Optimization of coffee milk formulation using a mixture design

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Background

• Designed experiments provide the product developer feedback on the relationship between formulation variables and consumer acceptability (e.g., a multivariate physicohedonic function). While actionable, this approach assumes a linear psychophysical relationship between concentration and sensation (eg Keast & Hayes, 2011).

• Critically, this assumption may not be valid, especially in cases where perceptual interactions may occur, when a single ingredient may contribute more than one sensory attribute, or when individuals perceive similar intensities from different physical concentrations. The third case is seen for many non-nutritive sweeteners: in the asymptotic portion of the dose response curve, adding more AceK will not increase sweetness.

• Thus, additional information can be gained by considering the psychohedonic (sensation-liking) function, as ingredients can influence more than one attribute. For example, perceived sweetness and creaminess are much better predictors of liking that fat and sucrose concentration (Hayes & Duffy 2008).

• Here, we compare two different models for a coffee flavored beverage:

Classical (Physicohedonic) Formulation Model:

Concentration ⟶ Liking

Multipart (Psychophysical / Psychohedonic) Formulation Model:

Concentration ⟶ Intensity ⟶ Liking

Objective: This study was originally designed to optimize formulation of a new beverage (a coffee flavored milk) for retail sale in a campus facility. Here, we explore the insight gained from moving beyond a physicohedonic model to a multipart model that considers psychophysical and psychohedonic relationships separately.

Methods

Twenty milk-based coffee beverages were formulated using a mixture design in eChip software that varied the amount of coffee syrup, milk, sugar and water. The exact composition of each formula is shown in Table 1. A constant amount of pectin (0.2%) was added to all samples.

Overall liking was assessed by 388 consumers on a standard 9-point hedonic scale. Formulas were presented in an incomplete block design, so that each participant evaluated 4 out of 20 possible products. Of these 388 consumers, 256 also rated the samples for intensity of *coffee flavor*, *milk flavor*, *sweetness* and *thickness* on continuous line scales (0-100). Other data (JAR, ideal point, segmentation variables) were collected but are not reported here. All data were collected via Compusense *five* (Guelph ONT).

Procedures were exempted from IRB review by the Penn State Office of Research Protections staff under the wholesome foods exemption in 45 CFR 46.101(b)(6). Participants provided implied informed consent and were compensated for their time.

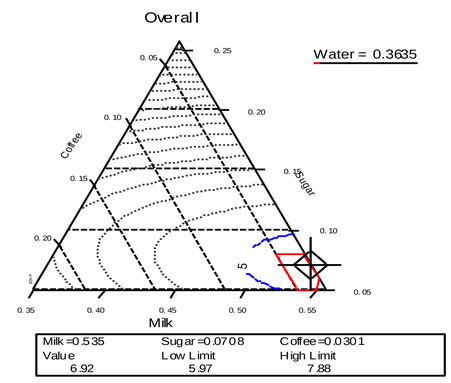
Mean liking and intensity across all consumers yielded an optimal formulation. Two separate regression models were conducted to test effects of formulation variables and perceived intensity on liking ratings.

Table 1. Formulations

Formula	Milk	Water	Coffee	Sugar
1	0.36	0.55	0.04	0.05
2	0.45	0.45	0.04	0.05
3	0.37	0.55	0.03	0.05
4	0.54	0.35	0.03	0.08
5	0.35	0.52	0.05	0.08
6	0.35	0.55	0.05	0.05
7	0.45	0.44	0.05	0.07
8	0.36	0.55	0.03	0.07
9	0.54	0.35	0.03	0.08
10	0.55	0.35	0.05	0.05
11	0.45	0.45	0.03	0.08
12	0.55	0.35	0.04	0.07
13	0.55	0.37	0.03	0.05
14	0.35	0.54	0.03	0.08
15	0.52	0.35	0.05	0.08
16	0.55	0.35	0.04	0.07
17	0.35	0.54	0.03	0.08
18	0.35	0.55	0.05	0.05
19	0.37	0.55	0.03	0.05
20	0.35	0.53	0.04	0.08

Results

Finding 1: Optimal Formula from eCHIP Software



Finding 2: In the classical physicohedonic model, amount of sugar and milk significantly predicted liking, while amount of coffee syrup did not.

