ศาสตร์แห่งการออกแบบความหวานที่สมบูรณ์แบบในเครื่องดื่มลดน้ำตาล

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SCOPE

Part 1 — Current Trends and Challenges in Reduced-Sugar Beverages

Part 2 — Designing the Sweetness Matrix for Modern Beverage Systems

Part 3 — Flavor Modifying Properties:
From Sweetness Enhancement to Flavor Masking

Part 4 — Ingredient Strategies for Sugar Reduction
without Compromising Consumer Acceptance

Part 5 — Case Studies of Successful Reduced-Sugar Beverage Formulations

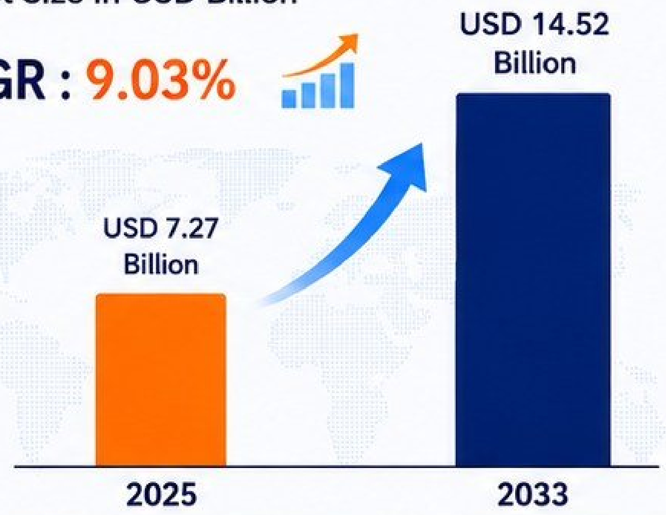
Part 1. Current Trends and Challenges in Reduced-Sugar Beverages

Sugar plays a vital role in sweetness, flavor, texture, and preservation.
The global shift toward **less sugar** is transforming the beverage industry.

GLOBAL SUGAR REDUCTION MARKET

Market Size in USD Billion

CAGR : 9.03%



Forecast Period
2026 – 2033

Market Size
(Base Year 2025)
USD 7.27 Billion

Market Size
(Forecast Year 2033)
USD 14.52 Billion

CAGR
9.03% (2026–2033)

Market value (2025)	Expected market value (2033)	CAGR (2026–2033)
USD 7.27 Billion	USD 14.52 Billion	9.03%

SUGAR REDUCTION REGIONAL MARKET SHARE (2025)

North America	Largest current market	40%
Europe	Strong regulatory support	30%
Asia-Pacific	High growth potential	20%
Latin America		5%
Middle East & Africa		5%

KEY TAKEAWAY

Although North America currently dominates the market, **Asia-Pacific is expected to deliver the fastest growth** over the next decade.

Source: https://www.databridgemarketresearch.com/reports/global-sugar-reduction-market
https://www.datainsightsmarket.com/reports/sugar-reduction-393876, https://www.innovamarketinsights.com/trends/global-sugar-reduction/

Part 1

Current Trends and Challenges in Reduced-Sugar Beverages

MARKET GROWTH DRIVERS

1. Increasing Consumer Awareness

- ✓ Obesity
- ✓ Diabetes
- ✓ Cardiovascular disease

↓

Consumers are seeking healthier beverages.

»

2. Government Regulations

- ✓ Sugar tax
- ✓ Front-of-pack labeling
- ✓ Nutrition policy

↓

Manufacturers are reformulating products.

»

3. Changing Consumer Preferences

- ✓ Natural ingredients
- ✓ Clean label
- ✓ Reduced sugar

↓

Innovation in beverages & rise of functional beverages.

These three forces are driving the global shift toward less sugar and shaping the future of the beverage industry.

Source: https://www.databridgemarketresearch.com/reports/global-sugar-reduction-market
https://www.datainsightsmarket.com/reports/sugar-reduction-393876, https://www.innovamarketinsights.com/trends/global-sugar-reduction/

Part 1

Current Trends and Challenges in Reduced-Sugar Beverages

WHY ASIA-PACIFIC IS THE FASTEST-GROWING MARKET?

1 URBANIZATION

Rapid urban growth changes lifestyles and drives higher demand for ready-to-drink beverages.

2 RISING INCOME

Higher disposable income makes consumers willing to pay more for healthier products.

3 HEALTH AWARENESS

Growing focus on health leads to higher demand for low-sugar beverages, weight management, and prevention of NCDs.

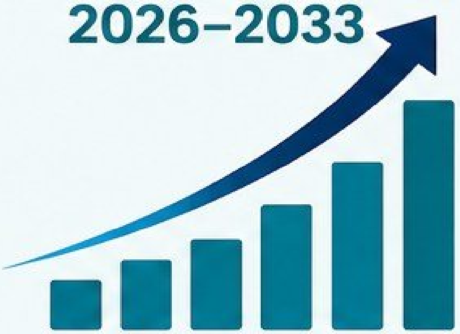
4 FUNCTIONAL BEVERAGES

Strong growth of beverages that deliver both health benefits and great taste meets consumer expectations.

ASIA-PACIFIC

FASTEST-GROWING REGION

2026–2033



KEY MESSAGE

Asia-Pacific represents the **greatest opportunity** for **reduced-sugar** beverage innovation.

Source: https://www.databridgemarketresearch.com/reports/global-sugar-reduction-market
https://www.datainsightsmarket.com/reports/sugar-reduction-393876, https://www.innovamarketinsights.com/trends/global-sugar-reduction/

Part 1 Current Trends and Challenges in Reduced-Sugar Beverages

GLOBAL SUGAR REDUCTION TRENDS

Key forces shaping the shift toward less sugar and better-for-you beverages

CONSUMERS EXPECT
LESS SUGAR
WITHOUT
COMPROMISING TASTE

KEY MARKET TRENDS

1. HEALTH-CONSCIOUS CONSUMERS

- Growing awareness of obesity, diabetes, and cardiovascular diseases.
- Reduced-sugar products are perceived as healthier choices.

2. NATURAL SWEETENERS ON THE RISE

- Stevia
- Monk fruit extract
- Erythritol

Low-calorie sweeteners such as aspartame and sucralose also compete in the market.

3. CLEAN LABEL & "NO ADDED SUGAR" DRIVING PURCHASE

NO ADDED SUGAR

- Natural ingredients
- Transparent labeling
- Better nutritional profile

4. INNOVATION BEYOND SUGAR REPLACEMENT

- Sweetness enhancement
- Flavor masking
- Functional beverages with added benefits

MARKET OPPORTUNITIES

Natural Sweeteners
Clean and plant-based solutions in demand

Flavor Modifiers
Mask off-notes and enhance taste

Sweetness Enhancers
Improve sweetness profile and reduce sugar content

Functional Beverages
Combining health benefits with great taste

KEY TAKEAWAY

Today's consumers expect beverages that are healthier, naturally sweetened, and clean-label—without sacrificing taste.

Part 1 Current Trends and Challenges in Reduced-Sugar Beverages

CURRENT CHALLENGES IN SUGAR REDUCTION

Key obstacles manufacturers face when developing great-tasting, reduced-sugar beverages

1 TASTE ACCEPTANCE

- Bitterness and off-notes
- Metallic or licorice aftertaste
- Different sweetness onset
- Lingering sweetness
- Overall taste balance

2 FORMULATION COMPLEXITY

- Achieving the right sweetness intensity and profile
- Balancing mouthfeel and body
- Masking off-notes
- Interactions between ingredients

3 COST OF ALTERNATIVE INGREDIENTS

- Natural sweeteners are often more expensive
- Added cost of flavor modifiers and enhancers
- Impact on overall product profitability

4 REGULATIONS & COMPLIANCE

- Evolving sugar tax policies
- Restrictions on high-intensity sweeteners
- Labeling and claim requirements
- Different regulations across regions

5 CONSUMER ACCEPTANCE

- Perceived "unnatural" ingredients
- Sensitivity to taste differences
- Price sensitivity
- Building trust and purchase intent

KEY MESSAGE

Reducing sugar is no longer just about replacing sucrose—
it requires balancing taste, functionality, cost, and consumer acceptance.

Part 2 Designing the Sweetness Matrix for Modern Beverage Systems

WHAT IS THE SWEETNESS MATRIX?

Sweetness is more than sugar concentration.

RETHINK SWEETNESS

Consumers do not perceive sugar concentration.

They perceive sweetness that the brain interprets.

Two drinks with the same sugar level can taste different.

A drink with less sugar can taste sweeter—with the right design.

SWEETNESS EXPERIENCE

SWEETENER

AROMA
Enhances sweetness through smell.

MOUTHFEEL
Impacts body, smoothness and sweetness perception.

ACIDITY
Balances sweetness and reduces cloyingness.

TEXTURE
Affects thickness, viscosity and sweetness intensity.

FLAVOR
Certain flavors enhance or mask sweetness.

TEMPERATURE
Cold can suppress, warm can enhance perceived sweetness.

ALL FACTORS INTERACT TO CREATE A UNIQUE SWEETNESS EXPERIENCE.

IT'S NOT JUST ABOUT SUGAR

SUGAR 10 g ≠ SUGAR 10 g

Different sweetness experience

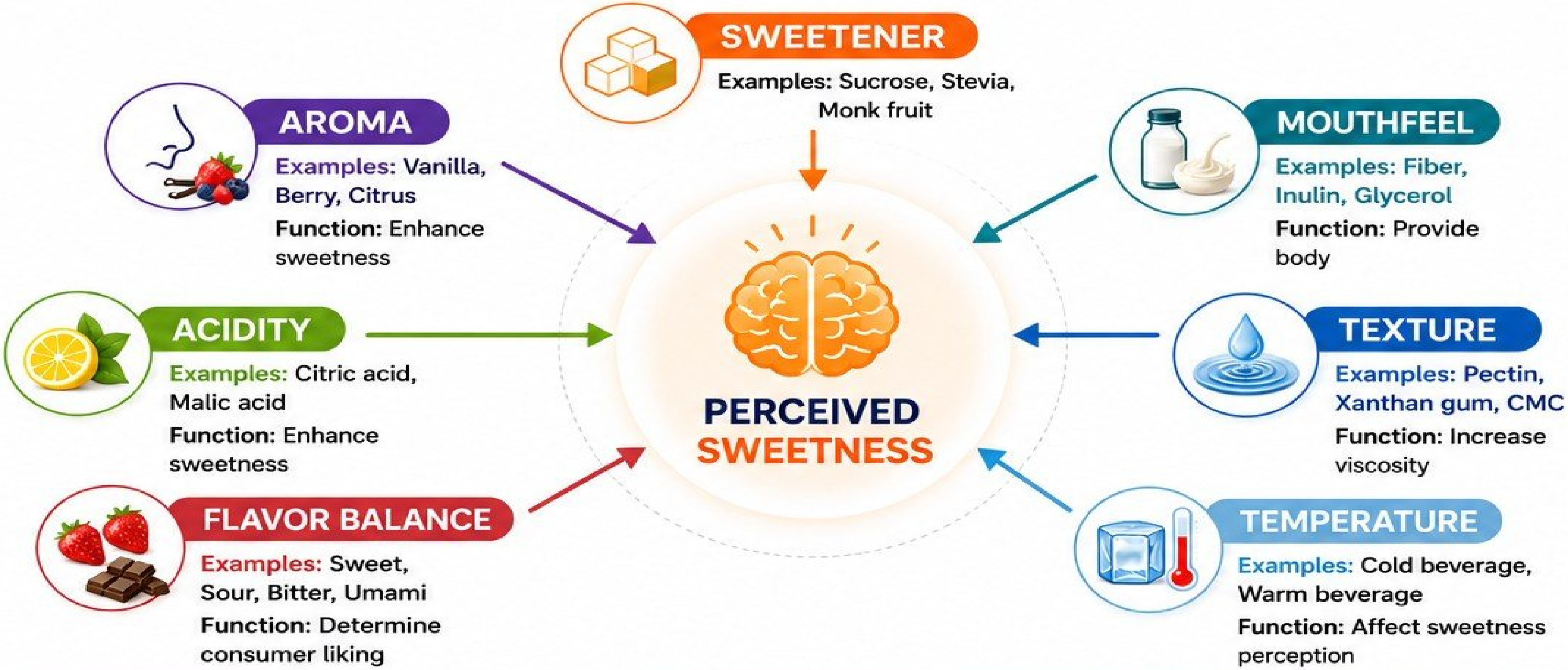
SUGAR 5 g = SUGAR 10 g

Same sweetness experience

The brain integrates multiple sensory signals to determine sweetness.

