# FACTORS INFLUENCING CONSUMER PERCEPTION AND ACCEPTANCE OF STEVIA-SWEETENED ICE CREAM BEYOND INTRINSIC CUES

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## ABSTRACT

FACTORS INFLUENCING CONSUMER PERCEPTION AND ACCEPTANCE OF STEVIA-SWEETENED ICE CREAM BEYOND INTRINSIC CUES

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A wealth of research exists concerning the role of intrinsic attributes of ice cream (e.g. flavor, texture, appearance) on consumer acceptability; however, the importance of extrinsic product cues has not been as deeply discussed. Two studies explored the influence of extrinsic factors on consumer perception of naturally sweetened ice cream. The objectives of the first study were to 1) determine how consumers value label factors in evaluating ice cream, 2) identify an ideal target market for stevia-sweetened ice cream, and 3) investigate the relationship between consumer knowledge of sweeteners and perception of stevia-sweetened ice cream. Conjoint analysis revealed that sweetener type was the most important factor in consumers' liking and purchase intent of naturally sweetened ice creams. K-means clustering identified three distinct consumer clusters, one of which showed a strong preference for stevia. Consumers with higher knowledge of sweeteners were found to be more receptive to stevia-sweetened ice cream than those with low knowledge. The second study aimed to extend a proposed lighting-food temperature congruency effect to a cold food (i.e. ice cream). Adult ice cream consumers (n=136) evaluated four vanilla ice cream samples under warm or cold light. There was no significant main effect of lighting temperature ($P>0.05$). However, a significant interaction between lighting temperature and familiarity was found; when familiarity was high, warm lighting improved evaluations of overall and flavor liking ($P<0.001$). Findings do not support a lighting-food temperature congruency effect and instead corroborate existing evidence that warm lighting may improve food acceptability.

This thesis is dedicated to my boys, Louie and Finn. Thank you for the much-needed love and laughs.

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# CHAPTER 1: LITERATURE REVIEW

The importance of intrinsic sensory attributes of food—flavor, texture, aroma—on hedonic evaluation is well-documented; however, these factors provide only a partial framework for explaining consumer preferences and behaviors. Extrinsic attributes—those that are externally related to the food—are also instrumental in determining how consumers perceive food. The environmental context, or ambience, of an eating experience is composed of factors of the surrounding area that are extrinsic to the food (Stroebele & De Castro, 2004). These factors may include music (Kantono et al., 2016; Xu et al., 2019), serving dishes (Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012; Piqueras-Fiszman & Spence, 2012), package labels (Mueller & Szolnoki, 2010; Palazzo & Bolini, 2017; Peres, Esmerino, Silva, Racowski, & Bolini, 2018; Romano, Rosenthal, & Deliza, 2015; Sakagami, Sato, & Ueta, 2006; Sutterlin & Siegrist, 2015), and lighting (Biswas, Szocs, Chacko, & Wansink, 2017; Cho et al, 2015; Hasenbeck et al., 2014; Horska & Bercik, 2014; Oberfeld, Hecht, Allendorf, & Wickelmaier, 2009; Otterbring, Lofgren, & Lestelius, 2014; Tsujimura & Yanagisawa, 2015). The research presented in this thesis will focus on the latter two attributes—packaging labels (Manuscripts 1 and 2) and lighting (Manuscript 3).

## 1.1 Packaging labels

The attributes that consumers consider most important to product quality and enjoyment vary among different foods. For instance, sweetness and creaminess are highly valued sensory attributes for ice cream. However, the components responsible for these desirable attributes—namely fat and sugar—are known to increase the risk of adverse health effects, including obesity, hypertension, and Type 2 diabetes (Bowman et al., 2017; Malik, Popkin, Bray, Després, & Hu,

2010). A Mintel (2018) market research report found that, after sugar-sweetened beverages, desserts were a top concern among consumers as sources of added sweeteners. In 2017, U.S. sales of ice cream and frozen novelties exceeded $13 billion (Frozen & Refrigerated Buyer, 2018); by 2022, this figure is forecasted to increase by 14.7% (Mintel, 2018). The ice cream industry has directed its focus toward the growing category of "healthy indulgence" or "guilt-less" treats, which offer low-calorie, low-sugar, and high-protein options to satisfy sweet cravings (Kennedy, 2018). One relatively new solution that ice cream producers are leveraging to meet these goals is stevia. Stevia is a zero-calorie sweetener that is extracted from the leaves of the *Stevia rebaudiana* plant (Ashwell, 2015). Unlike the majority of non-nutritive sweeteners currently used in the U.S., stevia is of natural rather than artificial origin (FDA, 2018). Natural ingredients are generally viewed more favorably by consumers, who believe them to be safer and healthier than artificial alternatives (Rozin, 2006).

Despite stevia's status as a natural non-nutritive sweetener, consumers are hesitant to consume products containing stevia. Stevia sweeteners are often associated with bitterness or lingering sweet taste that consumers find unappealing (Espinoza et al., 2014). Innovations in extraction and processing methods have been successful in greatly improving sensory qualities (Chranioti, Chanioti, & Tzia, 2016; Formigoni et al., 2018), but negative prior experiences with stevia may prevent consumers from trying it again. Another obstacle to stevia acceptance is low familiarity. In the U.S., stevia may appear on food ingredient lists as "stevia extract," "steviol glycosides," "rebaudioside A," or other variations, making it difficult for consumers to readily identify on labels. Further, although they are seeking more natural sweeteners, consumers may be overlooking stevia entirely—a 2016 Mintel report found that only 30% of respondents could identify stevia as a natural sweetener.

Stevia sweeteners present a solution that meets demands for sweetness and calorie reduction as well as natural sourcing. Marketing stevia-sweetened ice cream is not straightforward, however, and the semantics are potentially important in consumer perceptions and ultimate acceptance. Manuscripts 1 and 2 of this thesis will address two objectives pertaining to labeling of stevia-sweetened ice creams. The first objective (Manuscript 1) was to determine what labeling attributes are most influential in consumer evaluations of naturally sweetened ice cream. The second objective (Manuscripts 1 and 2) was to identify defining characteristics of a target market for stevia-sweetened ice cream.

### 1.2 Lighting temperature

Lighting is a multi-faceted extrinsic factor with the potential to influence eating behavior. Much of the work in this area has focused on illuminance level, or brightness. Rebollar et al. (2017) found that illuminance level affected perceived healthiness and sweetness of yogurt. Hasenbeck et al. (2014) observed illuminance level's effect on appearance liking and willingness to eat (WTE) for bell peppers: low illuminance decreased liking and WTE, while high illuminance increased these attributes.

Source type is another facet of lighting condition that can be manipulated to induce perceptual changes. In a retail setting, Barbut (2001) found that consumers preferred the color appearance of fresh meat when presented under incandescent light over that of meat under fluorescent and metal halide sources. The color of ambient light can be changed to mask visual characteristics of a product and has been shown to impact consumer liking and acceptance. Hasenbeck et al. (2014) observed the influence of lighting color on consumer's willingness to eat (WTE) bell peppers: appearance liking and WTE increased most under yellow and least under

blue lighting. In another study, Cho et al. (2015) found that blue lighting decreased food consumption in men while not significantly impacting overall acceptability.

Lighting temperature is a component of lighting that is not deeply explored in its relation to food perception. Lighting temperature refers to the color emitted by a blackbody when heated to extreme temperatures (Davidson & Abramowitz, 2015). Measured in Kelvin (K), lighting temperature can be used to describe the "yellowness" or "blueness" of white light (Davidson & Abramowitz, 2015). Lower temperatures (up to approximately 3,000 K) correspond to lower wavelength colors such as red and yellow, while higher temperatures (greater than 4,600 K) correspond to higher wavelength colors such as blue (Davidson & Abramowitz, 2015). Lighting temperature can influence one's psychological and physical perceptions of their environment. Nakamura and Oki (2000) found that subjects perceived rooms illuminated by low color temperature lights as being warmer than those with high color temperature. This effect is attributed to the psychological "hue-heat" associations between warm colors and warm temperatures, and vice versa (Laurentin, Bermtto, & Fontoynont, 2000; Nakamura & Oki, 2000).

While manufacturers are limited in their control of consumer's eating environment, there is potential for intervention at the point of sale. Retail lighting is generally cold but can easily be varied by section of the store (Clare & Hancer, 2016). Fresh meat, for instance, can be presented under very warm lighting in order to accentuate the red oxymyoglobin pigment, an important quality indicator for consumers (Barbut, 2005). Freezer cases, on the other hand, are typically illuminated by cold lighting (Otterbring, Löfgren, & Lestelius, 2014). A 2014 study by Otterbring et al. investigated the relationship between lighting temperature and consumer perceptions of packaged frozen meals. Subjects viewed packaged meals presented in retail freezers under cold (blue LED) or warm (yellow LED) lighting and evaluated the products on

four attributes: inferred quality, perceived price, attractiveness, and inferred taste (Otterbring et al., 2014). As they predicted, the packaged meals received more positive evaluations for inferred quality and attractiveness under warm lighting and did not differ significantly in perceived price between lighting conditions; contrary to the hypothesis for inferred taste, however, a significant difference was observed with the package under warm lighting receiving more positive evaluations (Otterbring et al., 2014).

It has been theorized that congruency between lighting temperature and expected food eating temperature may be a contributing factor in evaluations of inferred taste (Otterbring et al., 2014). Though purchased frozen, ready meals are intended to be eaten warm; when paired with warm lighting, the inferred temperature of the food is reinforced, processing fluency is improved, and positive ratings increase (Herrmann, Zidansek, Sprott, & Spangenberg, 2013; Otterbring et al., 2014). A model proposed by Tsujimura and Yanagisawa (Tsujimura & Yanagisawa, 2015) also accounts for the role of consistency and processing fluency on the formation of visual expectations of food. The model can be divided into two levels—physical phenomena and cognitive structure. At the physical level, measurable visual features of a food (luminance, saturation, and hue) are determined by the illuminance level and color temperature of the lighting source (Tsujimura & Yanagisawa, 2015). At the cognitive level, the relationship between a food's surface color temperature and the anticipated sensible heat of a food—that is, the temperature at which the food would typically be consumed—is referred to as the "cold-warm sensation" (Tsujimura & Yanagisawa, 2015). Analogous to Otterbring et al. (2014), Tsujimura and Yanagisawa (2015) have suggested that consistency of the cold-warm sensation improves processing fluency and generates a more positive visual expectation evaluation (Reber, Schwarz, & Winkielman, 2004; Tsujimura & Yanagisawa, 2015).

One proposed mediator in the relationship between ambient lighting and food perception is the familiarity of the food stimulus. Food neophobia is the reluctance of a consumer to taste unfamiliar food products (Pliner & Hobden, 1992; Raudenbush & Frank, 1999). It is regarded as both a developmental stage and a personality trait (Dovey, 2010). In the early years of life, children reject new foods based on visual cues; with time and exposure, the "schemata" of acceptable foods expands and relative neophobia decreases (Dovey, 2010). Trait food neophobia, which is established sometime between adolescence and early adulthood (Mcfarlane & Pliner, 1997; Nicklaus, Boggio, Chabanet, & Issanchou, 2005), differs from person to person. Individuals with high aversion to unfamiliar foods are classified as neophobic, while those with an attraction to such foods are neophilic (Pliner & Hobden, 1992). Neophobic and neophilic individuals differ in their hedonic expectations of unfamiliar foods. In comparing expected liking scores between these groups, Raudenbush and Frank (1999) found that neophobic subjects gave significantly lower scores for expected liking and were less willing to try unfamiliar foods than neophilics; after tasting, however, no difference in actual liking was observed across groups. This supports the notion that familiarity plays an important role in neophobic consumers' expectations of food.