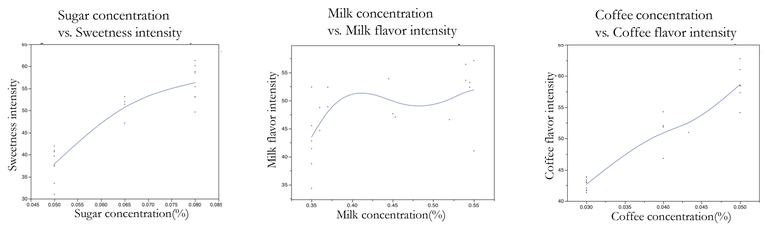
Concentration ⟶ Liking



In the physicohedonic model, concentration variables (amount of coffee syrup, milk, and sugar) explained 52% of the variance in liking in main effects multiple regression (p=0.0075). The amount of sugar (β= 0.46) and milk (β= 0.46) contributed significantly to the model (p's <0.02) while coffee syrup (β = -0.17) did not (p =0.35). Amount of sugar and milk were equally important to consumer liking in this model. Although not significant, greater amounts of coffee syrup seemed to negatively influence liking.

Finding 3: As expected, concentration predicts perceived intensity.

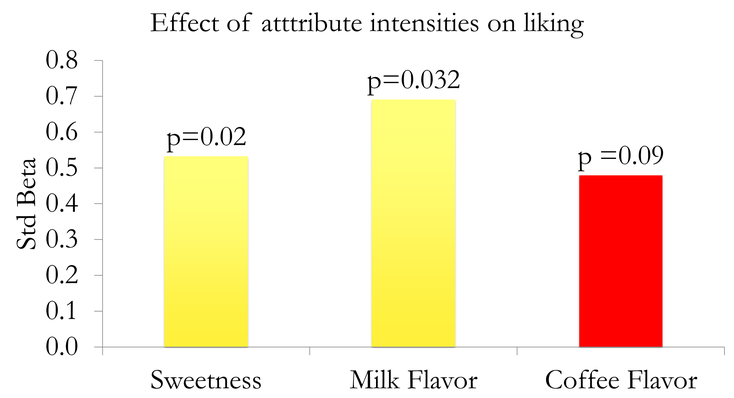
Concentration ⟶ Intensity ⟶ Liking



Results Continued

Finding 4: Modeling liking as a function of perceived intensity reveals a different picture

Concentration ⟶ Intensity ⟶ Liking



In the psychohedonic model based on perceived intensity (rated sweetness, milk flavor and coffee flavor), the variance in consumer liking explained was 63% (p=0.001). Perceived *sweetness* (β= 0.53) and *milk flavor* (β= 0.69) contributed significantly to the model (p's <0.04), and *coffee flavor* (β= 0.48) was marginal (p =0.09). In contrast to the formulation (physicohedonic) model, *milk flavor* had a larger influence on liking than *sweetness*. More critically, the effect for coffee was in the opposite direction from the formulation model. More *coffee flavor* resulted in greater liking.

Discussion

• Here, the psychohedonic model explained more variance in liking than the physicohedonic model, consistent with prior results (Hayes & Duffy 2008). That perceived intensities are a better predictor of liking than formulation is entirely expected, as perceived intensity is presumed to mediate the relationship between concentration and liking. Notably, a physicohedonic model cannot account for complex stimuli, nonlinear dose response functions, or individual differences.

• We found there influence of coffee changed dramatically across the two models. In the psychohedonic model, samples with more *coffee flavor* were liked more, while in the physicohedonic model, adding more coffee syrup either had no effect, or may haven even decreased liking. Informal tasting revealed that more coffee syrup increased *bitterness* in addition to *coffee flavor*. We failed to ask consumers to rate *bitterness*, and we thus unable to model it's effect on liking directly.

• Naïve, untrained consumers were able to make intensity ratings that provided useful insight, further blurring the classical distinction between affective consumer tests and trained panelists.

Take Home Message

Product developers and sensory specialists should always remember single ingredients may influence more than one perceptual attribute. Here, adding more coffee syrup not only increases coffee flavor but also bitterness. Measuring coffee flavor independently from amount of coffee syrup revealed additional information, allowing the sensory specialist to give better feedback to the product developer.

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