COMPONENTS OF THE SWEETNESS MATRIX

Multiple sensory factors interact to create perceived sweetness.



SWEETENER
Examples
- Sucrose
- Stevia
- Monk fruit

Primary Function
Sweetness intensity

AROMA
Examples
- Vanilla
- Berry
- Citrus

Primary Function
Enhance sweetness

ACIDITY
Examples
- Citric acid
- Malic acid

Primary Function
Balance sweetness

MOUTHFEEL
Examples
- Fiber
- Inulin
- Glycerol

Primary Function
Body

TEXTURE
Examples
- Pectin
- Xanthan gum
- CMC

Primary Function
Viscosity

TEMPERATURE
Examples
- Cold
- Warm

Primary Function
Sweetness perception

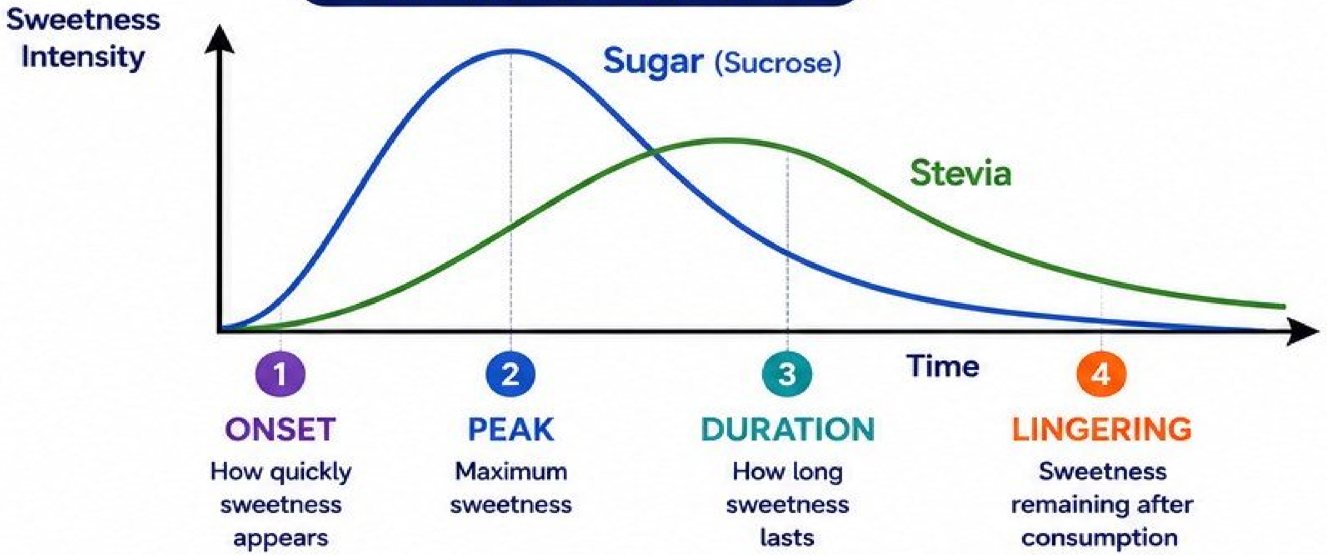
FLAVOR BALANCE
Examples
- Sweet – Sour
- Sweet – Bitter
- Sweet – Umami

Primary Function
Consumer liking

TEMPORAL SWEETNESS PROFILE

Consumers perceive not only how sweet a beverage is, but also how sweetness changes over time.

SWEETNESS OVER TIME



SWEETNESS PARAMETERS

1. **ONSET** — How quickly sweetness appears.
2. **PEAK** — Maximum level of sweetness.
3. **DURATION** — How long sweetness lasts in the mouth.
4. **LINGERING** — Sweetness or aftertaste that remains after swallowing.

SWEETENER COMPARISON

Sweetener	Onset (How quickly sweetness appears)		Lingering (Aftertaste)	
Sugar (Sucrose)	Medium	●●○○○	Short	●○○○○
Stevia	Slow	●○○○○	Long	●●●●○
Monk Fruit	Medium	●●○○○	Medium	●●○○○
Sucralose	Fast	●●●○○	Medium	●●○○○

DESIGNING SWEETNESS RATHER THAN ADDING SUGAR

The future of sugar reduction is not just about what we remove, but how we design sweetness for a better consumer experience.

TRADITIONAL APPROACH

Sugar

Sweetness

In the past, we thought sugar reduction = change sweetener.

VS

MODERN SWEETNESS DESIGN

Sweetener
Provide sweetness intensity

+

Flavor
Modulates sweetness perception

+

Aroma
Enhances perceived sweetness

+

Acidity
Balances sweetness and flavor

+

Texture
Creates viscosity and structure

+

Mouthfeel
Adds body and richness in the mouth

↓

Perceived Sweetness

↓

Consumer Acceptance

Part 3: Flavor Modifying Properties: From Sweetness Enhancement to Flavor Masking

What are Flavor Modifying Properties (FMPs)?

"Flavorings with modifying properties (FMPs) are flavorings that modify or enhance the flavor profile of a flavoring or the food to which they are added.

They may not impart a characteristic flavor of their own, but instead modify flavor attributes by intensifying **desirable characteristics**, **reducing undesiriable characteristics**, **masking off-notes or bitterness**, or **altering the onset and duration of flavor perception.**"

Ref: Hurman, C. L., Hallagan, J. B., & FEMA Science Committee Sensory Data Task Force. (2013/2022). *Sensory testing for flavorings with modifying properties. Food Technology,* 67(11), 44–47.

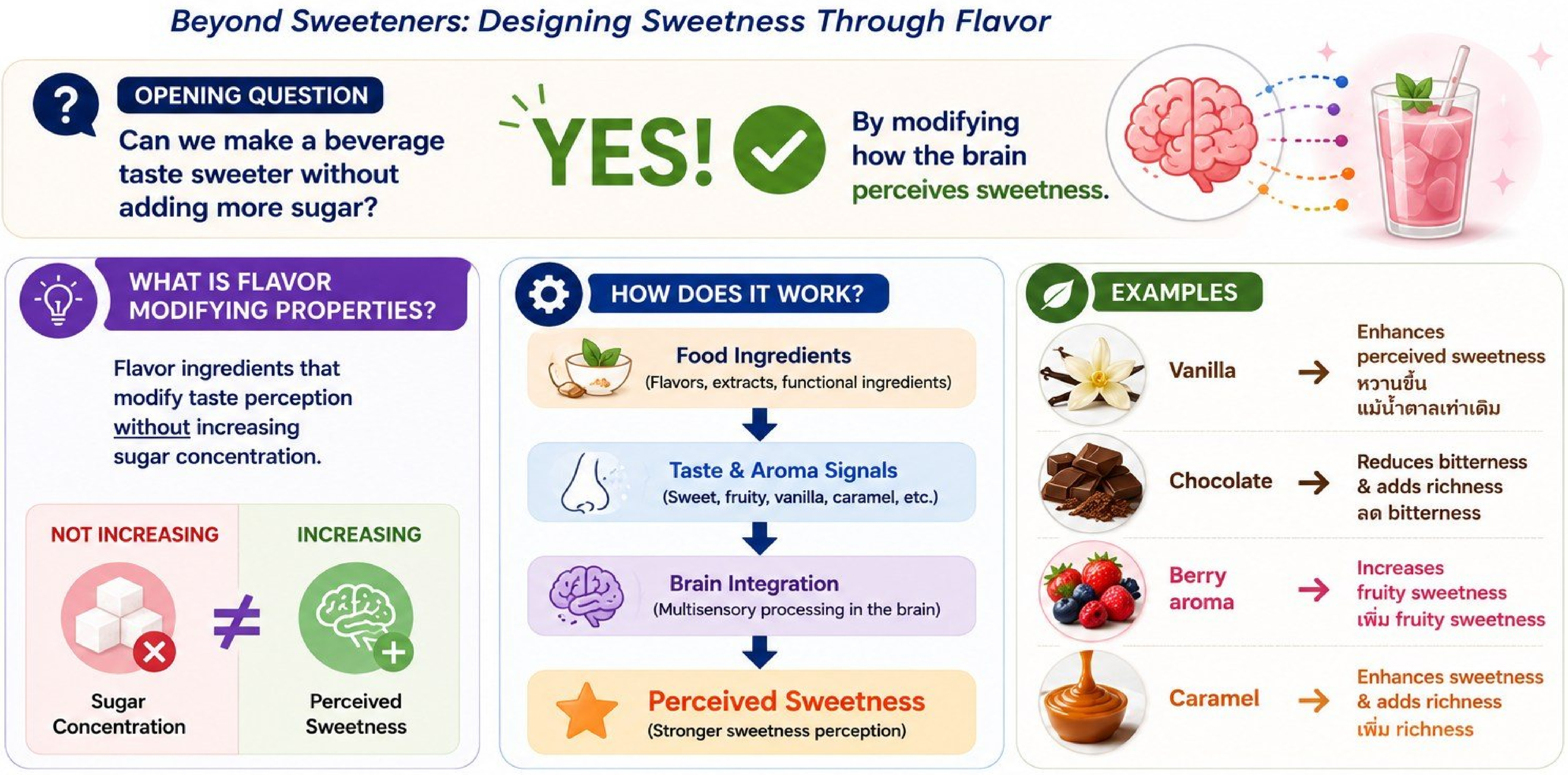
"A **flavor modifier** is a compound or mixture of compounds which is not perceived intensively by taste, smell or touch, but substantially **changes (masks, enhances or diminishes) the taste, smell or tactile perception of the material to which it is added.**"

Ref: Maruocová, J., Opletal, L., Lapčík, O., Čopíková, J., Uher, M., & Drašar, P. (2008). *Compounds Influencing Perception of Organoleptic Properties (Flavor Modifiers). Chemické Listy,* 102(12), 1002–1010.

