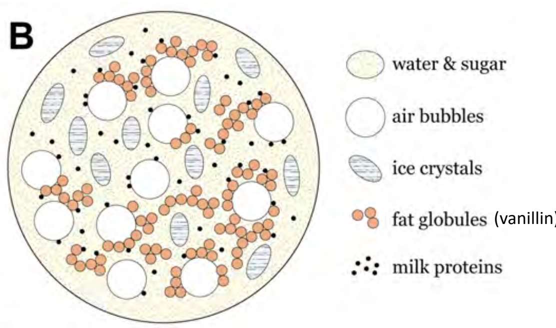
3.2.12 LogP Vanillin

log Kow = 1.37

Hansch, C., Leo, A., D. Hoekman. Exploring QSAR - Hydrophobic, Electronic, and Steric Constants. Washington, DC: American Chemical Society., 1995., p. 42

▸ Hazardous Substances Data Bank (HSDB)

25:1



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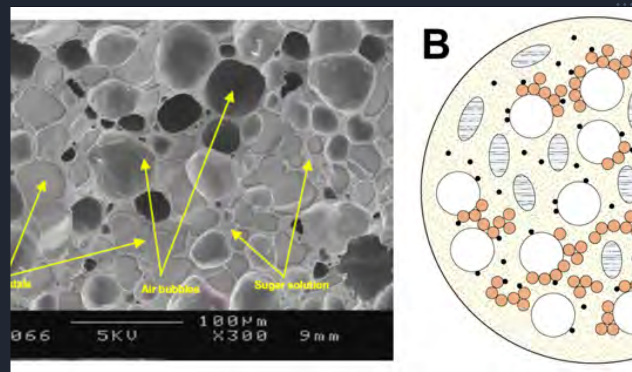

Vanilla: complex chemistry, diffusivity, mass transfer, matrix/composition…

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Alter matrix to improve flavor….?

No consistent and complete set of data is available in the literature for comprehensive model validation. In particular, the reported experimental data lack information on the temperature dependence of the diffusion coefficient in the polymer membrane and on the average number of unit cell in the foam layer. This data is critically important for the development of reliable foam diffusion models.

Pilon, 2000; Georgia Institute of Technology,

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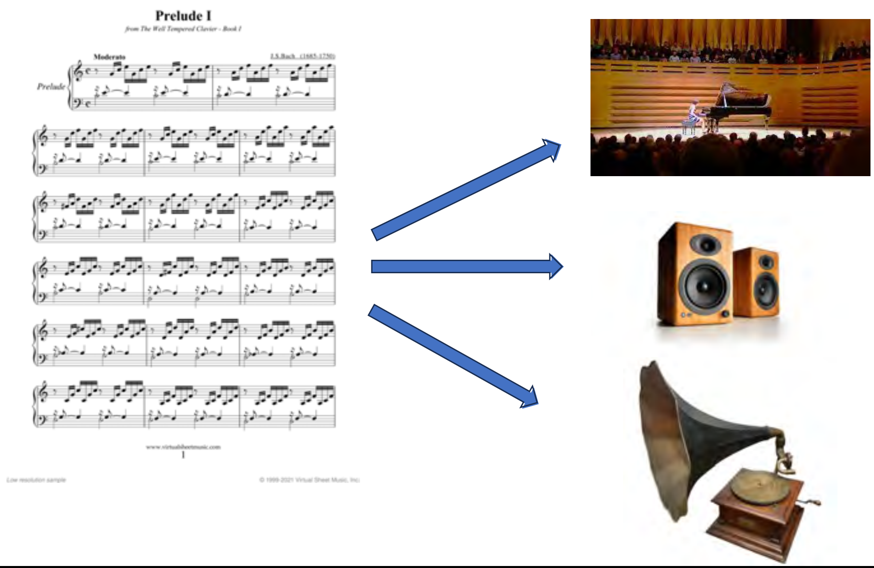
Flavor complexity: consider the music model



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A few key points

IC structure is complex, so are flavors – this is trouble

Some practical principles –> novel approaches

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A few words of caution

- These are new approaches, lack of confidence
- Principles are not universally applicable
- Re-think how we approach food flavor
- Are they really novel?