Ice cream sweetened with stevia is a relatively novel product that is likely to be unfamiliar to consumers. To present such a product in an appealing way is crucial to encourage consumption, and there is evidence to support lighting temperature's role in improving consumer perceptions. Manuscript 3 will address two hypotheses: (1) congruency between lighting and food temperature (i.e. cold lighting and cold food) will improve consumer evaluations of ice cream, and (2) evaluations of less familiar ice cream (e.g. stevia-sweetened, non-dairy) will be more susceptible to the influence of lighting temperature.

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# CHAPTER 2: Manuscript 1—CONSUMER PERCEPTIONS OF NATURALLY SWEETENED ICE CREAM

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## 2.1 Abstract

Food package labels are a source of essential product information and, as such, play a fundamental role in consumer purchasing behavior. The aim of this study was to determine the influence of front-of-pack (FOP) labels on participants' liking of and willingness to purchase naturally sweetened vanilla ice cream using conjoint analysis. Conjoint attributes and levels evaluated included: 1) sweetener (*stevia*, *cane sugar*, *no information*); 2) claim language (*naturally sweetened*, *no artificial sweetener*, *no claim*); 3) calorie content per serving (*70 calories*, *105 calories*, *140 calories*); and 4) price per pint (*$3.39*, *$4.49*, *$5.59*). Using a fractional factorial experimental design to reduce respondent fatigue, nine hypothetical ice cream pint package labels were evaluated by 256 U.S. adult ice cream consumers. Conjoint analysis revealed that the sweetener source was the most important factor to determine consumers' liking and purchase intent of naturally sweetened ice creams, followed by claim, calories, and price. Cluster analysis using k-means based on the similarity in their preferences was used to identify an ideal target market for ice cream sweetened with stevia. Three distinct consumer clusters were identified, only one of which showed a strong preference for stevia. Further, these three clusters showed significant differences in self-assessed knowledge, purchase behavior, and attitudes toward non-nutritive sweeteners. The findings provide consumer insights that suggest marketing strategy to "light" ice cream marketers.

## 2.2 Introduction

The Centers for Disease Control and Prevention (CDC) recently reported that approximately two in five U.S. adults are obese, defined by a body mass index (BMI) ≥ 30 (Hales, Carroll, Fryar, & Ogden, 2017). This marks a significant increase in the prevalence of adult obesity over the past two decades (Hales et al., 2017). The U.S. Department of Health and Human Services (DHHS), National Heart, Lung, and Blood Institute (NHLBI), and American Diabetes Association (ADA) have all stressed the increased risk of health problems in obese individuals, including hypertension and Type 2 diabetes (DHHS & NHLBI, 2013). Studies suggest that excessive added sugar consumption is a major driver of obesity (Bowman et al., 2017; Drewnowski & Rehm, 2014; Malik, Popkin, Bray, Després, & Hu, 2010).

The 2013-2014 National Health and Nutrition Examination Survey (NHANES) reported that the average American consumed ~ 73 g of added sugar per day, contributing to > 14% of daily calorie intake on a 2000-calorie basis (Bowman et al., 2017). Soft drinks, baked goods, and dairy-based desserts are responsible for the majority of added sugars in the American diet (Drewnowski & Rehm, 2014; Popkin & Hawkes, 2016). The 2015-2020 Dietary Guidelines for Americans recommends that < 10% of daily calorie intake should come in the form of added sugars (DHHS & USDA, 2015). To make it easier for consumers to make informed decisions about foods that contain added sugars, the U.S. Food and Drug Administration (FDA) changed the nutrition facts label to include mandatory disclosure of added sugar content in 2016 (CDC, 2016; FDA, 2016).

Consumers are becoming increasingly aware of the consequences of sugar on health and are making efforts to reduce consumption (Aggarwal, Rehm, Monsivais, & Drewnowski, 2016; Mintel, 2016; Sylvetsky et al., 2017; Sylvetsky & Rother, 2016). They appear to be

compensating for reduced sugar intake by increasing consumption of high-intensity nonnutritive sweeteners (HINNS) (Sylvetsky et al., 2017; Sylvetsky, Welsh, Brown, & Vos, 2012; Sylvetsky & Rother, 2016). Mintel (2016) reported that over one-third of consumers feel that companies should be making a greater effort to reduce sugar in their products. One way that the food industry has tried to reduce sugar additions is through the introduction of artificial HINNS. Also called sugar substitutes, artificial HINNS are synthetic intensely sweet compounds whose high potency enables considerably lower usage by weight and, consequently, little to no calorie contribution (Shankar, Ahuja, & Sriram, 2013).

To date, the FDA has approved six artificial HINNS for food use: acesulfame K (Ace-K), advantame, aspartame, neotame, saccharin, and sucralose (FDA, 2014). Artificial HINNS have been scrutinized for their potential adverse health effects, most prominently saccharin (Arnold, 1984; Cohen, 1986) and aspartame (Choudhary & Pretorius, 2017; Nill, 2000). Despite a growing body of evidence in favor of their safety (Behnen, Ferguson, & Carlson, 2013; Brusick, Grotz, Slesinski, Kruger, & Hayes, 2010; Kroger, Meister, & Kava, 2006; Tey, Salleh, Henry, & Forde, 2017), consumer distrust remains pervasive. In addition to health and safety concerns, preconceptions of bitter taste and lingering sweetness are primary drivers of consumers' aversion to artificial sweeteners (Bearth, Cousin, & Siegrist, 2014; Reis, Alcaire, Deliza, & Ares, 2017; Shankar et al., 2013). Less than 20% of consumers feel that artificially-sweetened products taste as good as their sugar-based counterparts, according to a Mintel (2016) report.

In contrast to artificial sweeteners, natural sweeteners' taste is imparted by an innate sugar or related compound from a biological source, particularly plants or animals. Honey tops consumers' list of preferred natural sweeteners (Mintel, 2016); while honey does boast functional benefits in food processing due to its humectant properties (Aparna & Rajalakshmi,

1999), from a nutritional perspective it is not meaningfully different from sugar (USDA, 2018a). Monk fruit extract and stevia both are considered natural HINNS. Ripe extracts from monk fruit are ~ 200 times sweeter than sucrose; however, the fruit is difficult to produce outside of its native East Asian geography (Kasai et al., 1989). Conversely, stevia can be grown in various climates and regions including South America, China, Korea, and the U.S. (Brandle, Starratt, & Gijzen, 1998; Parris, Shock, & Qian, 2016). Steviol glycosides, the compounds responsible for the high-intensity sweetness of the leaf extract from *Stevia rebaudiana* Bertoni, are used in food products such as beverages, dairy products, and sugar-free confections (González, Tapia, Pérez, Pallet, & Dornier, 2014).

Despite stevia's identity as a zero-calorie natural sweetener, consumers remain wary of stevia-sweetened products. One probable source of this aversion is negative sensory expectation. While whole-leaf stevia has a long history of use (Brandle et al., 1998; Carakostas, Curry, Boileau, & Brusick, 2008), high-purity steviol glycosides—the form of stevia approved for use by the FDA—have only come into commercial use in the past few decades (FDA, 2018; Tanaka, 1982). Early formulations of sweeteners using these purified extracts suffered from a bitter taste and metallic off-flavors (Esaki, Reiko, & Shintaro, 1984; Kinghorn & Soejarto, 1985; Tanaka, 1997). Advancements in processing such as drying (Chranioti, Chanioti, & Tzia, 2016) and ethanol pretreatment (Formigoni et al., 2018) have been successful in reducing these undesirable attributes; however, the mere association between "stevia" and "bitterness" may be an obstacle to its acceptance. In a blind tasting, two fruit juices—one sweetened with sugar and the other with stevia—were rated as equally acceptable; in the informed condition, however, subjects reported bitterness in the stevia-sweetened juice (Reis et al., 2017). Clearly, there are non-sensory factors to be addressed regarding stevia perception.

Another potential barrier to receptiveness is consumers' predisposed distrust of unfamiliar ingredients. Several studies have shown that consumers reject such ingredients due to the belief that they are unsafe, unhealthy, or unnatural (Bearth et al., 2014; Rozin, 2006; Rozin, Fischler, & Shields-Argelès, 2012; Rozin et al., 2004; Wansink, Tal, & Brumberg, 2014). To consumers with no prior exposure or knowledge, stevia may fall into this category. A Mintel (2018) report found only 30% of consumers recognized that stevia is a natural sweetener. The report also revealed that only half of consumers were confident in their ability to distinguish natural sweeteners from artificial (Mintel, 2018b). This gap in public knowledge of sweeteners may contribute to consumers' hesitancy in trying stevia-sweetened products.

Other studies have investigated the modulating role of product labeling attributes such as ingredients (Hwang, Lee, & Lin, 2016; Peres, Esmerino, Silva, Racowski, & Bolini, 2018; Romano, Rosenthal, & Deliza, 2015), sweetener source (De Pelsmaeker, Schouteten, Lagast, Dewettinck, & Gellynck, 2017; Li, Lopetcharat, & Drake, 2015), and claim language (Palazzo & Bolini, 2017) on consumer evaluations of foods. The ice cream industry, a sizable contributor to dietary added sugars, has begun directing its focus toward the growing category of "healthy indulgence" or "guilt-less" treats, which offer low-calorie and low-sugar ice cream options (i.e., "light*"* ice cream) to satisfy sweet cravings (Kennedy, 2018). According to the FDA, "light*"* ice cream products need to present a minimum reduction of 50% of total fat or 33% of calories than the average of leading regional or national brands (FDA, 2013).

Presently, no studies have considered how the labeling attributes including sweetener source and claim language factor into a product rising rapidly in popularity, "light" ice cream (with the reduction of sugar). Thus, the primary objective of this study was to determine the influence of front-of-pack (FOP) labels on consumers' liking and purchase intent of naturally

sweetened vanilla ice cream. A secondary objective was to segment consumers to identify an ideal target market for "light" ice cream sweetened with stevia, a natural non-nutritive sweetener.

## 2.3 Materials & Methods

### *2.3.1 Conjoint study design*

A conjoint study was designed to determine the influence of sweetener (*stevia, cane sugar, no information*), claim (*no artificial sweeteners, naturally sweetened, no claim),* calorie content per serving (*70, 105, 140*), and price *($3.39, $4.49, $5.59*) on participants' liking of and willingness to purchase a pint of vanilla ice cream. Conjoint analysis (CA) is a widely used technique in consumer research to identify key drivers for consumer preference or purchase decision (Almli & Næs, 2018; Deliza, Macfie, & Hedderley, 2003). Conjoint design involves creating a set of product profiles using a number of product attributes with several attribute levels (Almli & Næs, 2018). Participants then evaluate these profiles in tasks and preference information can be deduced from the analysis (Almli & Næs, 2018). Several previous studies have employed this method to investigate consumer attitudes to novel food ingredients such as stevia used in chocolate (De Pelsmaeker et al., 2017), protein bars (Harwood & Drake, 2019), coffee beverages (Jervis, Lopetcharat, & Drake, 2012), fruit beverages (Mielby et al., 2016), and chocolate milks (Li et al., 2015). The protocol for this study was approved by the university's Institutional Review Board.