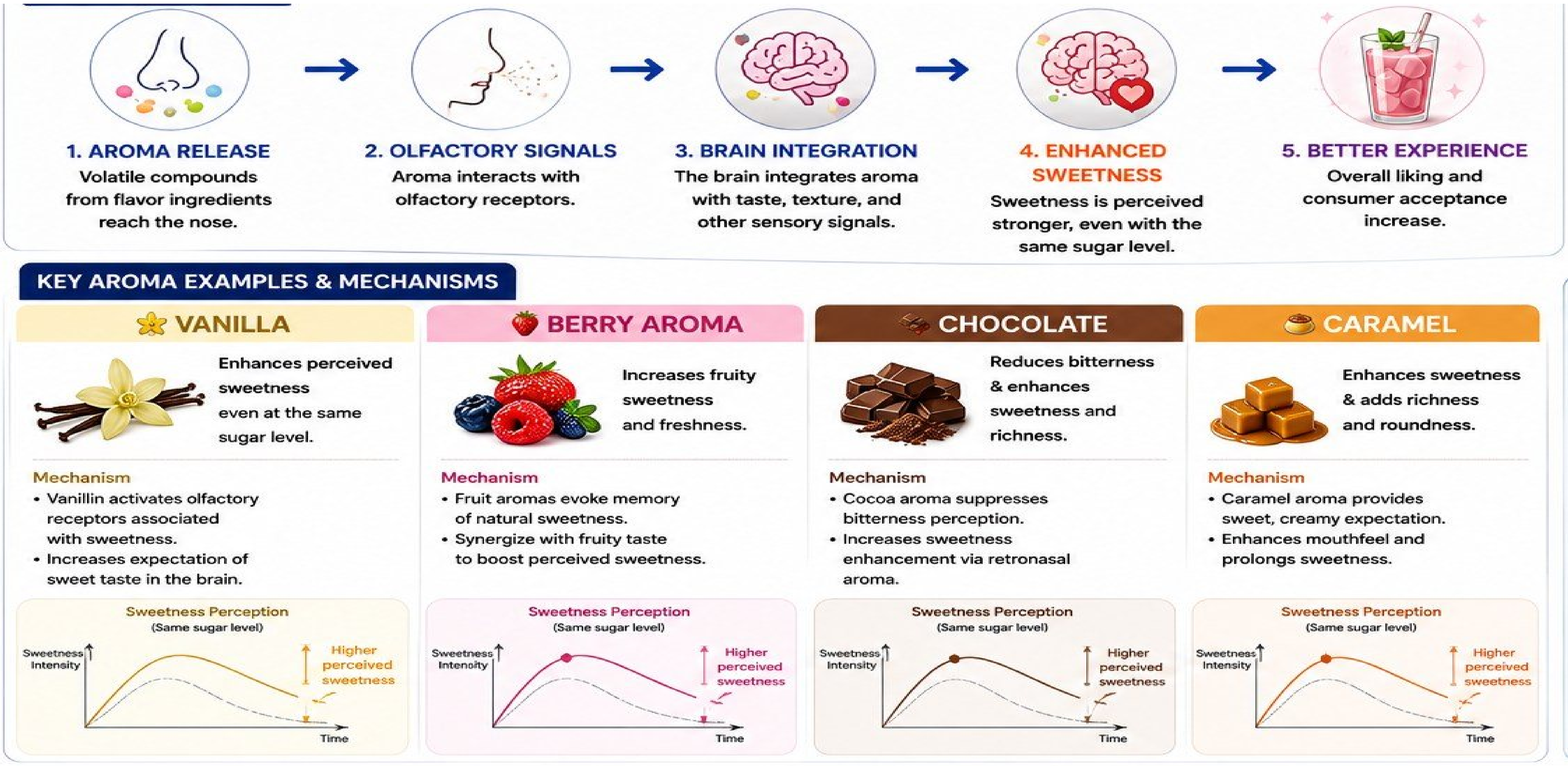
"**FMPs** do not necessarily have a sweet taste themselves but can **increase sweetness perception, reduce bitterness, mask undesiriable aftertastes**, and **improve the overall flavor profile**, enabling sugar **reduction** without compromising sensory quality."

Ref: Guentert, M. A. (2018). *Flavorings with modifying properties. Journal of Agricultural and Food Chemistry,* 66(15), 3735–3736. https://doi.org/10.1021/acs.jafc.8b00909

Part 3: Flavor Modifying Properties:
From Sweetness Enhancement to Flavor Masking



Part 3: Flavor Modifying Properties:
From Sweetness Enhancement to Flavor Masking



PART 3

Flavor Modifying Properties:
From Sweetness Enhancement to Flavor Masking

Goal:
Improve overall flavor profile by enhancing sweetness and reducing unwanted tastes.

1 Off-flavors in Functional / Plant-based Foods

Functional or plant-based ingredients often bring **unwanted off-flavors**.

- **Bitterness** — e.g., alkaloids, saponins
- **Beany / Green Notes** — e.g., legumes, soy, pea
- **Metallic / Mineral Taste** — e.g., minerals, iron, zinc
- **Astringency** — e.g., tannins, polyphenols
- **Aftertaste** — e.g., lingering bitterness, dryness

Common sources

- Polyphenols
- Tannins
- Saponins
- Proteins / Peptides
- Minerals
- Maillard compounds

2 Strategies for Flavor Masking & Profile Improvement

Through multiple mechanisms, we can **reduce unwanted tastes** and **enhance perceived sweetness**.

Taste–Taste Interaction

Sweetness can suppress bitterness.

BITTERNESS ⊣ SWEETNESS

Examples
Using high-potency sweeteners or sweetness enhancers

Aroma–Taste Interaction

Certain aromas enhance sweetness and mask off-flavors.

AROMA → ↑ PERCEIVED SWEETNESS

Examples
Vanilla, cocoa, fruity aromas

Physical Masking / Encapsulation

Physically reduce the perception of unpleasant compounds.

OFF-FLAVOR COMPOUNDS → ENCAPSULATED / MASKED

Examples
Spray drying, liposomes, cyclodextrin complexation

Flavor Modulation

Actively modify or balance the overall flavor profile.

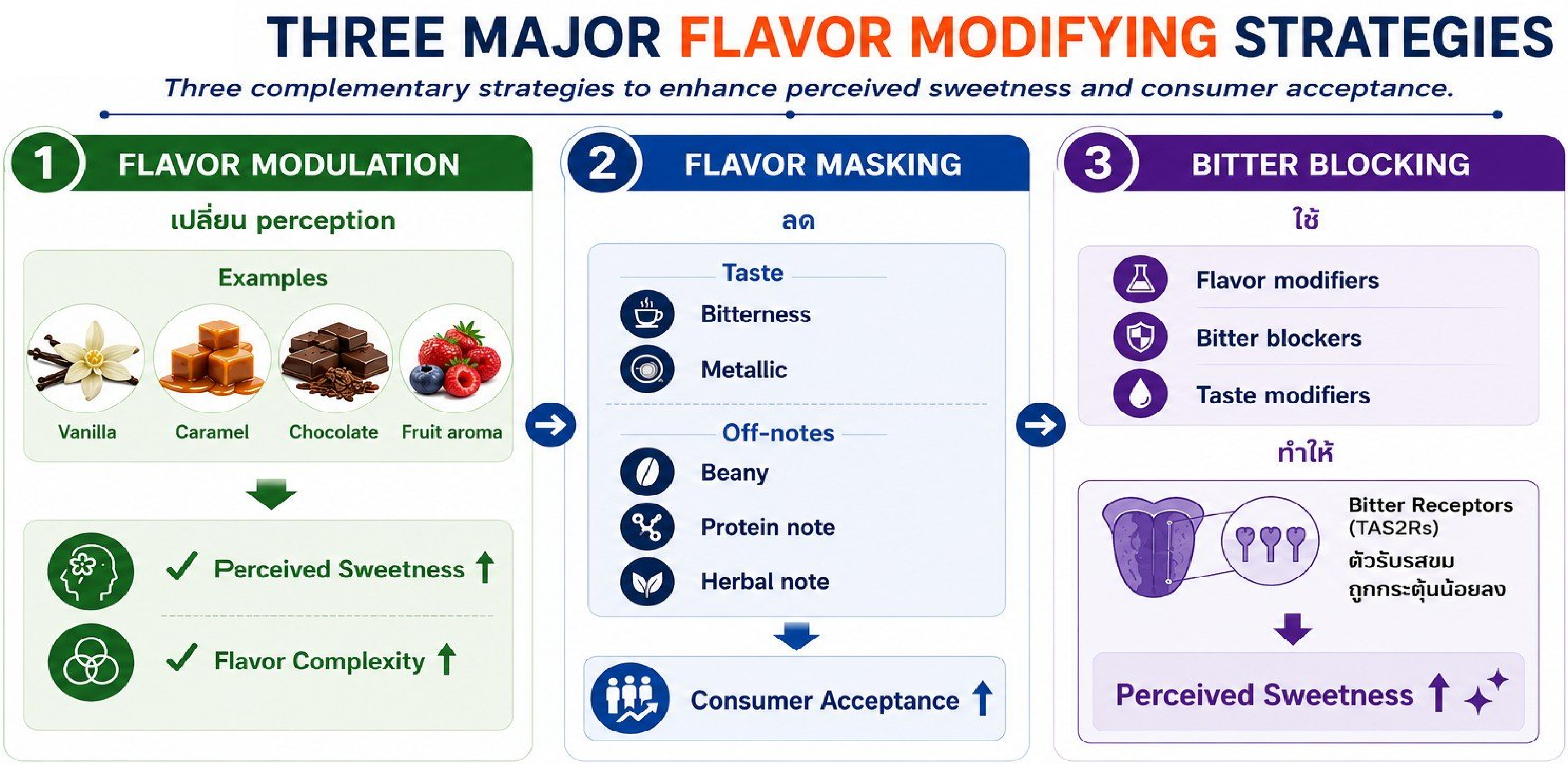
REDUCE OFF-FLAVORS | ENHANCE SWEETNESS | CREATE HARMONY
↓
BALANCED FLAVOR PROFILE

Examples
Blending, acidulants, mouthfeel modifiers, spice extracts

Key Takeaway
Flavor masking is not just hiding off-flavors, but designing a balanced, pleasant, and consumer-accepted flavor profile.

Off-Flavors (Unwanted tastes) → Science & Strategies (Masking & Modulation) → Pleasant Flavor (Consumer Acceptance)

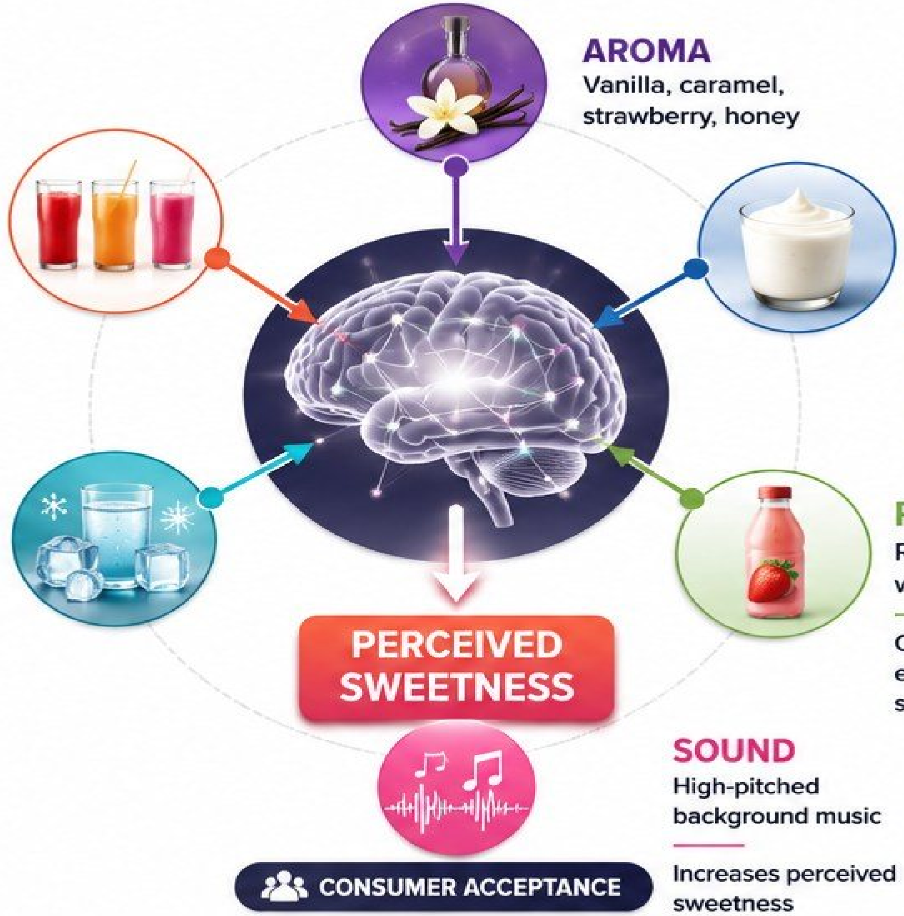
Part 3: Flavor Modifying Properties:
From Sweetness Enhancement to Flavor Masking



CROSS-MODAL INTERACTION

Sweetness Is a Multisensory Experience

The brain integrates multiple sensory cues to create the perception of sweetness.