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A new approach Illustrated

Camilla Arndal Andersen, 2019

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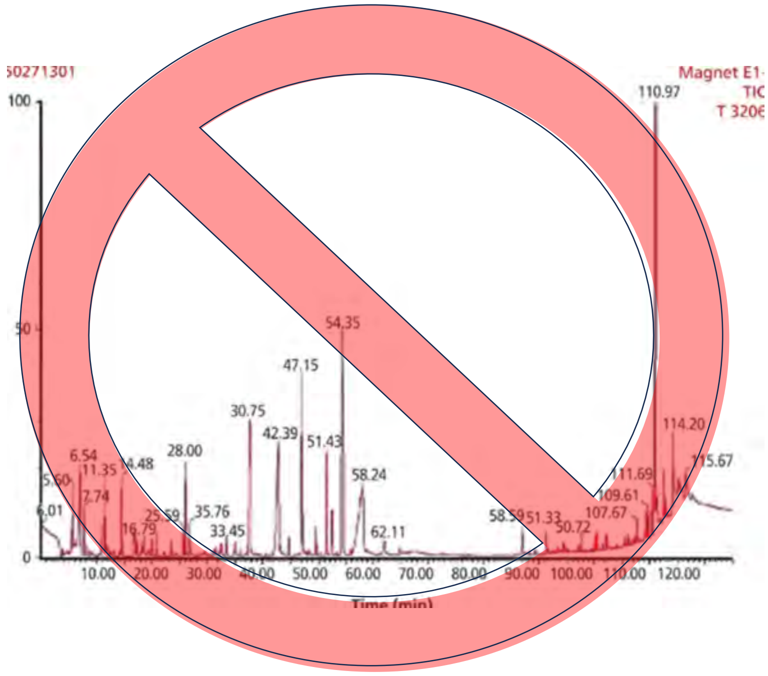
Practical principle #1

Non chemistry approaches:

Label, color, temperature, messaging, etc



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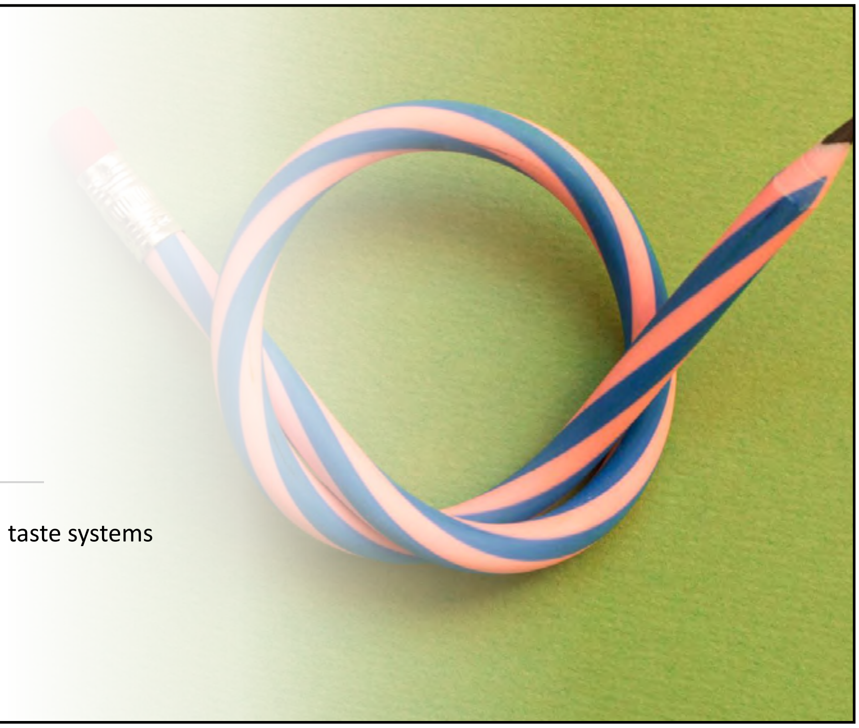
Practical principle #2