Attributes of interest were selected in response to the rise of guilt-less indulgent products in the market (Kennedy, 2018) as well as pending legislation surrounding the claim of "natural" on product labels (FDA, 2017; Hooker, Simons, & Parasidis, 2018). Three levels were used for sweetener: *cane sugar*, *stevia*, and *no information*. Stevia was chosen because many "light*"* ice

cream manufacturers leverage stevia sweeteners as a solution to reduced-calorie sweetness as well as consumer demands for natural sourcing. Cane sugar was chosen as the other sweetener because (a) it is a caloric alternative to stevia that maintains a "natural" halo, (b) is a popular sweetener in natural products striving to eliminate sweeteners such as high fructose corn syrup and (c) would reasonably be advertised in FOP food labels. The claim attribute had three levels—*naturally sweetened, no artificial sweeteners,* and *no claim*—which were selected for the purpose of comparing direct and indirect variants of a "naturalness" claim (Hooker et al., 2018). For caloric content, the *low* level (*70 calories*) was determined as an average calories per serving of popular low-calorie ice cream (Eden Creamery LLC, 2018), and the *high* level (*140 calories*) was selected from the calories per serving of vanilla ice cream as provided by the USDA National Nutrient Database for Standard Reference (USDA, 2018b). The *mid* level (*105 calories*) was calculated as the midpoint between the *low* and *high* levels. For price, an average price-per-pint of popular low-calorie ice cream was calculated and set as the *mid* level (*$4.49*) (Mintel, 2018a); the *low* (*$3.39*) and *high* (*$5.59*) price levels were determined by an approximately 25% reduction and increase of the *mid* price, respectively. Table 1 summarizes the attributes and the levels used in the study.

**Table 1.**
Attributes and levels of vanilla ice cream labels used in the study.

| Attributes | Levels |
|---|---|
| Sweetener | 1- Sweetened with cane sugar<br>2- Sweetened with stevia<br>3- No information on sweetener |
| Claim | 1- No artificial sweeteners<br>2- Naturally sweetened<br>3- No claim |
| Calories | 1- Low: 70 calories per serving<br>2- Mid: 105 calories per serving<br>3- High: 140 calories per serving |
| Price | 1- Low: $3.39<br>2- Mid: $4.49<br>3- High: $5.59 |

This study employed a fractional factorial experimental design with nine label profiles, generated using Conjoint Design in XLSTAT [Version 19.6] software (AddinSoft, New York, NY, USA). A fractional factorial design similar to that of Romano, Rosenthal, and Deliza (2015) mitigates fatigue in participants, as a complete design would require the evaluation of 81 profiles.

*2.3.2 Questionnaire*

An online survey was created and distributed to adult (≥ 18 years) U.S. ice cream consumers using the Qualtrics Survey Software (Qualtrics, Provo, UT, USA). The survey consisted of four sections: socio-demographic characteristics, measures of perceived knowledge (PK), conjoint rating tasks, and consumer attitudes. Prior research has shown that socio-demographic characteristics (e.g. age, gender, ethnicity, education) may be indicative of consumer preferences and behavior (Aggarwal et al., 2016; Bowman et al., 2017; Drewnowski & Rehm, 2015; Hailu, Boecker, Henson, & Cranfield, 2009; Harwood & Drake, 2019; Kamarulzaman, Jamal, Vijayan, & Jalil, 2014; Sylvetsky & Rother, 2016). In the perceived knowledge section, participants scored their subjective knowledge of five food and nutrition

topics—nutrition labels, food ingredients, sugar and other caloric sweeteners, zero-calorie sweeteners, human nutrition—on 7-point scales anchored at *not at all knowledgeable (1)* and *very knowledgeable (7)* (C. Y. Park, 2001). Perceived knowledge is a measure of a consumer's self-assessed expertise on a particular subject (C. W. Park, Gardner, & Thukral, 1988) and may provide greater insight about consumers' internal biases and decision-making processes than measures of actual knowledge (C. W. Park & Lessig, 1981). For the conjoint rating task, participants viewed nine digitally created images of ice cream pint packages (see Figure 1) one at a time in randomized order and evaluated their overall liking and purchase intention for each. Overall liking was scored on a 9-point hedonic scale (1=dislike extremely, 9=like extremely) and purchase intention on an 11-point Juster scale (0= no chance/almost no chance, 10=certain/practically certain) (Brennan & Esslemont, 1994). Finally, the consumer attitudes section of the survey addressed consumer behaviors such as purchasing habits and typical sweetener usage, as well as opinions on sugar and low-calorie sweeteners. Attitude-based metrics (Bearth et al., 2014; da Silva et al., 2014; Zanoli & Naspetti, 2002) and product usage (Leksrisompong, Lopetcharat, Guthrie, & Drake, 2013; Sylvetsky & Rother, 2016) have been shown to provide valuable context in consumer perception research.

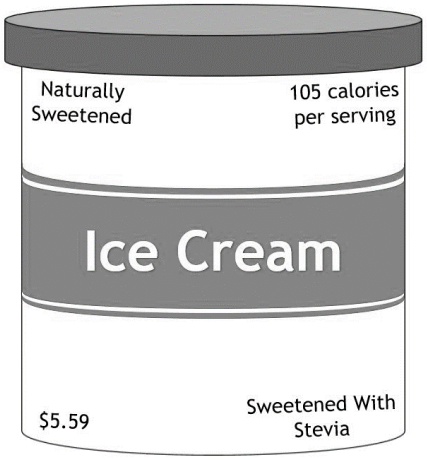


Figure 1. Example of package label used in the study: *Profile 1 in Table 4.*

*2.3.3 Data Analysis*

Data were analyzed using XLSTAT [Version 19.6] (AddinSoft, New York, NY, USA). Rating-based conjoint analysis was performed for the four product factors using the hedonic ratings of the nine package profiles. Zero-centered part-worth utilities and relative importance of each factor were estimated using ordinary least square regression (Jervis et al., 2012). Part-worth utilities were used as the basis for k-means clustering of consumers with similar responses (De Pelsmaeker et al., 2017; Koutsimanis, Getter, Behe, Harte, & Almenar, 2012; Li et al., 2015). Pearson chi-square tests were used to compare socio-demographic and behavioral characteristics across clusters (Jaeger, Mielby, Heymann, Jia, & Frøst, 2013; Shan et al., 2017).

**2.4 Results**

A total of 333 individuals provided complete and useful information to the online survey. All were $\geq 18$ years of age (mean $\pm$ standard error of the mean (SD) = $48 \pm 17$ years) and consumed ice cream at least once per month. Informed consent was obtained from all participants.

*2.4.1 Identification of fraudulent participants*

Due to the prevalence of "bots" and other deceitful participation in online surveys (Teitcher et al., 2015), potentially unreliable responses were excluded. Within the survey, two attention checks required the participant to select a specified answer; responses that did not pass both attention checks were excluded (Teitcher et al., 2015). Responses that included patterned answers (e.g. 1, 2, 1, 2…) or repetition (e.g. selecting 'true' for all questions) were also excluded (Teitcher et al., 2015). Finally, responses from participants who completed the survey in less than 300 sec were excluded, as this was determined to be below the threshold for an adequate amount of time in which to diligently read and complete the survey (Teitcher et al., 2015). In

total, 77 responses were excluded, yielding 256 useful responses for data analysis. The majority of participants were non-Hispanic white (65.6%), and more than half ate low/reduced-sugar products at least once per month (58.2%). Tables 2 and 3 outline the socio-demographic and consumer behavior characteristics and sample proportions of the 256 participants.

**Table 2.**
Socio-demographic characteristics of survey participants (n=256).

| Variable | Definition | Proportion (%) |
|---|---|---|
| Gender | | |
| | Male | 46.1 |
| | Female | 53.9 |
| Race/Ethnicity | | |
| | Non-Hispanic white | 65.6 |
| | Black | 8.6 |
| | Hispanic or Latino | 10.5 |
| | Asian | 8.2 |
| | Other | 7.0 |
| Education | | |
| | Less than high school diploma | 4.3 |
| | High school diploma or GED | 21.5 |
| | Some college credit, no degree | 19.5 |
| | Trade/technical training | 3.9 |
| | Associate degree | 10.9 |
| | Bachelor's degree | 30.5 |
| | Graduate degree | 9.4 |

**Table 3.**
Sweetener and ice cream consumption characteristics of survey participants (n=256).

| Variable | Definition | Proportion (%) |
|---|---|---|
| Regular[(1)] consumer of… | | |
| | Low-sugar foods and beverages | 58.2 |
| Ice cream products purchased within the past month | Reduced sugar | 21.9 |
| | Reduced calorie | 17.2 |
| Users[(2)] of HINNS | | |
| | Aspartame | 34.0 |
| | Saccharin | 30.5 |
| | Stevia | 43.8 |
| | Sucralose | 39.5 |

[(1)]Regular consumption defined as ≥ once per month. [(2)]At least one of the following uses: in a hot drink, in a cold drink, as a topping on prepared food, other.

*2.4.2 Conjoint analysis*

The mean overall liking and purchase intention scores for each of the nine product profiles are summarized in Table 4. Profile 5 (*sweetened with cane sugar, naturally sweetened, 70 calories per serving, $3.39*) received the highest mean score for both overall liking and purchase intention; Profile 1 (*sweetened with stevia, naturally sweetened, 105 calories per serving, $5.59*) received the lowest mean score for both.

**Table 4.**
Ice cream profiles of nine package labels used in conjoint analysis and mean scores for overall liking and purchase intention for each profile (n=256).

| Profile | Sweetener | Claim | Calories | Price | Overall Liking[(1)] (SEM) | Purchase Intention[(2)] (SEM) |
|---|---|---|---|---|---|---|
| 1 | Stevia (*Sweetened with stevia*) | Naturally sweetened | 105 | $5.59 | 4.7f (0.1) | 4.3e (0.2) |
| 2 | No information on sweetener | Naturally sweetened | 140 | $4.49 | 5.6bcd (0.1) | 5.5bc (0.2) |
| 3 | No information on sweetener | No artificial sweetener | 105 | $3.39 | 6.1ab (0.1) | 6.2a (0.2) |
| 4 | Cane sugar (*Sweetened with cane sugar*) | No artificial sweetener | 105 | $4.49 | 6.0abc (0.1) | 6.1ab (0.2) |
| 5 | Cane sugar (*Sweetened with cane sugar*) | Naturally sweetened | 70 | $3.39 | 6.5a (0.1) | 6.9a (0.2) |
| 6 | Cane sugar (*Sweetened with cane sugar*) | No claim | 140 | $5.59 | 5.4de (0.1) | 5.0cde (0.2) |
| 7 | Stevia (*Sweetened with stevia*) | No artificial sweetener | 140 | $3.39 | 4.9ef (0.1) | 4.7de (0.2) |
| 8 | No information on sweetener | No artificial sweetener | 70 | $5.59 | 5.6cd (0.1) | 5.2cd (0.2) |
| 9 | Stevia (*Sweetened with stevia*) | No claim | 70 | $4.49 | 4.9ef (0.1) | 4.7de (0.2) |

Means followed by different letters within a column are significantly different ($P < 0.05$). [(1)]9-point hedonic scale (1=dislike extremely, 9=like extremely). [(2)]11-point Juster scale (0=no chance/almost no chance, 10=certain/practically certain).

Table 5 summarizes the mean part-worth utilities and relative importance of each attribute and level for all participants. Sweetener had the greatest mean relative importance (RI) (36.8%) in the purchase decision, followed by claim (21.8%), calories (21.3%), and price (20.2%). Within the sweetener attribute, *sweetened with cane sugar* was the most appealing, followed by labels with no sweetener information and *sweetened with stevia* was the least appealing. The *naturally sweetened* claim was most preferred, and *no artificial sweetener* least. For calories and price, the *low* level was most attractive, and each subsequent increase (in calories per serving or dollars) was less attractive.