AROMA
Vanilla, caramel, strawberry, honey

COLOR
Red, orange, pink

Creates expectation of sweetness

TEXTURE
Creamy, viscous beverage

Increases body and sweetness perception

TEMPERATURE
Cold beverages

Lower sweetness perception; formulation adjustment may be needed

PACKAGE
Rounded shapes, warm colors

Creates an expectation of sweetness

SOUND
High-pitched background music

Increases perceived sweetness

HOW SENSORY CUES INFLUENCE SWEETNESS

AROMA	Examples: Vanilla, caramel, strawberry	Enhances perceived sweetness
COLOR	Examples: Red, orange, pink	Associated with sweeter taste
TEXTURE	Examples: Creamy, viscous beverage	Increases body and sweetness perception
TEMPERATURE	Example: Cold beverages	Lower sweetness perception; formulation adjustment may be needed
PACKAGE	Examples: Rounded shapes, warm colors	Creates an expectation of sweetness
SOUND	Example: High-pitched background music	Increases perceived sweetness

(Research by Charles Spence and colleagues)

CONSUMERS DO NOT TASTE SUGAR.
THEY EXPERIENCE SWEETNESS THROUGH MULTIPLE SENSORY CUES.

Designing sweetness means designing the entire **sensory experience.**

REFERENCES

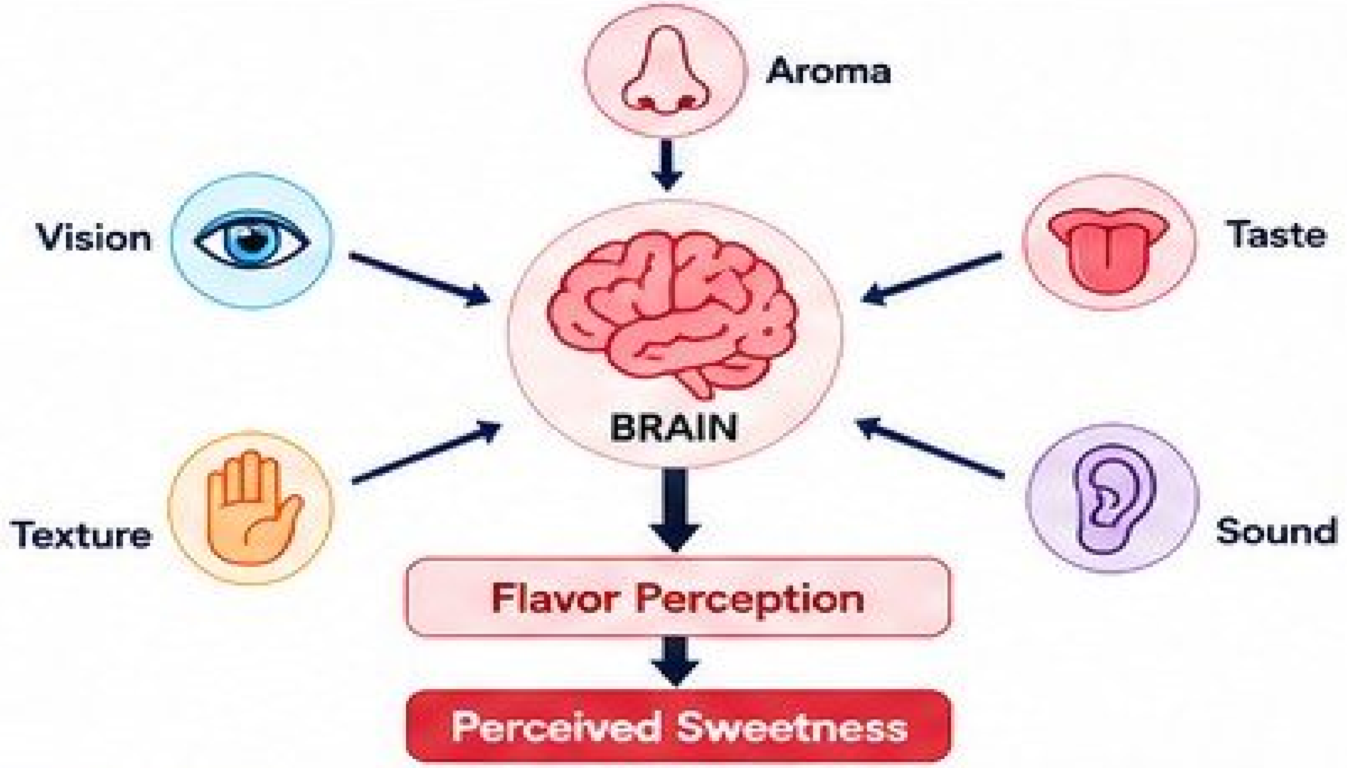
- Spence, C. (2015). Multisensory flavor perception. *Cell*, 161(1), 24–35.
- Spence, C. (2022). The role of intrinsic and extrinsic sensory factors in sweetness perception. *Food Quality and Preference*, 100, 104606.
- Delwiche, J. (2004). The impact of perceptual interactions on perceived flavor. *Food Quality and Preference*, 15(2), 137–146.
- Wang, Q. J., Keller, S., & Spence, C. (2019). Sounds spicy? *Food Quality and Preference*, 71, 35–42.

1 EVIDENCE FROM RESEARCH

Multisensory Flavor Perception

Spence (2015) – *Cell*

FLAVOR IS CREATED BY THE BRAIN, NOT BY THE TONGUE



KEY FINDINGS

- Flavor perception is multisensory.
- The brain combines taste, aroma, texture, vision, and sound into one flavor experience.
- Sweetness is influenced by more than sugar concentration.

PRACTICAL IMPLICATION

Instead of increasing sugar, we can enhance aroma, texture, and mouthfeel to increase perceived sweetness.

KEY MESSAGE Flavor is constructed in the brain through multisensory integration.

Reference: Spence, C. (2015). Multisensory flavor perception. Cell, 161(1), 24–35.

2

EVIDENCE FROM RESEARCH

Perceptual Interactions in Flavor

Delwiche (2004)

ONE SENSORY ATTRIBUTE CHANGES ANOTHER

- Aroma
- Taste
- Texture
- Temperature

Brain → Flavor → Perceived Sweetness

EXAMPLES OF INTERACTIONS

Fruit aroma
↑ Fruity sweetness

Chocolate
↓ Bitterness
↑ Richness

Acidity
Balances sweetness
Reduces cloying taste

Creaminess
Makes beverages taste sweeter

KEY FINDINGS

- Sensory attributes interact.
- Changing one attribute influences another.
- Flavor should be designed as a system.

KEY MESSAGE

Sweetness depends on sensory interaction—not sugar alone.

Reference: Delwiche, J. (2004). The impact of perceptual interactions on perceive
Food Quality and Preference, 15(2), 137–146.

3

EVIDENCE FROM RESEARCH

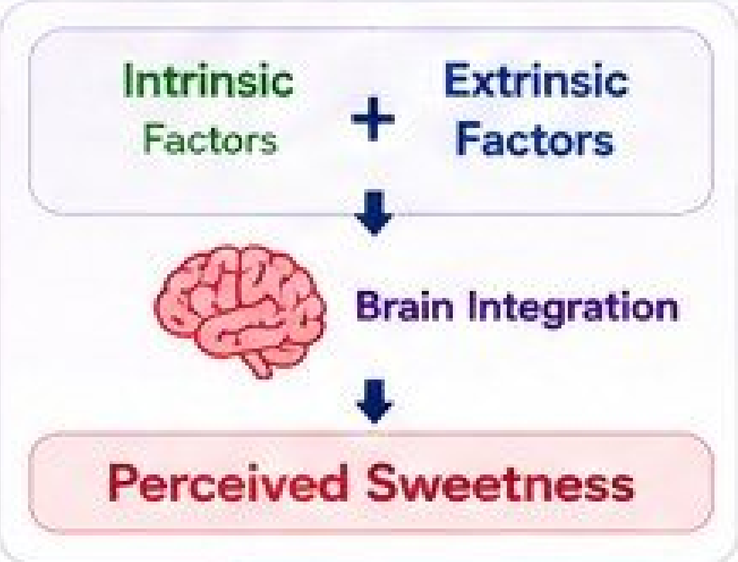
Intrinsic & Extrinsic Factors

Spence (2022)

SWEETNESS DEPENDS ON PRODUCT AND CONTEXT

INTRINSIC FACTORS (Product-related)

- Sweetener
- Aroma
- Acidity
- Mouthfeel
- Texture
- Temperature



EXTRINSIC FACTORS (Context-related)

- Color
- Package
- Glassware
- Music
- Environment

KEY FINDINGS

- Consumers do not evaluate sweetness from formulation alone.
- Expectation also changes sweetness perception.

PRACTICAL APPLICATION

Formula + Packaging + Color + Aroma = Better Acceptance

KEY MESSAGE Product design and sensory context work together.

Reference: Spence, C. (2022). The role of intrinsic and extrinsic sensory factors in sweetness perception. Food Quality and Preference, 100, 104606.

4

EVIDENCE FROM RESEARCH

Can Sound Change Sweetness?

Wang, Keller & Spence (2019)

YES—WHAT WE HEAR CHANGES WHAT WE TASTE

Sound
↓
Expectation
↓
Brain
↓
Taste Perception

SOUND	EFFECT ON FLAVOR PERCEPTION
High pitch (high frequency)	↑ Sweeter
Low pitch (low frequency)	↑ More bitter
Loudness	↑ Stronger intensity
Harmonious music	↑ Better liking

KEY FINDINGS

- Sound changes sweetness.
- Sound changes bitterness.
- Sound changes flavor intensity.
- Multisensory design improves eating and drinking experience.

INDUSTRIAL APPLICATION

- Restaurants
- Packaging
- Advertising
- Beverage experience

KEY MESSAGE What we hear changes what we taste.

Reference: Wang, Q. J., Keller, S., & Spence, C. (2019). Sounds spicy? Food Quality and Preference.

NATURAL SWEETENERS

Plant-derived options that support clean label and consumer demand

SWEETENER	SWEETNESS (vs. sucrose)	KEY ADVANTAGES	LIMITATIONS
Stevia (Reb A) 	200–300×	Natural origin (plant-based) Zero calories Heat stable (pH 3–9) Regulatory acceptance worldwide	Bitter / licorice aftertaste at high levels Taste can vary by brand
Monk Fruit Extract (Mogrosides) 	150–250×	Clean, pleasant sweetness Masks stevia aftertaste Natural origin Synergistic with other sweeteners	Higher cost Limited supply & availability
Erythritol 	60–70%	Provides bulk and mouthfeel Very low calories (0.2 kcal/g) Good digestive tolerance Stable in a wide pH range	Cooling sensation Lower sweetness than sugar May crystallize in some systems
Allulose 	~70%	Sugar-like taste and mouthfeel Browns & caramelizes like sugar Low calories (0.2 kcal/g) Supports clean label claims	Higher cost Lower sweetness than sugar Limited commercial availability

KEY MESSAGE

Natural sweeteners are rarely used alone.
They are often **blended to achieve a sugar-like sweetness profile** with minimal off-tastes.

KEY POINT

Consider source, sweetness intensity, taste quality, functionality, cost, and regulatory status.

APPLICATIONS

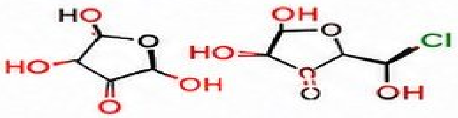
Beverages · Dairy · Confectionery · Nutrition

References:

- Magnuson, B. A., et al. (2016). Biological fate of low-calorie sweeteners. *Nutrition Reviews*, 74(11), 670–689.
- Prakash, I., et al. (2014). Development of Reb M sweetener. *Food and Chemical Toxicology*, 64, 75–82.
- O'Brien-Nabors, L. (2016). *Alternative Sweeteners* (5th ed.). CRC Press.

