Taste Physiology and Considerations in Sweetener Choices

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When it comes to the topic of making things taste sweeter and more sugar-like, have you ever wondered how to do it ....

- With something that is **not** sugar?
- With something that is wholesome, authentic, and **better** for me?
- With something **from nature**?
- As **simple** as possible?

I will focus today on how to make foods **sweeter, naturally and simply**
Outline

- Taste physiology and neuroscience 101
- Make things taste sweeter, naturally
- Make things taste sweeter, simply
- Take-home messages
“Flavor” = Smell + Taste

- Smell (Aroma)
- Taste (5+ primary)
- Trigeminal sensations (chemical irritants and temperature)
- Touch and Vision (“Seeing the flavor”. Acree, 2013)
Taste Perception Wiring System

The tongue has two nerve systems, each consist of 5,000 fibers, and each of which is coded, that is some fiber is sweet-specific. (DuBois, 2011)
Taste Buds

Taste buds are located on three kinds of papillae on human tongue. The number of taste buds on human tongue varies by a factor of 100.
Taste Cells

A taste bud is a cluster of 100 elongated taste cells like an orange segment. Each taste bud cell is taste-specific (One taste, one cell class, Zuker, 2011). There is integration of gustatory information from different taste cells (Sternini, 2013), that is “sensory processing circuitry” (Bigiani, 2011).
A tastant such as a sweetener in the saliva only touches the receptors at the tip of the taste bud cell. After it excites the taste bud cell, an electrical signal is carried to the synapse then to the brain. Sweet taste corresponds to a “hot spot” in the brain, separate from other primary tastes. (Zuker, 2011)
Taste Receptors

Sweetness receptor was identified during the rapid advances of taste physiology and neuroscience in the past 10 years (NIZO 2011)

- **Sweetness**: 1 Receptor: T1R2/T1R3. Family: GPCR. 2001.
- **Umami**: 1 Receptor: T1R1/T1R3. Family: GPCR. 2002.
- **Saltiness**: “Receptor”: ENaC. Family: Na Channel. 2010.
- **“Fat”**: Receptors: CD36, GPR120, FA1. Family: Several GPCR
- **“Calcium”**: Receptor: CaR. Family: GPCR
- **“Water”**: Receptor: Aquaporins. Family: Channel
Sweet Taste Receptor

Make Things Taste Sweeter, Naturally

- Keep it natural
  - Natural high potency sweeteners
    - Stevia extract
    - Monk fruit extract
  - Natural non caloric bulk sweeteners
    - Erythritol

- Blend them, each at low usage levels, to achieve maximum sweetness yet with minimal off flavors and lowest cost in use.
High Potency Sweeteners

Technologies go from “Emerging” (discovered but not yet commercialized) to “Pacing” (first to market sets the pace) and finally to “Mature” (patent expired and technology commoditized) (Alex Woo, W2O 2013)
Stevia Extract:
(Multiple suppliers’ websites)

- Natural
- Non caloric
- GRAS: FDA No Objection Letter
- Purity: RA 50 to RA100
- 200-400X as sweet as sugar
- Heat and pH (>3) Stable
- Non GMO
- Kosher & Halal Certified available
- 0.02% in beverages = about 6% SE
- Most commonly labeled as “stevia extract”
Monk Fruit Extract:
(Multiple suppliers’ websites)

- Natural
- Non caloric
- GRAS FDA No Objection Letter 2010, not yet in EU
- Purity: Up to Mogroside-V 55%
- 150-200X as sweet as sugar
- Heat Stable
- Non GMO
- Kosher Certified
- 0.01% in beverages = about 2% SE
- Labeled as “monk fruit extract”
Monatin: A unique natural amino acid that recently came alive

- Being developed by an ingredient technology leader
- Amino acid extracted from a South African plant Sclerochiton ilicifolius (root)
- 3,000x sugar @ 5% SE (R,R-form)
- Unique temporal profile: quick on set and no lingering, no bitter metallic, no astringent after taste (Fry, 2012)
- UV instability?
- Not yet approved anywhere
Non/low Caloric bulk Sweeteners
(Alex Woo, W2O 2013)

Emerging
- L Sugars
- Trehalose
- Tagatose

Pacing
- Isomalt
- Xylitol
- Erythritol

Mature
- Other Polyols
- Maltitol
- Sorbitol

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Erythritol: The only natural non-caloric bulk sweetener
(Multiple suppliers’ websites)

- Found in fruits and vegetables
- The only natural polyol made by fermentation
- Highest digestive tolerance amongst all polyols
- Non caloric (0-0.2 calorie per gram)
- Non GMO possible
- 65% as sweet as sugar
- 3.5% limit in beverages USA, GMP levels in many countries.
- (Not clean label to some)
Make Things Taste Sweeter, *Simply*