**Table 5.**
Mean part-worth utilities and relative importance of ice cream label attributes (n=256).

| Attributes | Levels | Mean part-worth utility (SEM) | Mean relative importance (%) |
|---|---|---|---|
| Sweetener | • No information on sweetener | 3.836 (0.952) | 36.8 |
| | • Cane sugar (*sweetened with cane sugar*) | 7.216 (1.068) | |
| | • Stevia (*sweetened with stevia*) | -11.052 (1.397) | |
| Claim | • No claim | -0.487 (0.745) | 21.8 |
| | • Naturally sweetened | 1.368 (0.537) | |
| | • No artificial sweetener | -0.880 (0.655) | |
| Calories | • Low (*70 calories per serving*) | 2.169 (0.632) | 21.3 |
| | • Mid (*105 calories per serving*) | 1.415 (0.604) | |
| | • High (*140 calories per serving*) | -3.584 (0.606) | |
| Price | • Low *($3.39*) | 5.078 (0.653) | 20.2 |
| | • Mid *($4.49*) | -0.267 (0.511) | |
| | • High (*$5.59*) | -4.811 (0.643) | |

*2.4.3 Consumer segmentation*

Pearson correlation tests were performed on overall liking and purchase intention for each product profile; overall liking was significantly correlated with purchase intention ($R^2$ = 0.731, $P < 0.001$, data not shown). Thus, the part-worth utilities derived from overall liking

scores were used in k-means clustering to generate three clusters: cluster 1 (n=87), cluster 2 (n=112), and cluster 3 (n=57) (Table 6).

Cluster 1 was distinguished by the heavy importance placed on the sweetener attribute (RI: 52.2%). They had a strong preference for *sweetened with cane sugar* and were much less receptive to *sweetened with stevia*. They assigned nearly equal importance to calories and price (RI: 16.3% and 16.2%, respectively). Cluster 1 was most attracted to the *mid* calorie level (*105 calories per serving*) and least attracted to the *high* level (*140 calories per serving*). They most favored the *low* price (*$3.39*) and found each subsequent dollar increase less attractive. Claim was of least importance to overall liking (RI: 15.3%); the *naturally sweetened* claim was most preferred and *no artificial sweetener* least.

Members of cluster 2 also placed greatest relative importance on sweetener (RI: 32.4%), but they most preferred *stevia* and were least drawn to the *no information* label. Claim was second-most important (RI: 26.7%); *no artificial sweetener* claim was preferred to *naturally sweetened*, though both were more appealing than the *no claim* condition. For calorie content (RI: 24.8%), cluster 2 was most drawn to the *low* calorie label (*70 calories per serving*) and least to *high* calorie (*140 calories per serving*). Finally, price was the least important contributor to overall liking (RI: 18.3%); the *mid* level price (*$4.49*) was most appealing and the *high* price (*$5.59*) least.

Cluster 3 was the only segment to assign greatest importance to price (RI: 29.8%)—the *low* price (*$3.39*) was most preferred and each subsequent dollar increase was substantially less attractive. Sweetener was second-most important (RI: 26.0%), with cane sugar the most preferred level and stevia the least. Calories and claim had nearly equal importance (RI: 22.0% and 22.0%, respectively). They found the *mid* calorie level most appealing and the *high* level the

least. Finally, cluster 3 was most drawn to *no claim* labels and was least receptive to *no artificial sweetener*.

**Table 6.**
Mean part-worth utilities and relative importance of label attributes by cluster.

| Attributes | Levels | Cluster 1 (n=87; 34%) | Cluster 2 (n=112; 44%) | Cluster 3 (n=57; 22%) |
|---|---|---|---|---|
| Sweetener | *Mean part-worth utilities (SEM)* | | | |
| | • No information on sweetener | 15.439 (1.458) | -3.213 (1.167) | -0.030 (1.609) |
| | • Cane sugar (*sweetened with cane sugar*) | 19.836 (1.694) | -0.967 (1.211) | 4.060 (2.007) |
| | • Stevia (*sweetened with stevia*) | -35.275 (1.629) | 4.180 (1.281) | -4.030 (1.516) |
| | *Relative importance (%)* | 52.2 | 30.2 | 26.0 |
| Claim | *Mean part-worth utilities (SEM)* | | | |
| | • No claim | 1.345 (1.164) | -5.739 (1.036) | 7.048 (1.382) |
| | • Naturally sweetened | 2.188 (1.000) | 1.653 (0.794) | -0.444 (1.000) |
| | • No artificial sweetener | -3.534 (1.093) | 4.086 (0.794) | -6.604 (1.375) |
| | *Relative importance (%)* | 15.3 | 26.7 | 22.0 |
| Calories | *Mean part-worth utilities (SEM)* | | | |
| | • Low (*70 calories per serving*) | -0.341 (1.114) | 5.630 (0.873) | -0.812 (1.242) |
| | • Mid (*105 calories per serving*) | 3.634 (1.206) | -2.137 (0.785) | 5.026 (0.921) |
| | • High (*140 calories per serving*) | -3.293 (1.197) | -3.493 (0.895) | -4.213 (1.014) |
| | *Relative importance (%)* | 16.3 | 24.8 | 22.2 |
| Price | *Mean part-worth utilities (SEM)* | | | |
| | • Low (*$3.39*) | 6.344 (1.120) | 0.390 (0.753) | 12.380 (1.345) |
| | • Mid (*$4.49*) | -1.305 (0.978) | 1.092 (0.646) | -1.364 (1.168) |
| | • High (*$5.59*) | -5.039 (1.318) | -1.482 (0.675) | -11.016 (1.229) |
| | *Relative importance (%)* | 16.2 | 18.3 | 29.8 |

The socio-demographic characteristics of the three clusters are outlined in Table 7. Between-cluster differences in socio-demographic profiles were assessed using Pearson chi-square tests for proportions and ANOVA for means. No significant associations between consumer segment and age, gender, race/ethnicity, or education level were found ($P > 0.05$).

**Table 7.**
Socio-demographic characteristics of survey participants by cluster.

| Variable | Definition | Cluster 1 (n=87; 34%) | Cluster 2 (n=112; 44%) | Cluster 3 (n=57; 22%) |
|---|---|---|---|---|
| Gender (%) | | | | |
| | Male | 43.7 | 50.0 | 42.1 |
| | Female | 56.3 | 50.0 | 57.9 |
| Age (y) | | | | |
| | Mean (SD) | 48.2 (16.1) | 48.2 (17.9) | 48.0 (16.3) |
| Race/Ethnicity (%) | | | | |
| | Non-Hispanic white | 58.6 | 67.9 | 71.9 |
| | Black | 6.9 | 12.5 | 3.5 |
| | Hispanic or Latino | 14.9 | 8.9 | 7.0 |
| | Asian | 9.2 | 8.0 | 7.0 |
| | Other | 10.3 | 2.7 | 10.5 |
| Education (%) | | | | |
| | Less than high school diploma | 5.7 | 2.7 | 5.3 |
| | High school diploma or GED | 14.9 | 26.8 | 21.1 |
| | Some college credit, no degree | 23.0 | 18.8 | 15.8 |
| | Trade/technical training | 4.6 | 3.6 | 3.5 |
| | Associate degree | 14.9 | 9.8 | 7.0 |
| | Bachelor's degree | 29.9 | 28.6 | 35.1 |
| | Graduate degree | 6.9 | 9.8 | 12.3 |

The distribution of regular low-sugar food and beverage consumers differed significantly across clusters—cluster 2 had the largest proportion of regular consumers (72.3%), followed by cluster 3 (63.2%) and cluster 1 (36.8%) (Table 8). Regular consumers of HINNS also differed by

cluster. Cluster 2 had a significantly higher proportion of aspartame, saccharin, and stevia users compared to both other clusters, and a higher proportion of sucralose users than cluster 1. Segments also differed in their recent ice cream product purchases. Cluster 2 also had a greater percentage of reduced-sugar ice cream purchasers (33.0%) than cluster 1 (10.3%) and cluster 3 (17.5%).

**Table 8.**
Sweetener and ice cream consumption characteristics of consumer segments generated by k-means clustering.

| Variable | Definition | Cluster 1 (n=87; 34%) | Cluster 2 (n=112; 44%) | Cluster 3 (n=57; 22%) | |
|---|---|---|---|---|---|
| Regular[(1)] consumer of… (%) | Low-sugar foods and beverages | 36.8b | 72.3a | 63.2a | *** |
| Ice cream products purchased within the past month (%) | Reduced-sugar | 10.3b | 33.0a | 17.5b | *** |
| | Reduced-calorie | 11.5 | 22.3 | 15.8 | N.S. |
| Users[(2)] of HINNS (%) | Aspartame | 24.1b | 46.4a | 24.6b | *** |
| | Saccharin | 17.2b | 43.8a | 24.6b | *** |
| | Stevia | 19.5b | 60.7a | 29.8b | *** |
| | Sucralose | 24.1b | 51.8a | 38.6ab | *** |

Proportions followed by different lowercase letters within a row are significantly different ($P < 0.05$). *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. [(1)]Regular consumption defined as ≥ once per month. [(2)]At least one of the following uses: in a hot drink, in a cold drink, as a topping on prepared food, other.

Participants indicated the extent to which they agreed or disagreed with seven opinion statements related to sweeteners and food choice (Table 9). Consumer segments differed significantly in their level of agreement on four items. To the item, "Nutritional labels help me to decide which products to buy," cluster 2 agreed significantly more than cluster 1 ($P<0.05$). To

the item, "Natural sweeteners are better for your health than artificial sweeteners," cluster 1 agreed more than cluster 2 and cluster 3 ($P<0.001$). To the item, "Zero/low-calorie sweeteners can help reduce sugar intake," cluster 2 agreed more than cluster 1 ($P<0.05$). To the item, "Stevia is a healthy sweetener because it is natural," cluster 2 and cluster 3 agreed significantly more than cluster 1 ($P<0.001$).

**Table 9.**
Mean extent of agreement with sweetener opinion statements across consumer segments.

| Statement Item[(1)] *"Indicate the extent to which you agree or disagree with each of the following statements."* | Cluster 1 (n=87; 34%) | Cluster 2 (n=112; 44%) | Cluster 3 (n=57; 22%) | |
|---|---|---|---|---|
| Nutritional labels help me to decide which products to buy. | 3.2b (0.1) | 3.6a (0.1) | 3.3ab (0.1) | * |
| Natural sweeteners are better for your health than artificial sweeteners. | 4.0a (0.1) | 3.3b (0.1) | 3.5b (0.1) | *** |
| I am willing to pay more for something I perceive as healthy. | 3.6 (0.1) | 3.8 (0.1) | 3.6 (0.1) | N.S. |
| Zero/low-calorie sweeteners can help reduce sugar intake. | 3.3b (0.1) | 3.7a (0.1) | 3.6ab (0.1) | * |
| Artificial sweeteners have an unpleasant aftertaste. | 3.9 (0.1) | 4.0 (0.1) | 3.9 (0.1) | N.S. |
| Stevia is a healthy sweetener because it is natural. | 3.1b (0.1) | 3.6a (0.1) | 3.7a (0.1) | *** |
| Natural products and ingredients are too expensive. | 3.7 (0.1) | 3.9 (0.1) | 3.9 (0.1) | N.S. |

Means followed by different letters within a row are significantly different ($P < 0.05$). *$P<0.05$, **$P < 0.01$, ***$P < 0.001$. [(1)]Scale: 1=strongly disagree, 5=strongly agree.

Participants reported their perceived knowledge (PK) on five topics: nutrition labels, food ingredients, caloric sweeteners (e.g. sugar), zero-calorie sweeteners, and human nutrition (Table 10). Consumer segments differed significantly on two topics. On sugar and other caloric sweeteners, cluster 2 and cluster 3 scored their perceived knowledge higher than cluster 1 ($P<0.05$). On zero-calorie sweeteners, cluster 2 and cluster 3 scored their perceived knowledge higher than cluster 1 ($P<0.05$).