ARTIFICIAL SWEETENERS

High-intensity sweeteners widely used in the beverage industry

SWEETENER	SWEETNESS (vs. sucrose)	KEY ADVANTAGES	LIMITATIONS
Aspartame 	~200×	Excellent sugar-like taste Well established safety Good synergy with Ace-K and sucralose Low cost	Not heat stable (> 80°C) Not suitable for baking, UHT or extended storage
Sucralose 	~600×	Very high sweetness Clean, sugar-like taste Heat stable (up to 120–130°C) Stable over wide pH and storage	May show a slight lingering sweetness in some systems High intensity may suppress other flavors
Acesulfame Potassium (Ace-K) 	~200×	Fast sweetness onset Highly stable (heat, pH, light) Synergistic with other sweeteners Low cost	Slight bitter aftertaste when used alone Metallic note at high concentrations

WHY ARE THEY BLENDED?

Aspartame Excellent taste quality + **Sucralose** High stability & clean taste + **Ace-K** Fast onset & stability

BLEND = CLOSER TO SUCROSE

Better balance in intensity, onset, and lingering

KEY MESSAGE

Artificial sweeteners provide excellent sweetness efficiency and stability, but blending is essential to improve temporal sweetness and minimize off-tastes.

SAFETY & REGULATION

All approved artificial sweeteners are evaluated by international authorities (e.g., JECFA, EFSA, FDA) and are safe when used within ADI limits.

COMMON APPLICATIONS

- Soft drinks
- Flavored water
- Ready-to-drink products
- Functional drinks

References:

- Magnuson, B. A., et al. (2016). Biological fate of low-calorie sweeteners. *Nutrition Reviews*, 74(11), 670–689.
- EFSA Panel on Food Additives and Flavourings (FAF). (2023). Scientific opinions on food additives and sweeteners.
- O'Donnell, K., & Kearsley, M. W. (2012). Sweeteners and Sugar Alternatives in Food Technology (2nd ed.). Wiley-Blackwell.

Ingredient Strategies for Reduced-Sugar Beverage Development

Select the right strategy based on the **sensory challenge**—not just the sweetener.

SENSORY PROBLEM	RECOMMENDED STRATEGIES	HOW IT WORKS
BITTERNESS (e.g., stevia, protein hydrolysate, polyphenols)	✔ **Bitter blocker** (e.g., glycyrrhizin, thaumatin) ✔ **Sweetness enhancer** (e.g., thaumatin, brazzein) ✔ **Flavor modifier** (e.g., vanilla, licorice)	Suppresses bitter perception or shifts the taste balance toward sweetness.
BEANY / GREEN NOTE (e.g., soy, pea, plant protein)	✔ **Vanilla**, dairy flavor ✔ **Cocoa**, caramel, nutty flavor ✔ **Fruity aroma** (berry, citrus, tropical) ✔ **Fermentation** (e.g., LAB, yeast)	Aromas mask undesirable notes and redirect perception to more pleasant flavors.
METALLIC TASTE (e.g., minerals, iron, zinc)	✔ **Flavor masking** (e.g., citrus, fruit) ✔ **Acid balance** (citric acid, malic acid) ✔ **Chelating agents / mineral balance**	Masks metallic notes and balances the overall flavor harmoniously.
THIN MOUTHFEEL (LOW BODY) (e.g., low sugar, low solids)	✔ **Inulin**, soluble fiber ✔ **Pectin, CMC, HPMC** ✔ **Xanthan gum, guar gum** ✔ **Protein / plant protein**	Increases viscosity, body and creaminess to improve mouthfeel and sweetness perception.
LOW SWEETNESS (WEAK SWEET PERCEPTION)	✔ **Sweetness enhancers** (e.g., thaumatin, brazzein) ✔ **Sweet proteins** (thaumatin, mabinlin, monellin) ✔ **Flavor modulation** (vanilla, caramel) ✔ **Aroma enhancement**	Enhances perceived sweetness without adding more sugar or calories.
LONG AFTERTASTE (UNPLEASANT AFTERTASTE) (e.g., stevia, sucralose, acesulfame-K)	✔ **Sweetnesr blending** (stevia + sucralose, etc.) ✔ **Flavor masking** (vanilla, citrus, cocoa) ✔ **Acid optimization** ✔ **Taste modifiers**	Shortens and softens aftertaste, leaving a cleaner and more pleasant finish.






MODERN SUGAR REDUCTION MINDSET

Replace Sugar

Design Sweetness

Design the entire sweetness experience—not just the sweetener.

TOOLBOX SUMMARY

SENSORY CHALLENGE	RECOMMENDED STRATEGY
Bitterness	Bitter blocker + Sweetness enhancer
Beany / Green note	Vanilla + Cocoa + Fruity aroma
Metallic taste	Citrus flavor + Acid balance
Low sweetness	Sweet enhancer + Aroma enhancement
Thin mouthfeel	Hydrocolloid + Fiber + Protein
Long aftertaste	Sweetener blend + Flavor modifier + Acid

DECISION GUIDE

1. Identify sensory problem →
2. Select right strategy / ingredients →
3. Formulate & optimize →
4. Sensory test (Descriptive & Hedonic) →
5. Consumer acceptance improvement

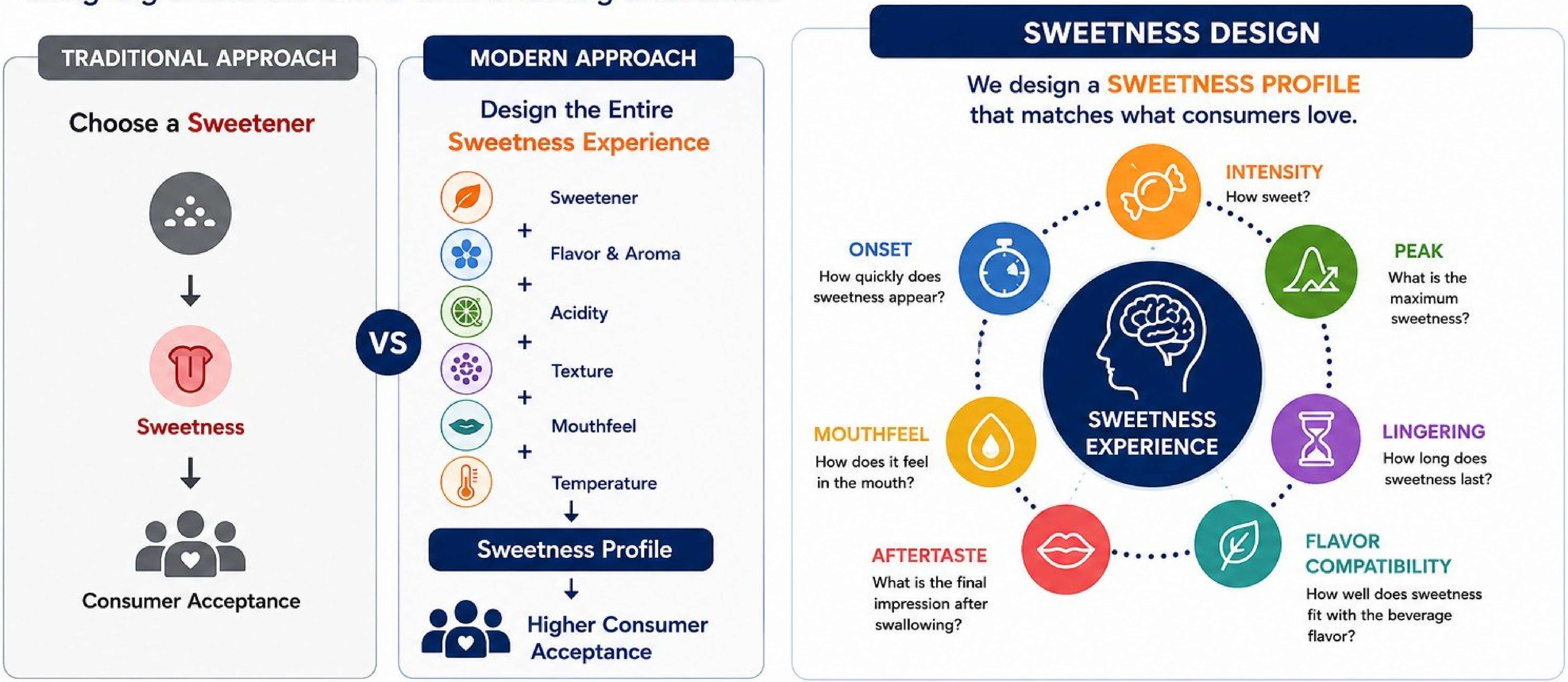
KEY MESSAGE

“ Successful sugar reduction is not about replacing sugar. It is about **designing the entire sweetness experience.**

References: Guentert, M. A. (2018). Flavorings with modifying properties. J. Agric. Food Chem., 66(15), 3735–3736. | Newman, J., O'Riordan, D., Jacquier, J. C., & O'Sullivan, M. (2015). LWT, 63, 751–757. Spence, C. (2015). Multisensory flavor perception. Cell, 161(1), 24–35. | Câmara, A. K. F. I., et al. (2023). Foods, 12, 4609.

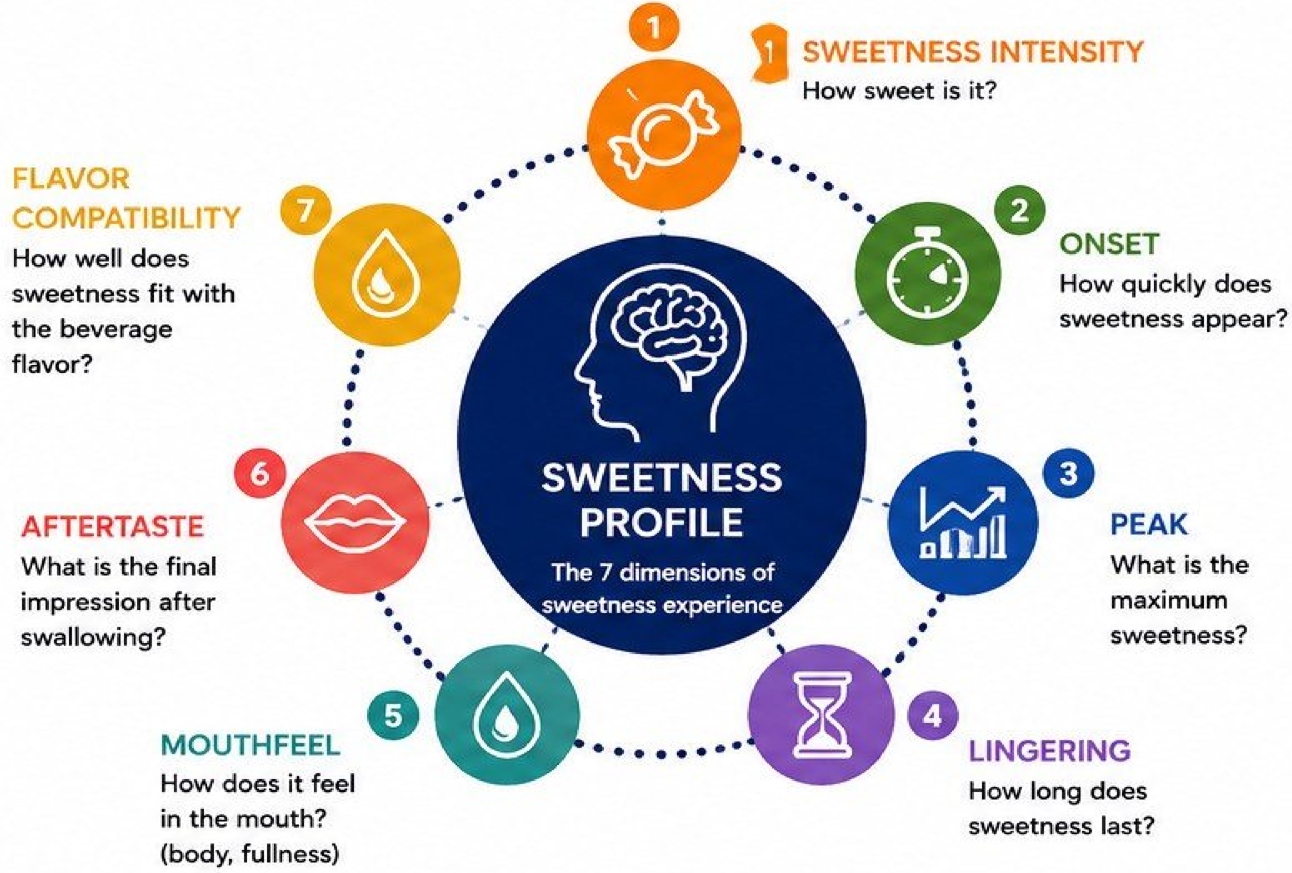
1. WHAT IS SWEETNESS DESIGN?