Significant latitude in many flavor, taste systems



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322 R. M. PANGBORN AND M. E. GIOVANNI

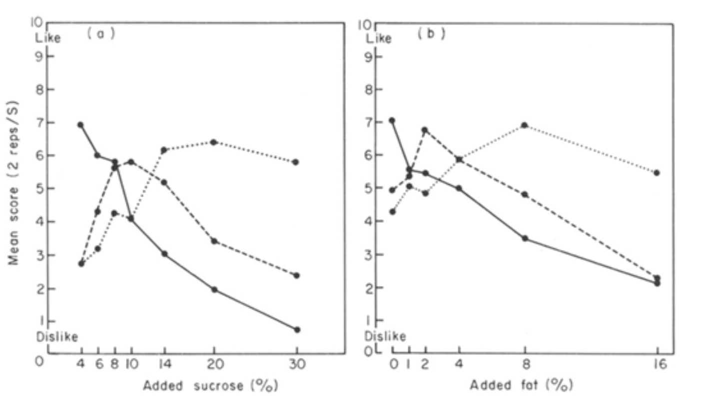

FIGURE 1. Mean hedonic responses to increasing concentrations of (a) sucrose in lemonade and (b) to fat in milk, subdivided by the subjects' liking for low, medium, or high levels. Each point represents the mean of two replications for the number of subjects represented. ●——●, Low (3, 21); ●– – –●, medium (38, 26); and ●------●, high (10, 6) levels. Figures in parentheses are the number of subjects represented for sucrose and butterfat respectively.

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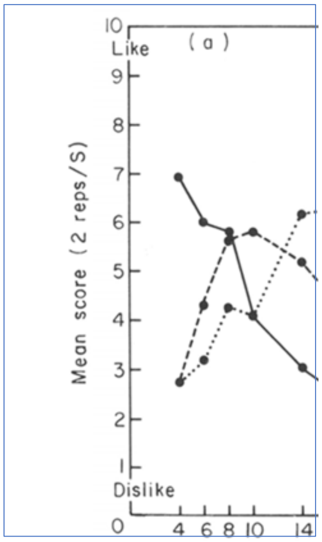
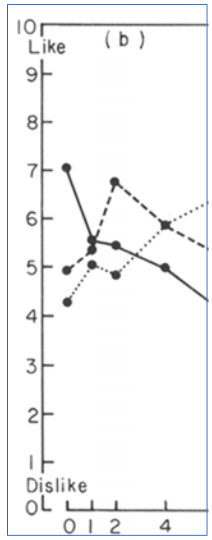
Relationship: sugar, fat to liking?