**Table 10.**
Mean perceived knowledge (PK) scores for nutrition and sweetener topics by cluster.

| Topic[(1)] *"Indicate how informed you feel on each of the following topics."* | Cluster 1 (n=87; 34%) | Cluster 2 (n=112; 44%) | Cluster 3 (n=57; 22%) | |
|---|---|---|---|---|
| Nutrition labels | 4.9 (0.1) | 5.0 (0.1) | 5.1 (0.2) | N.S. |
| Food ingredients | 5.2 (0.1) | 5.1 (0.1) | 5.3 (0.1) | N.S. |
| Sugar and other caloric sweeteners | 4.9b (0.2) | 5.3a (0.1) | 5.4a (0.1) | * |
| Zero-calorie sweeteners | 4.3b (0.2) | 4.9a (0.1) | 5.0a (0.2) | * |
| Human nutrition | 4.8 (0.1) | 4.9 (0.1) | 4.9 (0.2) | N.S |

Means followed by different letters within a row are significantly different ($P < 0.05$).
[(1)]Scale: 1=not at all, 7=extremely.

## 2.5 Discussion

From the overall results, it was found that sweetener attribute (RI: 36.8%) had the greatest contribution to overall liking of ice cream labels, followed by claim (RI: 21.8%), calories (RI: 21.3%) and price (20.2%). Overall cane sugar was the most attractive, while stevia was the least attractive. Cane sugar is one of the top preferred natural nutritive sweeteners due to its familiarity. Enneking, Neumann, and Henneberg (Enneking, Neumann, & Henneberg, 2007) also indicated that sugar, "queen of sweeteners" showed significant preference over new alternative sweetening system in soft drinks. Further, cane sugar could have a "natural" halo effect. The health halo imparted by the "naturalness" of a product may be related to a tendency to use heuristics in evaluations of food. Sütterlin and Siegrist (Sütterlin & Siegrist, 2015) found that breakfast cereals sweetened with "fruit sugar" were perceived as healthier than those sweetened with sugar. They proposed that an identifier with a healthy connotation—for instance, "fruit"—imparts a health (Sütterlin & Siegrist, 2015). This poses a concern to consumers who believe they are making healthy choices but in fact are consuming the same amount of sugar as before.

The mean relative importance of claim, calories, and price were almost evenly distributed. It was shown that naturally sweetened claim was more appealing than no artificial sweetener and no claim. One possible reason for this is the negative connotation of the words; "no artificial sweetener" is perceived  intended to carry the same message, the former is perceived as a subtractive concept (i.e. an undesirable substance was removed) while the latter implies it is unrefined (i.e. never contained the undesirable substance) (Rozin, 2006). As expected, consumers displayed preferences for reduced-calorie options and lower price when evaluating ice cream. However, the most attractive level in each labeling attribute differed across three consumer clusters.

Consumers in cluster 1 were characterized by the high relative importance of sweetener in product evaluations. This group found cane sugar markedly more appealing than stevia and even preferred labels with no information over the natural zero-calorie sweetener. Claim, calories, and price had relatively low influence on overall liking for consumers in this cluster; this suggests that to improve these consumers' receptiveness to stevia-sweetened ice cream, their perception of the sweetener itself must first be addressed. Cluster 1 had the smallest proportions of low-sugar product consumers and HINNS users, suggesting that these consumers were not only averse to stevia but to zero-calorie sweeteners in general. This aversion may be explained in part by expectations of bitterness and lingering sweetness that are commonly associated with HINNS (Peres et al., 2018)—consumers in cluster 1 felt that artificial sweeteners have an unpleasant aftertaste, and they agreed the least that HINNS are a good way to reduce sugar intake.

Concerns about the safety and healthfulness of these sweeteners may also be a contributing factor. Cluster 1 agreed most strongly with the notion that natural sweeteners are

healthier than their artificial counterparts, yet expressed less agreement with the statement, "Stevia is a healthy sweetener because it is natural." This inconsistency may stem from two possible lines of reasoning: they did not believe that stevia is healthy regardless of its natural origin, or they did not know that stevia is a natural sweetener. In support of the latter is cluster 1 consumers' self-assessed knowledge of both caloric and non-caloric sweeteners, which was significantly lower than the other clusters. This may indicate that their aversion to stevia was driven by the apprehension of consuming unfamiliar foods and supports the notion that familiarity plays a role in consumers' acceptance of novel food products (C. W. Park & Lessig, 1981; Pliner & Hobden, 1992; Raudenbush & Frank, 1999). From a marketer's perspective, this presents as an opportunity to educate these consumers on stevia and potentially improve receptiveness among those who are seeking more natural sweeteners.

Cluster 2 consumers were unique in their preference for stevia over cane sugar on ice cream labels. More than half of these consumers were stevia users—three times that of cluster 1 and twice that of cluster 3—and nearly three-quarters were regular consumers of low-sugar foods and beverages. Consumers in cluster 2 exhibited great receptiveness to HINNS and agreed most strongly that zero-calorie sweeteners are an acceptable means to reduce sugar consumption. These findings provide further support to the notion that familiarity acquired through regular exposure fosters receptiveness to new food products (Leksrisompong et al., 2013; Martins & Pliner, 2005; C. W. Park & Lessig, 1981).

While sweetener was most important to their evaluation, claim and calories also had a considerable impact. These consumers were more receptive to labels with a claim than those without and were particularly drawn to *no artificial sweetener*. Cluster 2 agreed more strongly than others that nutritional labels help guide their purchase decisions; this may indicate that these

consumers paid greater attention to other aspects of labels as well, such as claims. In addition to their unique affinity for stevia, consumers in cluster 2 were the only ones who most preferred the *low* calorie ice cream label. These findings are consistent with the reduced-sugar ice cream purchases of cluster 2, which were significantly greater than those of the other clusters. Although reduced-sugar ice cream falls within the category of reduced-calorie, notably fewer consumers in cluster 2 reported purchasing reduced-calorie ice cream. This may be a key insight into the intentions of their purchases. The HINNS use and low-sugar product consumption of cluster 2 suggest a strong motivation to reduce sugar intake. Therefore, it is plausible that their responses were reflective of the factor they actively sought out in their ice cream purchases: "reduced-sugar" rather than "reduced calorie." Regardless, these consumers represent the ideal target market for stevia-sweetened ice cream and should be the focus of marketing efforts.

While all segments exhibited a clear preference for low price compared to high, only cluster 3 consumers considered price to be the most important attribute. Sweetener was also highly important to this group who, like cluster 1, preferred cane sugar to stevia. Cluster 3 had low proportions of HINNS users; however, over 60% of this group reported regular consumption of low-sugar foods and beverages. This suggests that they were receptive to products formulated with HINNS but did not utilize the tabletop versions of these sweeteners to add to their own drinks or recipes. One possible reason is that these consumers were unsure of how to use them. While some HINNS are available as blends with bulking agents that measure equivalently to sugar, others are highly concentrated and require only a single packet or a few drops to obtain the desired sweetness level. Consumers may find this process of calculation and trial-and-error to be intimidating or time-consuming, and instead elect to purchase pre-sweetened low-sugar products.

It is worth noting that few consumers in cluster 3 had purchased reduced-sugar or reduced-calorie ice cream within the past month. Despite their overall receptiveness to low-sugar products, it appears that these consumers were not receptive to a low-sugar ice cream. This is further supported by their preference for the *mid* calorie option—while they would prefer ice cream with fewer calories, they were wary of low-calorie options. Many consumers hold the belief that sensory attributes must be sacrificed in order to improve the nutrition quality of a food (Reis et al., 2017), particularly an inherently indulgent food like ice cream (da Silva et al., 2014). Fortunately, there is still evidence that these consumers may be open to stevia in other products, as they tended to agree that stevia is a healthy natural sweetener. By expanding the array of stevia-sweetened products and improving the practicality of tabletop formulations, the stevia market may find success in capturing part of this consumer segment as well.

## 2.6 Conclusion

This study found that sweetener was of greatest relative importance to the average ice cream consumer, followed by claims, calories, and price. While perception of stevia as a sweetener in ice cream was poor compared to cane sugar, receptiveness to its use was high among regular users of non-nutritive sweeteners. These consumers are evidence of acceptance—they want low-calorie ice cream and appear open to alternatives. A primary goal should be to grow this segment by leveraging current members as opinion leaders to bolster stevia's report as a natural HINNS. The second-largest consumer segment strongly preferred cane sugar over stevia; however, their attitudinal and behavioral responses indicated that some of this aversion may be driven by unfamiliarity with zero-calorie sweeteners. This segment should be targeted by efforts to educate consumers and ideally foster acceptance of stevia. The smallest consumer segment identified was sensitive to price but receptive to low-sugar products. Although not an

ideal audience for reduced-sugar ice cream, this segment may be open to stevia in other food and beverage formats.

Further studies are necessary to identify the unique attributes of the stevia-receptive consumer segment, as simple socio-demographic characteristics were not indicative of preference. Frequent users of zero-calorie sweeteners were more receptive to stevia-sweetened ice cream than infrequent users. It has been suggested that improving consumer knowledge of unfamiliar food ingredients may play a role in fostering acceptance. Future research is required to investigate the role of knowledge in perception of stevia and to determine the effectiveness of educational intervention on stevia perception. The findings of this study may be of interest to the ice cream industry as guidance for marketing of low-calorie products that meet both sensory and perceptual demands.

Marketers of ice cream sweetened with stevia have an uphill challenge. Concerns about the taste, or aftertaste, of ice creams substituting HINNS for sugar will have to first overcome perceptual barriers before they can get their ice cream in the carts and mouths of customers. While HINNS can improve the overall nutritional claims for ice creams, the reduction in real and perceived bitterness will not be an easy or trivial matter to address.

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# CHAPTER 3: Manuscript 2—ROLE OF CONSUMER KNOWLEDGE OF SWEETENERS IN PERCEPTION OF NATURALLY SWEETENED ICE CREAM

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## 3.1 Abstract


### *3.1.1 Background*

The rise in global obesity rates has prompted consumers to limit their caloric intake from added sugars. Stevia, a natural zero-calorie sweetener, has seen a surge in popularity in recent years; however, many consumers are unfamiliar with stevia and are hesitant to purchase products containing the sweetener. This study aimed to investigate the relationship between consumers' actual knowledge (AK) and perceived knowledge (PK) of sweeteners and their receptiveness to a stevia-sweetened food (vanilla ice cream).

### *3.1.2 Results*

Consumers with high AK were more receptive to concepts of stevia-sweetened ice cream than those with low AK ($P<0.05$). High AK consumers tended to be more frequent users of zero-calorie sweeteners and low-sugar foods and beverages compared to Low AK consumers ($P<0.05$). Both consumer groups obtained information about sweeteners most frequently from food package labels and found them to be the most trustworthy sources.

### *3.1.3 Conclusion*

Findings of this study demonstrate the importance of consumer knowledge in relation to novel food ingredients. Food package labels were identified as practical avenues for

implementing educational measures to improve consumer knowledge and foster acceptance of stevia as a natural zero-calorie sweetener.

### 3.2 Introduction

The contribution of excessive sugar consumption to the world obesity epidemic is of vital concern to health care professionals, the food industry, and consumers alike. Increased awareness of sugar's role in the development of health problems such as Type 2 diabetes has prompted consumers to seek alternative ways to satisfy their need for sweetness (Aggarwal, Rehm, Monsivais, & Drewnowski, 2016; Sylvetsky et al., 2017; Sylvetsky, Welsh, Brown, & Vos, 2012; Sylvetsky & Rother, 2016). A popular option is the use of high intensity non-nutritive sweeteners (HINNS), which are intensely sweet substances that contribute little or no calories to food (Shankar, Ahuja, & Sriram, 2013). The most commonly used HINNS in the U.S.—sucralose, saccharin, and aspartame (Statista, 2018)—are artificial in origin, though the natural HINNS stevia have grown in popularity in response to consumer demands for naturally sourced ingredients (Statista, 2016).