Designing Sweetness Rather than Choosing Sweeteners



2. COMPONENTS OF A SWEETNESS PROFILE

Sweetness is more than just how sweet. It's a complete experience.



THE BRAIN INTEGRATES ALL SIGNALS

Our brain integrates all these dimensions together to create the overall sweetness experience.

→ **PERCEIVED SWEETNESS**

WHAT EACH COMPONENT MEANS

COMPONENT	DESCRIPTION
1. SWEETNESS INTENSITY	The overall level of sweetness perceived at its highest point.
2. ONSET	The speed at which sweetness is first perceived after tasting.
3. PEAK	The maximum point of sweetness perceived.
4. LINGERING	The duration of sweetness that remains in the mouth.
5. MOUTHFEEL	The physical sensations such as body, fullness, thickness, and smoothness.
6. AFTERTASTE	The lingering taste (sweet or off-notes) after swallowing.
7. FLAVOR COMPATIBILITY	How well sweetness harmonizes with the beverage's flavor profile.

Designing sweetness means optimizing all 7 dimensions to create a balanced and pleasant sweetness experience.

3. WHY BLEND SWEETENERS?

No single sweetener can perfectly replicate sucrose.

NO SWEETENER IS PERFECT

Each sweetener has unique strengths and limitations.

High Intensity
But may have bitterness / aftertaste

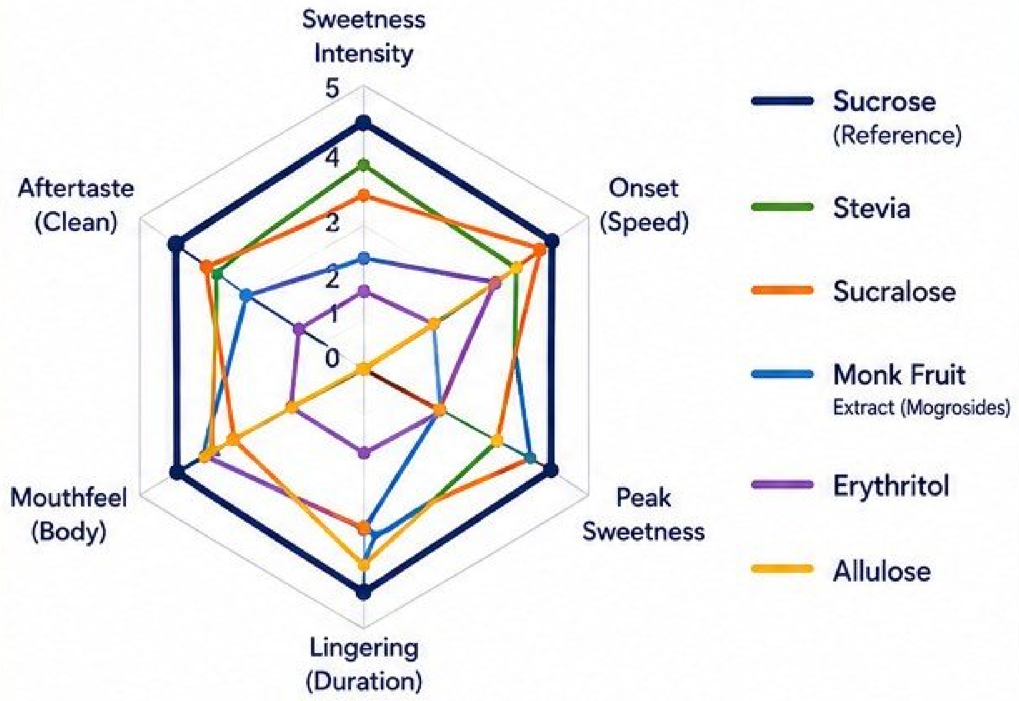
Fast Onset
But short lingering sweetness

Good Mouthfeel
But low sweetness intensity

Sugar-like Profile
But may be more expensive

BLENDING CREATES SYNERGY to overceme weaknesses and enhance strengths.

COMPARISON WITH SUCROSE (REFERENCE)



Sucrose provides the most balanced profile across all dimensions. Blending helps us get closer to this balance.

REASONS TO BLEND SWEETENERS

IMPROVE TASTE
- Reduce bitterness, metallic or licorice notes
- Achieve cleaner, more pleasant sweetness

BETTER TEMPORAL PROFILE
- Adjust onset, peak and lingering
- Create a longer-lasting sweetness

BETTER MOUTHFEEL
- Improve body, fullness and smoothness
- Compensate for thin or cooling effects

REDUCE COST
- Use high-intensity sweeteners in small amounts with bulking agents

ENHANCE STABILITY
- Improve stability in heat, pH, and storage conditions

MEET REGULATORY & LABEL CLAIMS
- Reformulate to meet sugar reduction, calorie or clean-label goals

4. PRACTICAL EXAMPLES OF SWEETENER BLENDS

Different blends, different strengths—design the sweetness profile you want.

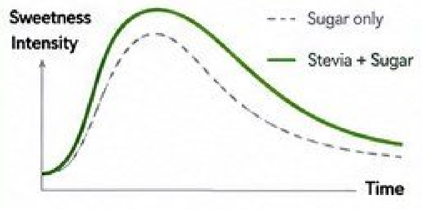
① STEVIA + SUGAR

Lower sugar, keep great sweetness

Stevia + Sugar (Sucrose)

- ✔ Sugar rounds off bitterness
- ✔ More natural taste & mouthfeel

Sweetness Profile Impact



Best For

Soft drinks · Fruit juice · Tea · RTD coffee & milk drinks

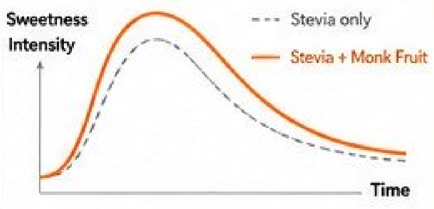
② STEVIA + MONK FRUIT

Reduce aftertaste, improve overall taste

Stevia + Monk Fruit Extract

- ✔ Monk fruit improves taste quality
- ✔ Less lingering bitter/metallic notes

Sweetness Profile Impact



Best For

Fruit beverages · Functional drinks · Yogurt drinks · Low-sugar tea

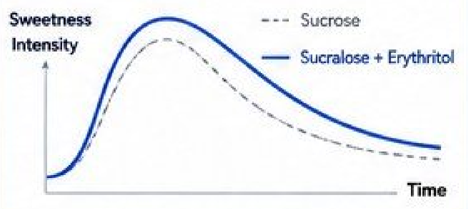
③ SUCRALOSE + ERYTHRITOL

Fast sweetness with better mouthfeel

Sucralose + Erythritol

- Sucralose provides high intensity
- Erythritol adds body & cooling balance

Sweetness Profile Impact



Best For

Clear beverages · Sugar-free soft drinks · Sports drinks · Energy drinks

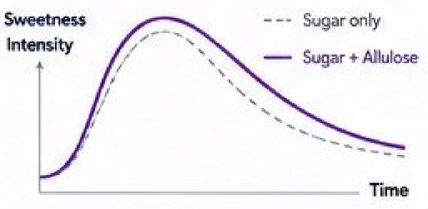
④ SUGAR + ALLULOSE

Sugar-like profile with fewer calories

Sugar (Sucrose) + Allulose

- Allulose mimics sugar's profile
- Reduces calories & helps browning

Sweetness Profile Impact



Best For

Bakery beverages · Coffee beverages · Dairy beverages · Dessert drinks

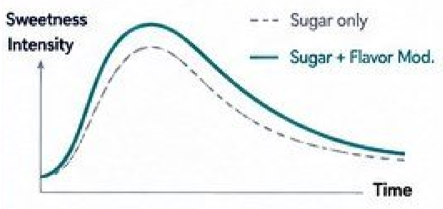
⑤ SUGAR + FLAVOR MODIFIER

Enhance perceived sweetness without adding more sugar

Sugar (Sucrose) + Flavor Modifier (e.g., vanillin)

- Flavor enhances sweetness perception
- Better flavor harmony & balance

Sweetness Profile Impact



Best For

Flavored milk · Chocolate drinks · Fruit flavored drinks · Botanical / herbal drinks

5. SWEET PROTEINS: THE NEXT GENERATION OF SWEETNESS

Natural protein-based solutions that enhance sweetness and improve overall flavor experience.

1 THAUMATIN

Nature's Sweetness Enhancer

SOURCE
Thaumatococcus daniellii fruit

SWEETNESS
2,000–3,000×
sweeter than sucrose

HEAT STABILITY
Up to 100°C

KEY BENEFITS

- Enhances sweetness and overall flavor
- Masks bitterness and off-notes (e.g., stevia, caffeine)
- Synergistic with other sweeteners (plant-based and artificial)

APPLICATIONS

- Beverages
- Dairy & plant-based products
- Confectionery & snacks
- Pharmaceuticals

USE LEVEL
10–300 ppm

TASTE IMPACT
Enhances sweetness, improves flavor balance

2 BRAZZEIN

Heat-Stable Natural Sweetness

SOURCE
Pentadiplandra brazzeana fruit

SWEETNESS
500–2,000×
sweeter than sucrose

HEAT STABILITY
Up to 100°C (pH 3–8)

KEY BENEFITS

- Extremely heat-stable (suitable for pasteurization and UHT processes)
- Natural origin, clean taste
- Sugar-like sweetness quality (less lingering aftertaste)

APPLICATIONS

- RTD beverages
- Dairy & plant-based drinks
- Frozen desserts
- Health & nutrition products

USE LEVEL
5–50 ppm

TASTE IMPACT
Provides clean, rounded sweetness with high stability

3 MIRACULIN

The Miracle Berry Protein

SOURCE
Synsepalum dulcificum fruit

SWEETNESS
NOT SWEET
(It is a taste modifier, not a sweetener)

HEAT STABILITY
Heat sensitive (< 60°C)

HOW IT WORKS

Sour / Acidic (e.g., lemon) → Miraculin binds to taste receptors → Perceived as Sweet

KEY BENEFITS

- Transforms sourness into sweetness
- Reduces need for added sugar in sour-based products
- Natural, exciting consumer experience

APPLICATIONS

- Citrus beverages
- Functional drinks
- Confectionery
- Taste-modification applications

USE LEVEL
50–300 mg

TASTE IMPACT
Does not add sweetness by itself, but changes taste perception

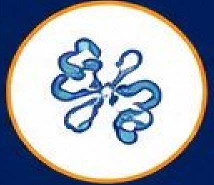
IMPORTANT NOTES

- These proteins are used in very low levels.
- They do not replace sugar completely, but enhance sweetness and improve overall flavor quality.
- Regulatory acceptance varies by country.

COMPARISON SUMMARY

	THAUMATIN	BRAZZEIN	MIRACULIN
Sweetness	2,000–3,000×	500–2,000×	Not sweet
Heat Stability	Up to 100°C	Up to 100°C (pH 3–8)	Heat sensitive (< 60°C)
Main Function	Enhancer / Bitterness masker	Clean sweetness / High stability	Taste modifier (sour → sweet)
Best For	Masking bitterness, enhancing flavor	Heat-treated beverages & dairy	Sour-based beverages & candies

THE ROLE OF SWEET PROTEINS



Sweet proteins are powerful tools for sweetness design—enhancing sweetness, masking off-notes, and creating unique taste experiences with less sugar.