- Cleaner than clean: when natural is not enough (Scott-Thomas, 2013)

- Use “cross-modal correspondences” to enhance sweetness: How brain process information from different senses to form multisensory experiences in our daily lives (Spence, 2013)
  - Smell on taste
  - Trigeminal on taste
  - Sight on taste
  - Sound on taste
This is because although the sweetness is perceived in the mouth when a sweetener in the saliva touches the receptors at the tip of the taste bud cell.
...., there is interaction between olfaction and gustation (Taylor, 2010). That is, retronasal “sweet” aroma (smell) in the nose increases the sweet perception in the mouth (taste).
Smell and Taste Cross-Modal Association

All of these sweet taste modulators (in black) are legally labeled as natural flavors, thus cleaner label. Humans have 350 odor receptor genes (Hayes, 2013) operating on a pattern-recognition model (Buck and Axel, 2004) detecting 1,000 odorants (Acree, 2013) (Schieberle, 2013) (Alex Woo, W20 2013)
“Using molecular biology to trick your taste buds is kind of novel for the food industry” (Tepper, 2013)

- Example: Fresh tomato aroma makes tomato tastes sweeter (Bartoshuk, 2013)
- Example: Sugar distillate enhances beverage sweetness, tea essence enhances sweetness in tea (supplier literature, 2013)
- Example: Vanilla below or above aroma threshold enhances sweetness in US (various empirical reports, up to 2012) but saltiness in Japan (Spence, 2013)
Smell and Taste Cross-Modal Association

Many non-specific sweet enhancers are labeled as natural flavor so clean, but the better positive allosteric modulators (PAMs) and bitterness blockers need to be natural to be clean label (Alex Woo, W2O 2013)
Some FDA GRAS natural high potency sweeteners are also approved under FEMA GRAS, as “natural flavor” when used is extremely low level as sweetness and/or flavor enhancers (FEMA GRAS list 2013)

- Example: Thaumatin (0.5 to 1ppm. supplier literature)
- Example: Monk fruit extract (< 50ppm. suppliers’ website)
Trigeminal and Taste Cross-Modal Association

- Trigeminal on sweetness enhancement:
  - **Carbonation**, a trigeminal pain agent, reduced sweetness perception and made artificial high potency sweetener tasted more like sugar. (Sternini, 2013). Labeled as “carbonated water”.
  - Stevia was significantly more potent in cold water (Fry, 2011)
  - Drinking hotter water prior made dark chocolate taste sweeter (Monya, 2013)
Look Mom, no ingredient!

- Vision on sweetness: (Shape Symbolism-Sub-consciously setting up sensory expectations in the minds of consumers. Spence, 2013)
  - Shape (food): More rounded shape tended to associate with sweeter stimuli (Spence, 2013) including juices (Spence, 2013)
  - Shape (food): Round chocolate tastes sweeter (Spence, 2013)
  - Shape (Contextual): Gazing at round shape make 0.3% sugar tasted sweeter (Roy and Liang, 2013) and beer sweeter (Deroy, 2013)
Look Mom, no ingredient!

- Vision on sweetness: Taste lies in the eyes of the beholders

- Color (contextual): Strawberry mousse 10% sweeter and more liked on a white plate than a black plate (Adria, 2011. Spence, 2012)

- Color (contextual): Hot chocolate tasted sweeter and more aroma in dark cream cup than in white or red cup (Spence, 2012.)

- Color (contextual): Red room, red fruits, and red round shape objects in a “sweet room” made whisky tasted sweeter (Spence, 2013)
Sound on sweetness: The sound of food, packaging, machine and environment can exert a profound, if often unacknowledged, role in flavor perception. (Sound Symbolism, Spence, 2012 and 2011)

- **Twinkling/Higher pitches** enhances sweetness in toffee and lower tones emphasize bitterness: Biological basis: Tongue curls upward = higher pitches = draw in sweeter foods. (Crisinel, 2012) (Spence, 2013)
- **Higher frequency sounds** pair well with sweet wine (Burzynska, 2013)
Take-home messages:

- Can achieve clean label reduced sugar beverages and foods with high potency and bulk sweeteners, naturally

- Can make them taste even sweeter with cross-modal correspondences, simply

- “The physiology of today, is the medicine of tomorrow.” (Ernest Starling 1866-1927. Nobel Prize and discoverer of the first hormone.)

- “The taste physiology of today, is the food ingredient of tomorrow.” (Alex Woo, W2O Food Innovation, 2013)