Attitudes toward HINNS are a divisive issue among consumers. Artificial sweeteners, particularly saccharin (Arnold, 1984; Cohen, 1986) and aspartame (Choudhary & Pretorius, 2017; Nill, 2000), have been the subject of scrutiny in regards to potential adverse health effects; although extensive research has supported their safety (Behnen, Ferguson, & Carlson, 2013; Brusick, Grotz, Slesinski, Kruger, & Hayes, 2010; Kroger, Meister, & Kava, 2006; Tey, Salleh, Henry, & Forde, 2017), many consumers retain concerns of health and safety toward artificial HINNS. Taste is also a common issue affecting some consumers' acceptance of artificial sweeteners; bitter taste and lingering sweetness have been associated with artificial sweeteners

(Bearth, Cousin, & Siegrist, 2014). According to a Mintel (2016) report, less than 20% of consumers feel that artificially sweetened products taste as good as the full-sugar product.

Stevia (*Stevia rebaudiana* Bertoni), a natural HINNS is gaining popularity among consumers as it is plant-based. Stevia is used in a variety of food products such as beverages, dairy products, sugar-free confections (González, Tapia, Pérez, Pallet, & Dornier, 2014). However, stevia-sweetened products are also shown to have bitter aftertaste and lingering sweetness (Reis, Alcaire, Deliza, & Ares, 2017; Shankar et al., 2013), resulting in potential consumers' aversion to stevia. To address these sensory issues, the sweetener industry continues to improve processing methods (Chranioti, Chanioti, & Tzia, 2016; Formigoni et al., 2018) and formulate new HINNS (Bishay, Bursey, & Bursey, 2016; Kumari, Arora, Choudhary, Singh, & Tomar, 2018; Nofre & Tinti, 2000) to better mimic the sweetness profile of sugar.

Another potential barrier to HINNS receptiveness that has not been explicitly addressed is consumers' limited knowledge pertaining to sweeteners. Stevia as a natural sugar substitute is relatively new, and only 30% of consumers know that stevia is a natural sweetener (Mintel, 2018). Further, stevia is often listed in the ingredient statement as "stevia extract," "steviol glycosides," "rebaudioside A (Reb A)," "stevioside," or other variations. Steviol glycosides, rebaudiosides, and stevioside are the compounds responsible for the high-intensity sweetness of the stevia leaf extract. However, these chemical names may lead consumer attitudes to reject the ingredients because they believe that these ingredients are less safe or healthy than those with common names (Bearth, Cousin, & Siegrist, 2014; Rozin, 2006; Rozin, Fischler, & Shields-Argelès, 2012; Rozin et al., 2004). For example, Tate & Lyle (2018) found that the term "steviol glycosides" had a more negative overall perception and lower purchase impact than stevia extract due to the lack of knowledge of stevia. Thus, the primary objective of this study is to

examine influence of sweetener knowledge on consumer perception of stevia sweetened ice cream products.

In this study, consumer knowledge was separated into two constructs: actual knowledge (AK) and perceived knowledge (PK). AK refers to objective factual information about a topic, whereas PK pertains to how much the consumer believes that they know (Park, Mothersbaugh, & Feick, 1994). Lack of AK has been shown to be a barrier to consumer acceptance of food technologies (Cardello, Schutz, & Lesher, 2007; Hicks et al., 2009). Further, consumers with higher AK of novel food ingredients have been found to be more receptive to their use (Stern, Haas, & Meixner, 2009), while those unfamiliar with ingredients reject them on the belief that they are unsafe, unhealthy, or unnatural (Bearth et al., 2014; Rozin, 2006; Rozin, Fischler, & Shields-Argelès, 2012; Rozin et al., 2004; Wansink, Tal, & Brumberg, 2014).

This study aimed to assess both constructs of consumer knowledge (AK and PK) as they pertain to sweeteners. Relative AK level was utilized to group consumers of similar understanding in order to investigate the relationship between knowledge and perception of the natural HINNS, stevia.

## 3.3 Materials & Methods

### *3.3.1 Participants*

A total of 333 individuals were recruited to participate in an online survey. In accordance with recruitment criteria, but only 256 responses were used in data analysis due to the prevalence of "bots" and other deceitful participation in online surveys (Teitcher et al., 2015). All participants were regular ice cream consumers (at least once per month) [54% females; mean age ± standard deviation (SD) = 48 ± 17 years; 65.6% non-Hispanic white; 39.9% bachelors or higher education].

*3.3.2 Questionnaire*

An online survey was conducted in 2018 using the Qualtrics Survey Software (Qualtrics, Provo, UT, USA). The survey consisted of questions to measure PK and AK with socio-demographics, consumer behavior and attitudes, and conjoint rating tasks (for details, see Cieslinski, Behe, & Cho, (n.d.). Briefly, participants first provided basic socio-demographic information such as age, gender, ethnicity, and education level, and then performed a self-assessment of their knowledge. They also reported how regularly they obtained information on sweeteners from and the trustworthiness of a variety of media sources. Conjoint rating tasks were conducted by showing participants nine digitally created images of ice cream pint package. AK was measured by asking a 14-item true/false test of statements pertaining to sweeteners (Appendix 1). These 14 questions were carefully selected from a preliminary test (data not shown). The consumer behavior and attitudes section of the survey addressed consumer behaviors such as purchasing habits and typical sweetener usage, as well as opinions on sugar and low-calorie sweeteners.

*3.3.3 Data analysis*

Data were collected in Qualtrics and data analysis was performed using XLSTAT [Version 19.6] (AddinSoft, New York, NY, USA). PK: Participants rated on a 7-point scale (1=not at all, 7=extremely) how informed they felt on each of the following topics: nutrition labels, food ingredients, sugar and other caloric sweeteners, non-caloric (zero-calorie) sweeteners, and human nutrition (Park, 2001). These scores were averaged to generate the PK score (Park, 2001).

AK: Assessed by the number of correct responses to 14 true/false items (Appendix 1). These items were selected from a preliminary survey (n=210) which screened 20 items for knowledge discriminability. To improve the likelihood of capturing real knowledge as opposed to guessing ability, a third option of "I don't know" was provided for each item (Page & Uncles, 2004). Each correct response received 1 point, and incorrect responses 0 points. "I don't know" responses were scored as incorrect, as it is the participant's self-admission of absence of knowledge (Page & Uncles, 2004). One item was excluded from scoring during analysis due to lack of clarity in phrasing; AK score, therefore, is based on the number of correct responses out of 13 possible points. The overall mean AK score was used to separate participants into Low AK (AK score<mean) and High AK (AK score>mean).

### 3.4 Results

The socio-demographic profiles of Low and High AK groups are summarized in Table 11. No significant differences in gender, age, race/ethnicity, or education level were found between the groups.

**Table 11.**
Socio-demographic characteristics of survey participants, grouped by actual knowledge (AK) level.

| Variable | Definition | Low AK[(1)] (n=117; 45.7%) | High AK[(2)] (n=139; 54.3%) |
|---|---|---|---|
| Gender (%) | | | |
| | Male | 43.6 | 48.2 |
| | Female | 56.4 | 51.8 |
| Age (y) | | | |
| | Mean (SD) | 46.8 (17.5) | 49.3 (16.2) |
| Race/Ethnicity (%) | | | |
| | Non-Hispanic white | 65.8 | 65.5 |
| | Black | 8.5 | 8.6 |
| | Hispanic or Latino | 11.1 | 10.1 |
| | Asian | 8.5 | 7.9 |
| | Other | 6.0 | 7.9 |
| Education (%) | | | |
| | Less than high school diploma | 5.1 | 3.6 |
| | High school diploma or GED | 23.1 | 20.1 |
| | Some college credit, no degree | 21.4 | 18.0 |
| | Trade/technical training | 5.1 | 2.9 |
| | Associate degree | 10.3 | 11.5 |
| | Bachelor's degree | 27.4 | 33.1 |
| | Graduate degree | 7.7 | 10.8 |

[(1)]AK<5.6. [(2)]AK>5.6.

Table 12 shows the difference in the results of conjoint rating tasks between High AK and Low AK. Profile 5 (*sweetened with cane sugar, naturally sweetened, 70 calories, $3.39*) received the highest scores for overall liking and purchase intention from both the Low AK and High AK groups (Table 12). Profile 1 (*sweetened with stevia, naturally sweetened, 105 calories, $5.59*) received the lowest overall liking and purchase intention scores from both the Low and High AK groups. Overall liking differed significantly across knowledge groups for the three *sweetened with stevia* profiles (Profiles 1, 7, and 9); in all cases, the High AK group gave these

profiles higher scores than did the Low AK group ($P<0.05$). Purchase intention also differed for these three profiles, as well as for Profile 8 (*no sweetener information, no artificial sweetener, 70 calories, $5.59*); as was observed for overall liking, purchase intention for these four profiles was greater for the High AK group than for Low AK ($P<0.05$).

**Table 12.**
Mean overall liking and purchase intention scores of the nine conjoint analysis profiles used in the study, compared across actual knowledge (AK) level of participants.

| Profile | Sweetener | Claim | Calories | Price | Overall Liking[(1)] (SEM) | | Purchase Intention[(2)] (SEM) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Low AK (n=117; 45.7%) | High AK (n=139; 54.3%) | Low AK (n=117; 45.7%) | High AK (n=139; 54.3%) |
| 1 | Stevia | Naturally sweetened | 105 | $5.59 | 4.3b (0.2) | 5.1a (0.2) | 3.8b (0.3) | 4.8a (0.3) |
| 2 | No info | Naturally sweetened | 140 | $4.49 | 5.5 (0.2) | 5.7 (0.2) | 5.3 (0.3) | 5.7 (0.2) |
| 3 | No info | No artificial sweetener | 105 | $3.39 | 6.1 (0.2) | 6.2 (0.2) | 5.9 (0.3) | 6.5 (0.2) |
| 4 | Cane sugar | No artificial sweetener | 105 | $4.49 | 5.9 (0.2) | 6.1 (0.2) | 5.8 (0.3) | 6.4 (0.2) |
| 5 | Cane sugar | Naturally sweetened | 70 | $3.39 | 6.5 (0.2) | 6.6 (0.2) | 6.8 (0.3) | 7.0 (0.2) |
| 6 | Cane sugar | No claim | 140 | $5.59 | 5.2 (0.2) | 5.6 (0.2) | 4.6 (0.3) | 5.3 (0.2) |
| 7 | Stevia | No artificial sweetener | 140 | $3.39 | 4.5b (0.2) | 5.2a (0.2) | 4.1b (0.3) | 5.2a (0.3) |
| 8 | No info | No artificial sweetener | 70 | $5.59 | 5.3 (0.2) | 5.8 (0.2) | 4.7b (0.3) | 5.6a (0.3) |
| 9 | Stevia | No claim | 70 | $4.49 | 4.5b (0.2) | 5.2a (0.2) | 4.1b (0.3) | 5.2a (0.2) |

Means followed by different letters within a row are significantly different ($P<0.05$). [(1)]9-point hedonic scale (1=dislike extremely, 9=like extremely). [(2)]11-point Juster scale (0=no chance/almost no chance, 10=certain/practically certain).

Sweetener consumption habits of participants differed across knowledge level (Table 13). The High AK group had a greater proportion of regular low-sugar product consumers than the Low AK group ($P<0.05$). The High AK group also had more users of all HINNS—aspartame ($P<0.01$), saccharin ($P<0.001$), stevia ($P<0.001$), and sucralose ($P<0.01$)—compared to the Low AK group. Of their ice cream purchases within the previous month, more High AK consumers had purchased reduced sugar ($P<0.01$) and reduced calorie ($P<0.05$) varieties than Low AK consumers.