Innovation today, better sweetness tomorrow.

6. DESIGNING THE IDEAL SWEETNESS PROFILE

Sweetness is not a single ingredient—it's a holistic design.

BEYOND SWEETENER SELECTION

TRADITIONAL MINDSET		MODERN MINDSET
Replace Sugar	VS	Design Sweetness
Focus on one ingredient (Sweetener)		Focus on the whole sweetness experience

SWEETNESS DESIGN PRINCIPLES

CONSUMER-CENTRIC
Start from consumer preference and target sweetness experience.

MULTI-DIMENSIONAL
Balance intensity, time, mouthfeel, aftertaste and flavor compatibility.

SYNERGISTIC BLENDING
Combine sweeteners, modifiers and other factors for synergy.

BALANCE IS THE KEY
Trade-offs must be balanced to achieve the best profile.

SCIENCE + CREATIVITY
Use data and sensory insights to drive formulation success.

THE SWEETNESS DESIGN EQUATION

Sweetener (Intensity) + Flavor Modifiers (Perception) + Acidity (Balance) + Mouthfeel & Body + Texture (Structure) + Temperature + Aroma & Flavor (Compatibility)

- **Sweetener (Intensity)**: Provide sweetness intensity
- **Flavor Modifiers (Perception)**: Enhance perceived sweetness, mask off-notes
- **Acidity (Balance)**: Balance sweetness and enhance brightness
- **Mouthfeel & Body**: Improve body, fullness and creaminess
- **Texture (Structure)**: Affect sweetness release and persistence
- **Temperature**: Influence sweetness perception and release
- **Aroma & Flavor (Compatibility)**: Create harmony and liking

↓

OPTIMIZED SWEETNESS PROFILE

Proper Intensity · Good Onset · Pleasant Peak · Appropriate Lingering · Desirable Mouthfeel · Clean Aftertaste · Flavor Compatibility

↓

CONSUMER ACCEPTANCE

Great Taste • Lower Sugar • Better for You

HOW TO DESIGN: A STEPWISE APPROACH

1. **Define Target**
   What level of sweetness and what kind of experience?
2. **Select Sweetness Tools**
   Choose sweeteners, modifiers, acidity, flavors, textures.
3. **Formulate & Blend**
   Design the blend and adjust each component.
4. **Test & Evaluate**
   Use sensory + instrumental analysis to optimize.
5. **Validate & Scale**
   Confirm stability, cost, regulatory and scale-up.

EXAMPLE OUTCOME

- 30–50% less sugar
- Similar sweetness vs. sucrose
- Fullness and balance
- Clean taste with no aftertaste
- High consumer liking

Part 5: Case Studies of Successful Reduced-Sugar Beverage Formulations

Real-world applications of flavor science to solve sensory challenges and drive consumer acceptance.

OBJECTIVE

How can flavor science be translated into commercially successful reduced-sugar beverages?

CASE STUDY 1

30% Sugar Reduction

- Maintain sweetness and flavor
- Improve overall acceptance

Sweetener + Aroma + Acid balance

CASE STUDY 2

High-Protein Beverage

- Mask bitterness
- Enhance mouthfeel and acceptance

Flavor modulation (sweeteners, aroma, acid balance, bitter blocker)

CASE STUDY 3

Vitamin Beverage

- Reduce metallic taste
- Improve freshness and likability

Citrus + Acid balance + Flavor masking

CASE STUDY 1

30% Sugar Reduction in RTD Fruit Beverage

Maintaining sweetness through integrated flavor design

1 CHALLENGE

Ready-to-Drink Fruit Beverage

↓

Reduce sugar by 30%

↓

Maintain sweetness, fruit flavor and overall liking

2 FORMULATION STRATEGY

Sugar Reductiok
Reduce sugar by 30% (from 100% to 70%)

↓

Stevia Blend
High-intensity sweetener for sweetness

↓

Natural Flavor (Vanilla)
Enhances perceived sweetness via aroma-taste interaction

↓

Citric Acid Optimization
Balances taste and enhances freshness

↓

Flavor Modulation
Supports sweetness and rounds the flavor profile

↓

Optimized Sweetness Profile
Balanced taste & high acceptance

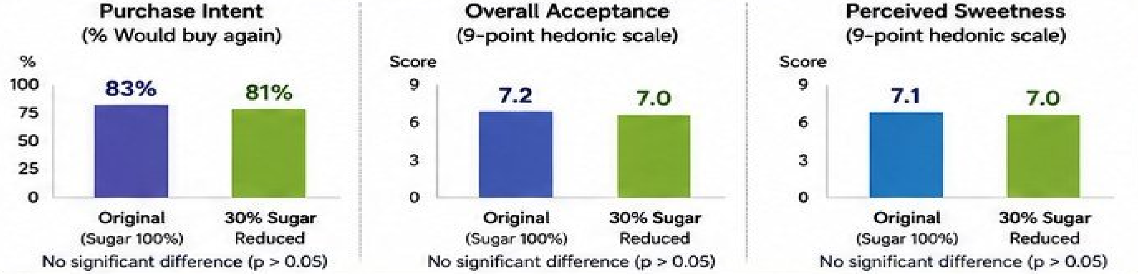
3 RESULTS (vs. Original Formula)

SENSORY OUTCOME (Capital Liking Test)

ATTRIBUTE	ORIGINAL (Sugar 100%)	30% SUGAR REDUCED (Optimized Formula)	CHANGE
Sugar Content	100%	70%	↓ 30%
Sweetness Perception	★★★★★	★★★★☆	≈ No significant difference
Fruity Flavor Intensity	★★★★★	★★★★★	≈ No significant difference
Overall Liking	★★★★★	★★★★☆	≈ No significant difference

* Rating scale: 1 (Disilke extremely) – 9 (Like extremely)
≈ No significant difference at $p > 0.05$ (paired t-test)

CONSUMER ACCEPTANCE (n = 120)



KEY TAKEAWAY

Successful sugar reduction is achieved by designing the whole sweetness system—not by simply replacing sugar.

Sweetener (Intensity) + **Flavor** (Aroma–Taste) + **Acid Balance** (Freshness) + **Sensory Optimization** (Overall Harmony) = **High Acceptance & Better Choice**

REFERENCES

- Ares, G., Antúnez, L., Vidal, L., et al. (2016). Consumer acceptance of sugar-reduced beverages: Sensory optimization strategies. Food Quality and Preference, 52, 1–10.
- Spence, C. (2015). Multisensory flavor perception. Cell, 161(1), 24–35.

Results & Takeaways

30% Sugar Reduction in RTD Fruit Beverage

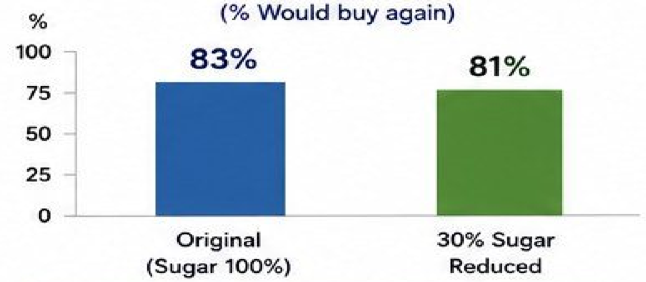
1 SENSORY OUTCOME (Capital Liking Test)

ATTRIBUTE	BEFORE (Original: Sugar 100%)	AFTER (30% Sugar Reduced)	CHANGE
Sugar Content	100%	70%	↓ 30%
Sweetness Perception	★★★★★	★★★★☆	≈ No significant difference
Fruity Flavor Intensity	★★★★★	★★★★★	≈ No significant difference
Overall Liking	★★★★★	★★★★☆	≈ No significant difference

★ Rating scale: 1 (Dislike extremely) – 9 (Like extremely)
≈ No significant difference at $p > 0.05$ (paired t-test)

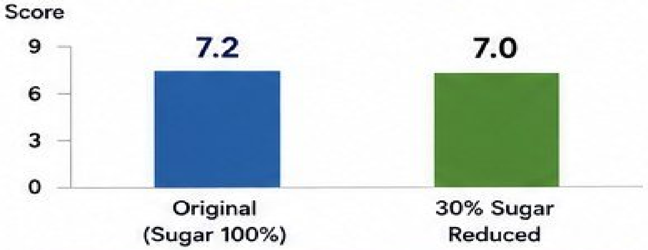
2 ILLUSTRATIVE CONSUMER TEST RESULTS (n = 120)

PURCHASE INTENT
(% Would buy again)



No significant difference at $p > 0.05$

OVERALL ACCEPTANCE
(9-point hedonic scale)



No significant difference at $p > 0.05$

3 WHY IT WORKED

Stevia Blend
Delivers sweetness with minimal calories.

Vanilla Aroma
Enhances perceived sweetness through aroma–taste interaction.

Citric Acid Optimization
Keeps flavor bright and well balanced.

Flavor Modulation
Rounds the taste and reduces sensory gap caused by sugar reduction.

4 KEY TAKEAWAY

A combination of sweeteners, aroma, acid balance, and flavor modulation can achieve **meaningful sugar reduction** while maintaining consumer acceptance and product quality.

REFERENCES

- Ares, G., Antúnez, L., Vidal, L., et al. (2016). Consumer acceptance of sugar-reduced beverages: Sensory optimization strategies. *Food Quality and Preference*, 52, 1–10.
- Spence, C. (2015). Multisensory flavor perception. Cell, 161(1), 24–35.

Masking Bitterness in High-Protein Beverages

1 CHALLENGE

Product: High-Protein Beverage (Whey protein / Plant protein)

Common Off-Flavors

Protein Hydrolysate
(or Plant Protein)

↓

Bitterness
Astringency
Chalkiness
Long Aftertaste

↓

Low Consumer Acceptance

Why?

Protein hydrolysates generate hydrophobic peptides, which strongly activate bitter taste receptors (T2Rs).

Plant proteins may also contribute beany, grassy, and earthy notes due to lipid oxidation products and volatile compounds.

Examples of Protein Ingredients & Typical Sensory Issues

Protein Ingredient	Typical Sensory Issue
Whey Protein Hydrolysate	Bitterness
Soy Protein	Beany, earthy
Pea Protein	Green / grassy note
Rice Protein	Chalky mouthfeel

KEY MESSAGE

Protein is nutritionally valuable, but sensory quality often limits consumer acceptance.

References

- Nieman, A., O'Riordan, D., Jaczynski, J. C., & O'Sullivan, M. (2018). Masking off-flavors in dairy protein hydrolysates: Comparison of an electronic tongue and a trained sensory panel as means of directing the masking strategy. LWT - Food Science and Technology, 91, 751–757.
- Gupta, R., Abu-Ghannam, N., & Gallagher, E. (2017). Protein hydrolysates as functional food/bioactive ingredients and sensory evaluation. Compr. Rev. Food Sci. Food Saf., 16, 1203–1218.

CASE STUDY 2

Solution Strategy – *Flavor Modifying Toolbox*

Bitterness in High-Protein Beverage

Vanilla Flavor

Aroma masking & sweetness enhancement through aroma–taste interaction

+

Sweetness Enhancer

- Thaumatin
- Sweet protein
- Monk fruit extract

Boosts perceived sweetness without calories

+

Bitter Blocker (Taste Modifier)

Interacts with bitter receptors and reduces bitterness at receptor level (e.g., Complex flavors, peptide modifiers)

+

Mouthfeel Enhancer

- Inulin
- Pectin
- Xanthan gum
- Gums

Adds body, creaminess, and richness

→ **Better Flavor Profile & Higher Acceptance**

KEY TAKEAWAY

A synergistic combination of flavor masking, sweetness enhancement, bitter blocking, and mouthfeel improvement is more effective than relying on a single strategy.