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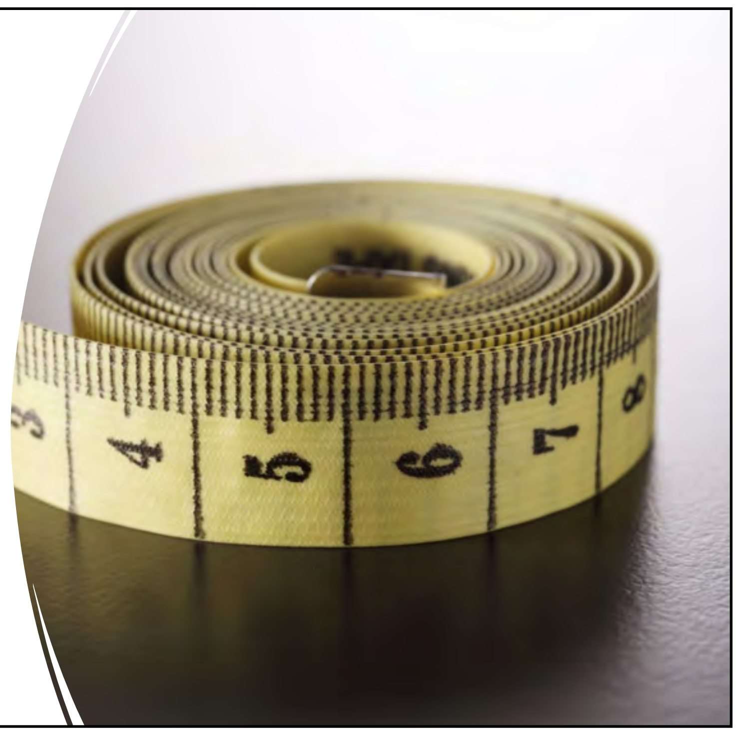
Implications?

- Sweetness, calories?
- Milkfat, calories?
- Flavor systems



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Practical principle #3

Flavor preference is fluid

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"We like what we eat more than we eat what we like" -Kurt Lewin

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Learned preferences

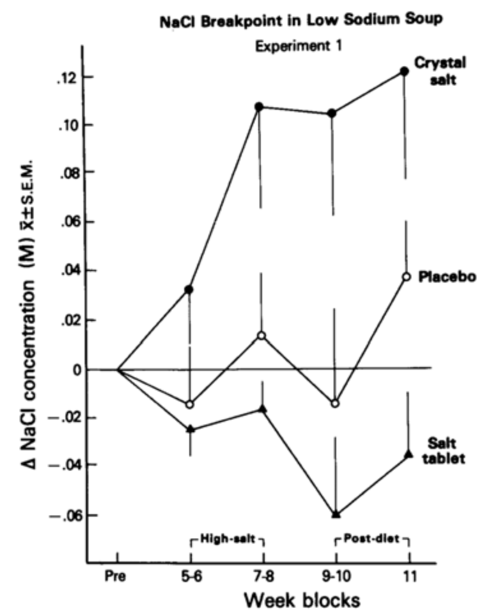

FIG. 1. Change in breakpoint concentration of NaCl in soup during Experiment 1: Crystal salt (n=7); Salt tablet (n=6); Placebo (n=6).

Bertino et al, 1986

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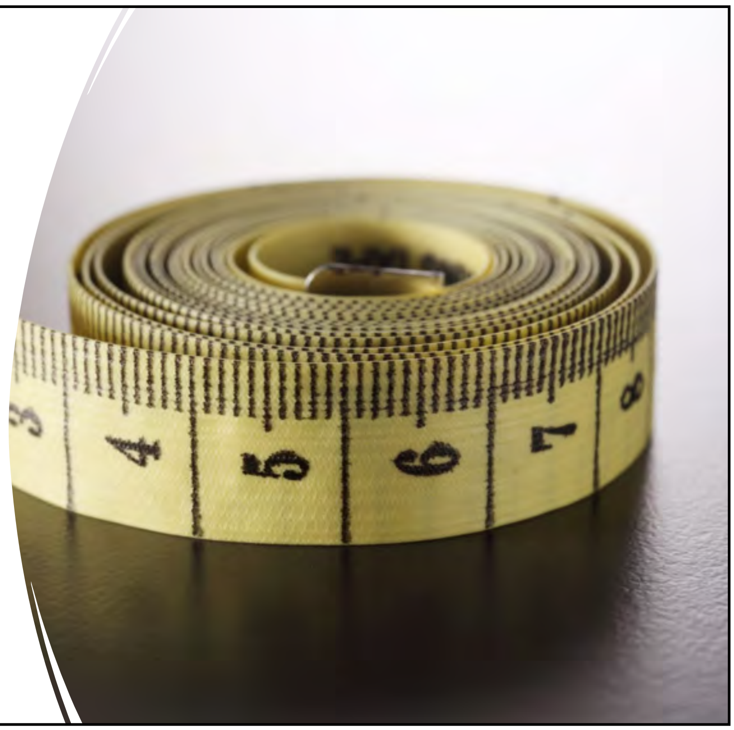
Implications?