**Table 13.**
Sweetener and ice cream consumption characteristics by actual knowledge (AK) level.

| Variable | Definition | Low AK[1] (n=117; 45.7%) | High AK[2] (n=139; 54.3%) | |
|---|---|---|---|---|
| Regular[3] consumer of… (%) | Low-sugar foods and beverages | 50.4b | 64.7a | * |
| Ice cream products purchased within the past month (%) | Reduced sugar | 13.7b | 28.8a | ** |
| | Reduced calorie | 11.1b | 22.3a | * |
| Users[4] of HINNS (%) | Aspartame | 24.8b | 41.7a | ** |
| | Saccharin | 20.5b | 38.8a | *** |
| | Stevia | 30.8b | 54.7a | *** |
| | Sucralose | 33.3b | 51.1a | ** |

[1]AK<5.6. [2]AK>5.6. [3]Regular consumption defined as ≥ once per month. [4]At least one of the following uses: in a hot drink, in a cold drink, as a topping on prepared food, other. *$P<0.05$, **$P<0.01$, ***$P<0.001$.

Both High and Low AK groups utilized food package labels most frequently to obtain information on sweeteners (Table 14). Both groups also indicated that the most trustworthy information sources were academic and professional publications. High AK consumers reported significantly higher frequency of use for all information sources compared to Low AK

consumers ($P<0.05$). Consumers in the High AK group perceived the trustworthiness of sources to be greater than those in the Low AK group ($P<0.05$), with the exceptions of social media and family and friends ($P>0.05$).

**Table 14.**
Frequency of use and perceived trustworthiness of sources of sweetener information, compared across actual knowledge (AK) levels.

| Attribute | Source | Low AK[(1)] (n=117; 45.7%) | High AK[(2)] (n=139; 54.3%) | |
|---|---|---|---|---|
| Frequency of use[(3)] | | | | |
| | Social media | 2.5bB (0.2) | 3.3aC (0.2) | *** |
| | TV, print media | 2.8bB (0.2) | 3.6aC (0.1) | *** |
| | Academic/professional | 2.5bB (0.2) | 3.6aC (0.2) | *** |
| | Food package labels | 4.2bA (0.1) | 5.2aA (0.1) | *** |
| | Family, friends | 3.9bA (0.2) | 4.4aB (0.1) | * |
| Perceived trustworthiness[(4)] | | | | |
| | Social media | 3.2C (0.2) | 3.3C (0.1) | N.S. |
| | TV, print media | 4.1bB (0.1) | 4.5aB (0.1) | * |
| | Academic/professional | 5.0bA (0.1) | 5.5aA (0.1) | ** |
| | Food package labels | 4.9bA (0.1) | 5.3aA (0.1) | ** |
| | Family, friends | 4.7A (0.1) | 4.7B (0.1) | N.S. |

Means followed by different lowercase letters within a row are significantly different ($P<0.05$). Means followed by different uppercase letters within a column and attribute are significantly different ($P<0.001$). [(1)]AK<5.6. [(2)]AK>5.6. [(3)]Scale: 1=never, 7=always. [(4)]Scale: 1=not at all trustworthy, 7=extremely trustworthy. *$P<0.05$, **$P<0.01$, ***$P<0.001$.

For all assessed topics, High AK consumers gave perceived knowledge scores greater than those of Low AK consumers ($P<0.01$) (Table 15). Low AK consumers felt most informed about food ingredients and least about zero-calorie sweeteners, whereas High AK consumers felt equally informed about all topics.

**Table 15.**
Mean perceived knowledge (PK) scores for nutrition and sweetener topics across actual knowledge (AK) levels.

| Topic[(1)] *"Indicate how informed you feel on each of the following topics."* | Low AK[(2)] (n=117; 45.7%) | High AK[(3)] (n=139; 54.3%) | |
|---|---|---|---|
| Nutrition labels | 4.7bAB (0.1) | 5.2a (0.1) | ** |
| Food ingredients | 4.9bA (0.1) | 5.4a (0.1) | *** |
| Sugar and other caloric sweeteners | 4.8bAB (0.1) | 5.5a (0.1) | *** |
| Zero-calorie sweeteners | 4.3bC (0.1) | 5.1a (0.1) | *** |
| Human nutrition | 4.5bBC (0.1) | 5.2a (0.1) | *** |

Means followed by different lowercase letters within a row are significantly different ($P<0.05$). Means followed by different uppercase letters within a column are significantly different (<<0.05). [(1)]Scale: 1=not at all informed, 7=extremely informed. [(2)]AK<5.6. [(3)]AK>5.6. *$P<0.05$, **$P<0.01$, ***$P<0.001$.

Opinions pertaining to sweeteners and natural ingredients differed between knowledge levels on three topics (Table 6). High AK consumers agreed more strongly than Low AK consumers that they were willing to pay more for something they perceived as healthy ($P<0.01$). The High AK group also agreed more strongly than the Low AK group that artificial sweeteners have an unpleasant aftertaste ($P<0.001$). Finally, consumers in the High AK group were in stronger agreement with the statement, "Stevia is a healthy sweetener because it is natural" than Low AK consumers ($P<0.001$).

**Table 16.**
Mean extent of agreement with sweetener opinion statements across actual knowledge (AK) levels.

| Statement Item[1] *"Indicate the extent to which you agree or disagree with each of the following statements."* | Low AK[2] (n=117; 45.7%) | High AK[3] (n=139; 54.3%) | |
|---|---|---|---|
| Nutritional labels help me to decide which products to buy. | 3.3 (0.1) | 3.4 (0.1) | N.S. |
| Natural sweeteners are better for your health than artificial sweeteners. | 3.5 (0.1) | 3.7 (0.1) | N.S. |
| I am willing to pay more for something I perceive as healthy. | 3.5b (0.1) | 3.8a (0.1) | ** |
| Zero/low-calorie sweeteners can help reduce sugar intake. | 3.4 (0.1) | 3.7 (0.1) | N.S. |
| Artificial sweeteners have an unpleasant aftertaste. | 3.7b (0.1) | 4.1a (0.1) | *** |
| Stevia is a healthy sweetener because it is natural. | 3.2b (0.1) | 3.6a (0.1) | *** |
| Natural products and ingredients are too expensive. | 3.7 (0.1) | 3.9 (0.1) | N.S. |

Means followed by different letters within a row are significantly different ($P<0.05$). [1]Scale: 1=strongly disagree, 5=strongly agree. [2]AK<5.6. [3]AK>5.6. *$P<0.05$, **$P<0.01$, ***$P<0.001$.

### 3.5 Discussion

Consumer knowledge of sweeteners was found to be positively associated with receptiveness to the natural HINNS stevia. High AK consumers were more receptive than Low AK consumers to ice creams sweetened with stevia, consistent with our hypothesis that knowledgeable consumers would be more accepting of stevia as a sweetener. However, even the High AK consumers were only neutral at best toward these products. This may suggest that these consumers have a more expansive mental schema of sweeteners that includes both positive and negative associations. High AK consumers also agreed more strongly than Low AK consumers that artificial sweeteners have an unpleasant aftertaste, which further supports this notion.

The High AK group had greater proportions of regular low-sugar product consumers and HINNS users than the Low AK group. It is reasonable to conclude that regular exposure to a product—in this case, HINNS—facilitates the acquisition of actual knowledge. Further, High

AK consumers were equally confident in their perceived knowledge of all assessed topics, including zero-calorie sweeteners; Low AK consumers, on the other hand, scored their perceived knowledge of all topics lower than those of the High AK group and were significantly less confident in their understanding of zero-calorie sweeteners.

Pertaining to sources of information on sweeteners, High AK consumers utilized all sources more frequently than Low AK consumers. It is reasonable to suggest that a primary goal of seeking information is to improve one's knowledge of the subject. Additionally, it is known that having some prior knowledge facilitates and improves the efficiency of searching for new information (Brucks, 1985). It makes logical sense, then, that consumers with high relative knowledge are also those that pursue information more frequently. High AK consumers were also more trusting of information sources than Low AK consumers, with two exceptions: social media, which was perceived by both groups as the least trustworthy source, and family and friends, which were viewed as moderately trustworthy. Perhaps the most intriguing finding here was that both consumer groups utilized food package labels most frequently of the information sources given, and both considered them to be just as trustworthy as academic or professional publications. This presents a practical avenue for the sweetener industry to implement an educational intervention. There is evidence to support the positive effect of consumer education on receptiveness to stevia—in a 2014 study, Wansink et al. (2014) found that consumers who were provided with a brief history of stevia's use rated its healthfulness significantly higher than consumers not given contextual information.

### 3.6 Conclusion

The findings of this study further stress the importance of consumer knowledge in fostering acceptance of novel food ingredients. Consumers with greater relative knowledge of

sweeteners were found to be more receptive to the concept of stevia-sweetened ice cream compared to those lacking in knowledge. Thus, consumer education programs to increase consumer knowledge levels of sweeteners may be an effective way to improve consumer understanding and promote acceptance of stevia. Even among willing consumers, however, this study found that perception of ice cream containing stevia was neutral at best. It is clear that additional factors beyond product knowledge will need to be addressed if stevia is to find success in the ice cream market.

# APPENDIX

# APPENDIX

Actual knowledge (AK) questionnaire items

*"Indicate whether each of the following statements are true or false. Select "Don't Know" if you are unsure."*

| | True | False | Don't Know |
|---|---|---|---|
| One gram of high fructose corn syrup contains the same number of calories as one gram of sugar. | X | | |
| Natural sweeteners contain fewer calories than artificial sweeteners. | | X | |
| Stevia often has an undesirable bitter aftertaste.* | X | | |
| Stevia is extracted from the leaves of a plant. | X | | |
| Stevia sweeteners can be purchased in powdered, liquid, and crystalline forms. | X | | |
| Stevia is not safe for diabetics. | | X | |
| Sucrose has zero calories. | | X | |
| Truvia and SweetLeaf are brands of stevia sweeteners that can be purchased at most grocery stores. | X | | |
| Sorbitol and xylitol are sugar alcohols that are often found in sugar-free candy and chewing gum. | X | | |
| Stevia is often used in combination with other sweeteners. | X | | |
| Stevia has been used as a sweetener for more than 1,500 years. | X | | |
| Humans are born with a disliking for sweet taste. | | X | |
| One gram of sugar contains the same number of calories as one gram of stevia. | | X | |
| Stevia has been shown to have health benefits such as reduced inflammation and lower blood pressure. | X | | |

* excluded from AK calculation

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# CHAPTER 4: Manuscript 3—INFLUENCE OF LIGHTING TEMPERATURE ON ACCEPTABILITY OF ICE CREAM

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## 4.1 Abstract

Lighting temperature has been shown to modulate food acceptability. For example, warm white light improved acceptability of warm foods, suggesting a congruency effect of food and lighting temperature. This study aimed to determine a lighting-food temperature congruency effect on cold food. Adult ice cream consumers (n=136) evaluated four vanilla ice cream samples under warm or cold lighting. Regular and reduced-carb samples were equally well-liked, while *"light"* and non-dairy samples were liked less. While a significant main effect of lighting temperature was found ($P$ =0.037) for texture liking, hedonic ratings of other attributes (appearance, flavor, and sweetness) as well as overall impression were not significantly affected by the lighting temperature ($P > 0.05$). However, there was a significant interaction between lighting temperature and familiarity for two attributes. Overall liking and flavor liking for "familiar" sample were higher under warm lighting than cold ($P < 0.05$). Results do not support the lighting-food temperature congruency effect and instead corroborate findings that warm lighting improves food acceptability.