Aroma + Sweetness + Bitter Blocker + Mouthfeel → Great Taste & Acceptance

References

- Newman, J., O'Riordan, D., Jacquier, J. C., & O'Sullivan, M. (2015). Masking of bitterness in dairy protein hydrolysates: Comparison of an electronic tongue and a trained sensory panel as means of directing the masking strategy. *LWT – Food Science and Technology, 63*, 751–757.
- Gupta, R., Abu-Ghannam, N., & Gallagher, E. (2017). Protein hydrolysates in functional foods: Flavor, bitterness, and sensory evaluation. *Compr. Rev. Food Sci. Food Saf., 16*, 1203–1218.

CASE STUDY 2

Sensory Outcome & Consumer Acceptance

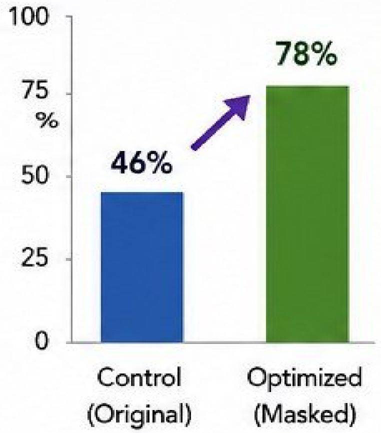
A. Trained Panel Results (n = 12)

Attribute (Scale 0–10)	CONTROL (Original)	OPTIMIZED FORMULA (Masked)	CHANGE
Bitterness Intensity (0 = none, 10 = strong)	7.2 ± 1.1	2.4 ± 0.9	↓ 67%
Sweetness Perception (0 = none, 10 = strong)	5.1 ± 1.2	7.6 ± 1.0	↑ 49%
Mouthfeel / Body (0 = weak, 10 = rich)	4.3 ± 1.0	7.2 ± 1.1	↑ 67%
Overall Liking (9-point hedonic scale)	5.6 ± 1.3	7.6 ± 1.1	↑ 36%

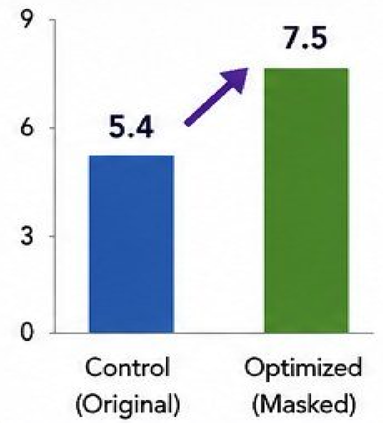
Statistical analysis: Significant difference at $p < 0.05$ (paired t-test)

B. Consumer Test Results (n = 120)

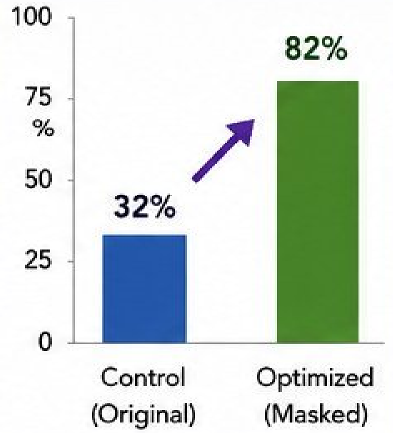
Purchase Intent
(% Would buy)



Overall Acceptance
(9-point hedonic scale)



Bitterness Acceptability
(% Acceptable)



✔ **Consumers significantly preferred the optimized formula in terms of flavor, mouthfeel, and overall liking, leading to higher purchase intent.**

TAKE-HOME MESSAGE

Successful protein beverages are created by balancing sweetness, bitterness, aroma, and mouthfeel—not by simply adding more sweetener.
A well-designed flavor system leads to high acceptance and repeat purchase.

References

- Newnam, J., O'Riordan, D., Jacquier, J. C., & O'Sullivan, M. (2018). Masking of bitterness in dairy protein hydrolysates: Comparison of an electronic tongue and a trained sensory panel as means of directing the masking strategy. *LWT – Food Science and Technology*, 91, 751–757.
- Gupta, R., Abu-Ghannam, N., & Gallagher, E. (2017). Protein hydrolysates in functional foods: Flavor, bitterness, and sensory evaluation. *Compr. Rev. Food Sci. Food Saf.*, 16, 1203–1218.

CASE STUDY 3

Reducing Metallic Taste in Vitamin Beverages

Using citrus flavor, acid balance, and flavor masking to improve taste and acceptance

1 CHALLENGE

Vitamin C & Mineral Beverage
(Iron, Zinc, etc.)

↓

Metallic Taste
(Bitter, sharp, lingering)

↓

Consumer Rejection
(Low acceptance & repurchase)

Why Does Metallic Taste Occur?

- Fe – Iron salts
- Zn – Zinc salts
- Cu – Copper ions
- High mineral concentration

→ Activate metallic sensation ↓ Mask fruit flavor ↓ Decrease freshness & liking

2 SOLUTION STRATEGY

Metallic Taste → Citrus Flavor + Acid Balance + Flavor Masking → Cleaner Flavor Profile

- **Citrus Flavor** ↓ Strong citrus aroma competes with and suppresses metallic perception
- **Acid Balance** ↓ Citric acid balances acidity and rounds harsh mineral notes
- **Flavor Masking** ↓ Flavor masking agents suppress residual metallic aftertaste and off-notes
- **Cleaner Flavor Profile** ↓ **Higher Acceptance & Repeat Purchase**

KEY MESSAGE

Citrus aroma and acid optimization effectively reduce metallic perception while maintaining a fresh and clean flavor profile.

3 EXPECTED IMPACT

- Lower metallic perception
- Better sweetness and fruitiness
- Improved freshness and mouthfeel
- Higher consumer liking and repeat purchase

REFERENCES

- Keast, R. S. J., & Breslin, P. A. S. (2003). An overview of binary taste–taste interactions. *Food Quality and Preference*, 14, 111–124.
- Lawless, H. T., & Heymann, H. (2010). *Sensory Evaluation of Food: Principles and Practices* (2nd ed.). Springer.

Sensory Outcome & Why Citrus Works

Using citrus flavor, acid balance, and flavor masking to reduce metallic taste and improve acceptance.

3 SENSORY OUTCOME (Trained Panel, n = 12)

Before (Control) | After (Optimized Formula)

Attribute (Scale 0–10)	Before (Control)	After (Optimized)	Change
Metallic Intensity (0 = none, 10 = very strong)	7.3	2.1	↓ 71%
Freshness (0 = none, 10 = very fresh)	3.1	7.2	↑ 132%
Overall Liking (9-point hedonic scale)	4.6	7.3	↑ 59%

Statistical analysis: Significant difference at $p < 0.05$ (paired t-test)

4 WHY CITRUS WORKS

Strong Citrus Aroma

Citrus volatile compounds compete with metallic perception in the retronasal pathway.

Citric Acid Balance

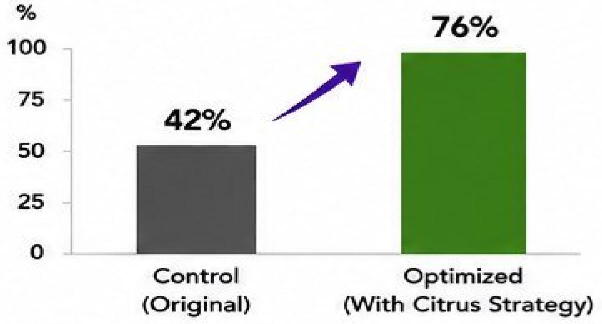
Balances acidity, enhances fruit character, and reduces sharpness of mineral salts.

Flavor Masking

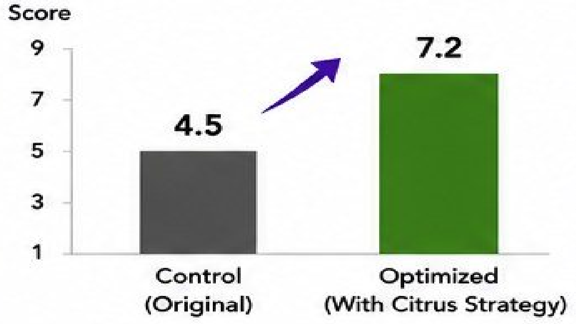
Flavor masking agents suppress residual metallic aftertaste and improve overall flavor harmony.

5 ILLUSTRATIVE CONSUMER TEST RESULTS (n = 120)

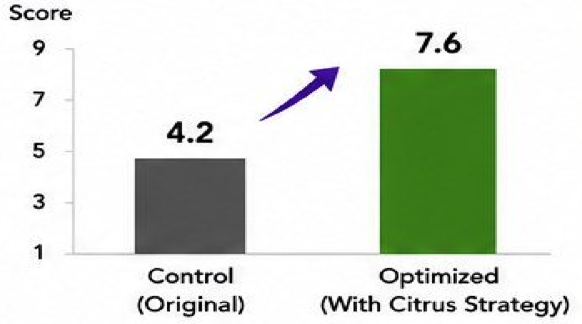
Purchase Intent (% Would buy)



Overall Acceptance (9-point hedonic scale)



Perceived Freshness (9-point hedonic scale)



6 KEY LEARNING

Flavor masking and acid optimization are effective strategies for minimizing metallic taste in fortified beverages, leading to higher consumer acceptance and satisfaction.

References

- Keast, R. S. J., & Breslin, P. A. S. (2003). An overview of binary taste–taste interactions. *Food Quality and Preference*, 14, 111–124.
- Lawless, H. T., & Heymann, H. (2010). *Sensory Evaluation of Food: Principles and Practices* (2nd ed.). Springer.

INDUSTRIAL SUCCESS STORIES

5 Leading Brands. 5 Different Challenges. 1 Common Goal.

How global beverage leaders use flavor science to deliver great taste with less sugar.

Coca-Cola Zero Sugar

MAIN CHALLENGE

Match the great taste of Coca-Cola Original with zero sugar.

FLAVOR SCIENCE STRATEGY

Optimize a blend of non-caloric sweeteners and specialized flavor compounds to closely replicate the signature taste and refreshment.

KEY LESSON

Sweetener alone is not enough. Flavor optimization is essential.

Source: The Coca-Cola Company (2021). Zero Sugar reformulation and taste improvement.

Pepsi Zero Sugar

MAIN CHALLENGE

Deliver the bold, intense cola taste consumers expect—without sugar.

FLAVOR SCIENCE STRATEGY

Use a proprietary sweetener blend and flavor system to maintain the balance of sweetness, acidity, and cola notes.

KEY LESSON

Matching the original taste is the key to consumer acceptance.

Source: PepsiCo (2021). Pepsi Zero Sugar product information.

Yakult Light

MAIN CHALLENGE

Reduce sugar while maintaining the unique taste and refreshing character of Yakult.

FLAVOR SCIENCE STRATEGY

Adjust sweetness—acidity balance to keep the signature taste, smooth mouthfeel, and refreshing finish.

KEY LESSON

Sweetness is not only about sweeteners—acid balance is equally important.

Source: Yakult Honsha Co., Ltd. (2020). Yakult Light product information.

Nestlé Milo Less Sugar

MAIN CHALLENGE

Reduce sugar content while keeping the signature chocolate malt taste kids love.

FLAVOR SCIENCE STRATEGY

Enhance cocoa aroma and malt notes to boost perceived sweetness and maintain richness and mouthfeel.

KEY LESSON

Aroma intensity can compensate for sweetness reduction and strengthen indulgent taste.

Source: Nestlé (2021). MILO Less Sugar product communication.

Danone HiPRO

MAIN CHALLENGE

Manage protein bitterness and ensure great taste with high protein content.

FLAVOR SCIENCE STRATEGY

Use flavor masking, aroma modulation, and mouthfeel optimization to reduce bitterness and enhance creaminess.

KEY LESSON

Protein beverages need bitterness management and texture optimization.

Source: Danone (2022). HiPRO product information.

Successful sugar reduction is achieved by designing the entire sweetness system—where science, creativity, and consumer insight come together.

REFERENCES

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Conclusions