- Keep presence in market



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Practical principle #4

Habituation effects

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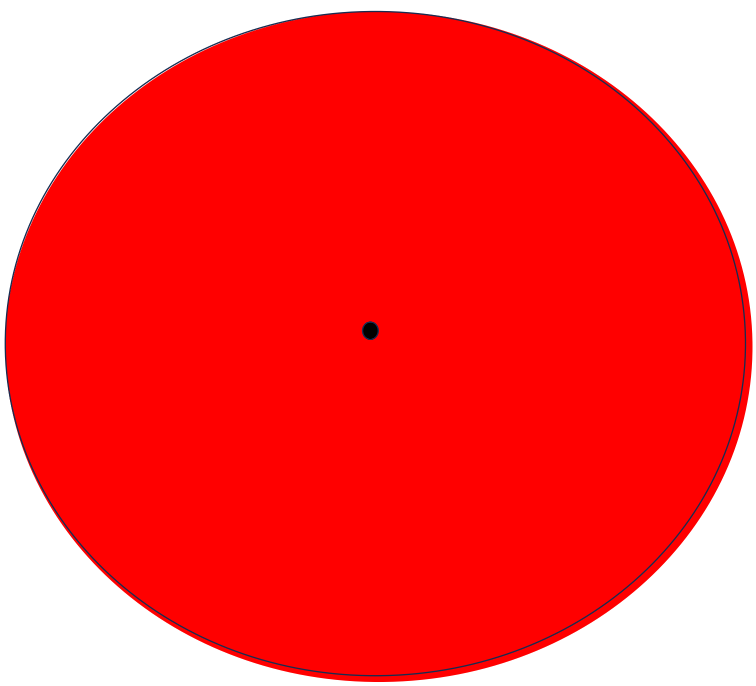

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Habituation effects

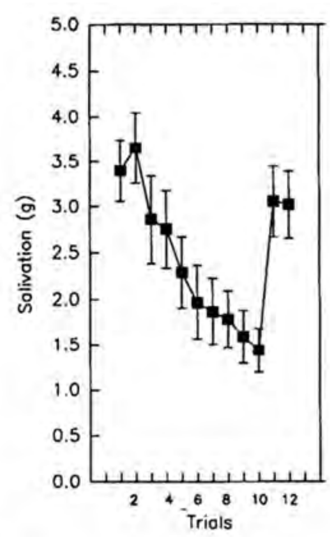

Figure 1.
Salivation (mean ± SEM) for subjects who received lemon or lime juice as the habituating stimulus in trials 1–10, the other juice as the dishabituator in trial 11, and presentation of the habituating stimulus in trial 12. Adapted from (Epstein et al., 1992). Copyright 1992 by Pergamon Press. Reprinted by permission.

Epstein et al., 2009

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Habituation effects

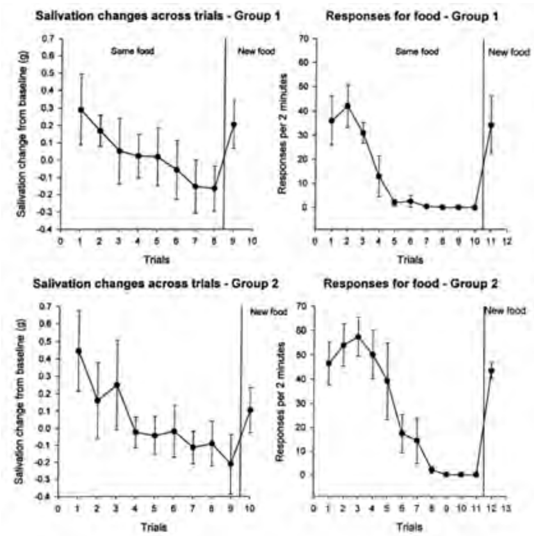

Figure 3.
Salivation (left graphs, mean ± SEM) and motivation (right graphs, mean ± SEM) for subjects who were presented cheeseburgers followed by apple pie as the new food. The introduction of the new food was delayed one trial for Group 2 in relationship to Group 1 test whether the recovery of responding occurred after presentation of the new food. Adapted from (Epstein et al., 2003). Copyright 2003 by Elsevier Ltd. Reprinted by permission.

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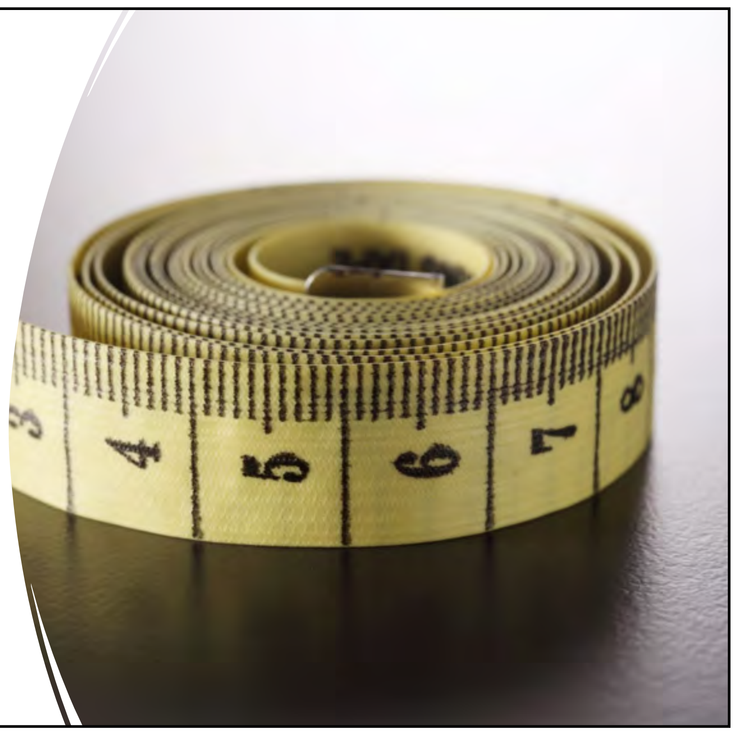
Implications?

- Stay in market
- Incremental changes



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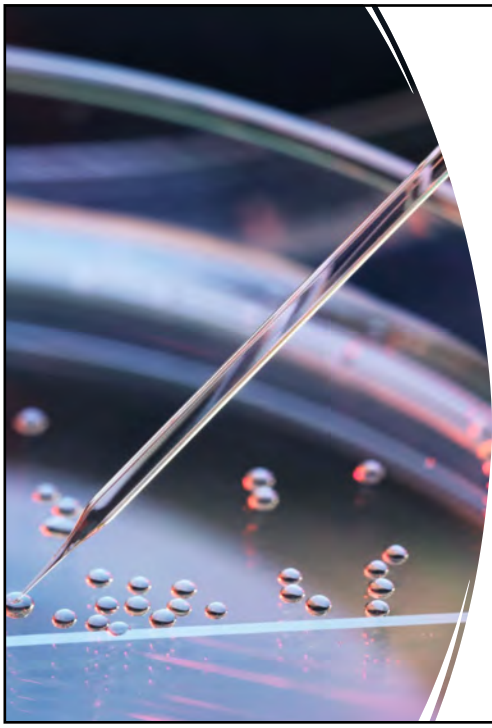

Microstructure and Flavor Release; some novel approaches

S.A. Rankin, Ph.D.

Oct, 2023

Frozen Dessert Center Conference

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