### *4.1.1 Practical applications*

The results of this study support the positive influence of warm light on food perception and suggest a way of improving receptiveness to cold foods. Presenting familiar cold food products in a more appealing warm light may foster consumers' willingness to try and acceptance of such products in settings where purchase and consumption location are the same,

such as restaurants or ice cream parlors. These findings would be of greatest interest to those with the ability to manipulate lighting temperature at the point of consumption rather than manufacturers of packaged ice cream products.

## 4.2 Introduction

The importance of intrinsic sensory attributes of food—flavor, texture, aroma—on hedonic evaluation is well-documented; however, these factors provide only a partial framework for explaining consumer preferences and behaviors. The environmental context, or ambience, of an eating experience is composed of factors of the surrounding area that are extrinsic to the food (Stroebele & De Castro, 2004). Lighting is a multi-faceted extrinsic factor with the potential to influence eating behavior. Much of the work in this area has focused on illuminance level, or brightness. Rebollar et al. (Rebollar, Lidón, Guzmán, Gil, & Martín, 2017) found that illuminance level affected perceived healthiness and sweetness of yogurt. Hasenbeck et al. (Hasenbeck et al., 2014) observed illuminance level's effect on appearance liking and willingness to eat (WTE) for bell peppers: low illuminance decreased liking and WTE, while high illuminance increased these attributes.

Lighting temperature is a component of lighting that is not deeply explored in its relation to food perception. Lighting temperature refers to the color emitted by a blackbody when heated to extreme temperatures (Davidson & Abramowitz, 2015). Measured in Kelvin (K), lighting temperature can be used to describe the "yellowness" or "blueness" of white light (Davidson & Abramowitz, 2015). Lower temperatures (up to approximately 3,000 K) correspond to lower wavelength colors such as red and yellow, while higher temperatures (greater than 4,600 K) correspond to higher wavelength colors such as blue (Davidson & Abramowitz, 2015). Lighting temperature can influence one's psychological and physical perceptions of their environment.

Nakamura and Oki (2000) found that subjects perceived rooms illuminated by low color temperature lights as being warmer than those with high color temperature. This effect is attributed to the psychological "hue-heat" associations between warm colors and warm temperatures, and vice versa (Laurentin, Bermtto, & Fontoynont, 2000; Nakamura & Oki, 2000).

While manufacturers are limited in their control of consumer's eating environment, there is potential for intervention at the point of sale. Retail lighting is generally cold but can be varied by section of the store (Clare & Hancer, 2016). Fresh meat, for instance, can be presented under very warm lighting in order to accentuate the red oxymyoglobin pigment, an important quality indicator for consumers (Barbut, 2005). Freezer cases, on the other hand, are typically illuminated by cold lighting (Otterbring, Löfgren, & Lestelius, 2014). A 2014 study by Otterbring et al. investigated the relationship between lighting temperature and consumer perceptions of packaged frozen meals. Subjects viewed packaged meals presented in retail freezers under cold (blue LED) or warm (yellow LED) lighting and evaluated the products on four attributes: inferred quality, perceived price, attractiveness, and inferred taste (Otterbring et al., 2014). As they predicted, the packaged meals received more positive evaluations for inferred quality and attractiveness under warm lighting and did not differ significantly in perceived price between lighting conditions; contrary to the hypothesis for inferred taste, however, a significant difference was observed with the package under warm lighting receiving more positive evaluations (Otterbring et al., 2014).

It has been theorized that congruency between lighting temperature and expected food eating temperature may be a contributing factor in evaluations of inferred taste (Otterbring et al., 2014). Though purchased frozen, ready meals are intended to be eaten warm; when paired with warm lighting, the inferred temperature of the food is reinforced, processing fluency is improved,

and positive ratings increase (Herrmann, Zidansek, Sprott, & Spangenberg, 2013; Otterbring et al., 2014). A model proposed by Tsujimura and Yanagisawa (2015) also accounts for the role of consistency and processing fluency on the formation of visual expectations of food. The model can be divided into two levels—physical phenomena and cognitive structure. At the physical level, measurable visual features of a food (luminance, saturation, and hue) are determined by the illuminance level and color temperature of the lighting source (Tsujimura & Yanagisawa, 2015). At the cognitive level, the relationship between a food's surface color temperature and the anticipated sensible heat of a food—that is, the temperature at which the food would typically be consumed—is referred to as the "cold-warm sensation" (Tsujimura & Yanagisawa, 2015). Analogous to Otterbring et al. (2014), Tsujimura and Yanagisawa (2015) have suggested that consistency of the cold-warm sensation improves processing fluency and generates a more positive visual expectation evaluation (Reber, Schwarz, & Winkielman, 2004; Tsujimura & Yanagisawa, 2015). Thus, the primary objective of this study was to extend lighting temperature congruency hypothesis to cold food products (i.e., ice cream). Our secondary objective was to determine how familiarity influences hedonic evaluation of ice cream under warm and cold lighting temperature. Several studies have shown that familiarity influences the amount and type of contextual cues that consumers use in evaluating a product; the less familiar the product, the greater the reliance on extrinsic attributes (i.e. ambient lighting) to form an opinion (Park & Lessig, 1981; Rao & Monroe, 1988). Our hypothesis was that consumers would be more susceptible to the influence of lighting temperature when evaluating a less familiar product.

## 4.3 Materials & Methods

### *4.3.1 Participants*

Participants in this study were naïve consumers and were recruited via the SONA Paid Research Pool (https://msucas-paid.sona-systems.com) the surrounding communities (East Lansing, MI). Eligibility requirements included absence of food allergies or sensitivities to non-nutritive sweeteners, absence of dairy-related dietary restrictions, and minimum age of 18. Of the 136 participants, 96% consumed ice cream at least once per month. Informed consent was acquired from all participants prior to testing. Participants were randomly assigned to one of two lighting temperature treatments. Table 17 outlines the gender, age range, and race/ethnicity frequencies of participants in each lighting temperature treatment group.

**Table 17.**
Age range, race/ethnicity, and gender frequency distribution of participants for each lighting temperature treatment.

| Attribute | Lighting Temperature | | *Total* |
|---|---|---|---|
| Age Range (y) | *Warm* | *Cold* | |
| *18-24* | 27 | 39 | 66 |
| *25-34* | 20 | 20 | 40 |
| *35-44* | 4 | 6 | 10 |
| *45-54* | 4 | 3 | 7 |
| *55+* | 7 | 6 | 13 |
| Race/Ethnicity | | | |
| *Non-Hispanic White* | 46 | 48 | 94 |
| *Hispanic/Latino* | 1 | 3 | 4 |
| *Black* | 4 | 7 | 11 |
| *Asian* | 9 | 13 | 22 |
| *Other* | 2 | 3 | 5 |
| Gender | | | |
| *Male* | 30 | 35 | 65 |
| *Female* | 32 | 39 | 71 |
| *Total* | 62 | 74 | 136 |

*4.3.2 Samples*

Four commercially available vanilla ice cream products were used. A regular full-calorie ice cream, an artificially sweetened reduced-carb ice cream, a naturally sweetened "light" ice cream, and a non-dairy coconut milk-based ice cream were purchased from a local grocery store. Selected nutrient compositions for each sample are shown in Table 2. The regular full-calorie ice cream served as the control, while the reduced-carb, "light," and non-dairy samples were selected to manipulate stimulus familiarity for sensory attributes. One #30-sized scoop (1.75" dia, 2T) of each sample were portioned into 2 oz plastic portion cups. Samples were scooped one day prior to testing and stored in an upright freezer at -20°F. On the test day, samples were transferred to a chest freezer where they were held at -5°F prior to serving.

**Table 18.**
Selected nutrient content of four vanilla ice cream samples used in the study.

| Nutrient Content (per ½ cup) | Sample | | | |
|---|---|---|---|---|
| | Regular | Reduced Carb | Light | Non-Dairy |
| Calories (kcal) | 140 | 90 | 70 | 160 |
| Fat (g) | 10 | 5 | 2 | 9 |
| Carbohydrates (g) | 16 | 12 | 14 | 17 |
| Sugar (g) | 15 | 3 | 6 | 14 |

Means followed by different letters within a column are significantly different ($P<0.05$). Scale: 1=dislike extremely, 9=like extremely.

*4.3.3 Procedure*

Testing was conducted in the MSU sensory lab (East Lansing, MI). Participants attended a single tasting session and were seated at individual divided booths under LED lighting [Philips Hue LightStrip Plus] (Philips Lighting, Amsterdam, Netherlands). The lighting conditions of warm (yellow light-emitting diode [LED], 3155K) and cold (blue LED, 6369K) were matched as

closely as possible to Otterbring et al. (2014). Lighting temperature was controlled using the Hue Pro app (Philips Lighting, Amsterdam, Netherlands) for Samsung Galaxy Tab S2 (Samsung Electronics Co., LTD, Suwon, South Korea). Samples were presented one at a time in a balanced randomized design with water for palate cleansing. Questionnaires were completed using RedJade Sensory Software (RedJade, Redwood Shores, CA, USA). Sweetness, texture, appearance, flavor, and overall liking were rated on 9-point hedonic scales (1=dislike extremely, 9=like extremely). Panelists were also asked to rate the familiarity of each sample (1=extremely unfamiliar, 9=extremely familiar) and how well it met their expectations for vanilla ice cream (1=much worse than expected, 5=much better than expected). Following sample evaluations, participants completed demographics questions (age group, gender, and race/ethnicity) as well as ice cream preference and behavior questions including consumption frequency, preferred flavors, and experience with reduced carb and non-dairy ice creams.

*4.3.4 Data analysis*

Data analysis was performed using XLSTAT Sensory v19.5 (AddinSoft, New York, NY, USA). A three-way analysis of covariance (ANCOVA) was performed treating lighting temperature (i.e. warm and cold), familiarity level (Famil Lvl) [low, '0' <6.2, and high, '1'>6.2] and ice cream sample as fixed effects and overall liking and attribute likings (appearance, flavor, texture, and sweetness) as the response variable. Expectation was used as a covariate since the hedonic ratings (overall liking and attribute liking) could be confounded by them. In the case of a significant difference of means, post hoc comparisons were performed using Fisher's least square difference (LSD) tests.

## 4.4 Results & Discussion

As expected, a significant main effect of sample was found for overall liking ($P < 0.001$) and for all attribute likings ($P < 0.001$). Participants showed a clear preference for the regular and reduced carb ice creams over the *"light"* and non-dairy samples in all aspects (Table 19). Vanilla ice cream has a long history as a popular food among Americans, but *"light"* and non-dairy variants of the frozen dessert have only become widely available within the past few decades. It is well known that humans are more receptive to familiar foods than those with which they have little or no prior experience (Archer & Sjödén, 1979; Barrena & Sánchez, 2013; Pliner & Hobden, 1992; Raudenbush & Frank, 1999). The familiarity ratings were 7.2 (±1.6), 6.9 (±1.7), 5.6 (±2.2), and 5.3 (±2.4) for regular, reduced-carb, non-dairy, and *"light"* ice cream, respectively. It is plausible that low familiarity with the *"light"* and non-dairy samples negatively influenced their ratings.

A significant main effect of lighting temperature was found for texture liking ($P = 0.037$), but not other hedonic ratings of appearance, flavor, and sweetness as well as overall liking ($P > 0.05$); it was shown that the participants rated texture liking significantly higher under warm lighting than cold lighting.

**Table 19.**
Mean hedonic ratings of vanilla ice cream sample attributes (n=136)

| Sample | Attribute | | | | |
|---|---|---|---|---|---|
| | Overall Liking | Appearance | Flavor | Texture | Sweetness |
| Regular | 7.1a (0.2) | 7.0a (0.2) | 7.1a (0.2) | 6.9a (0.2) | 7.3a (0.2) |
| Reduced Carb | 7.1a (0.2) | 7.4a (0.2) | 7.0a (0.2) | 7.2a (0.2) | 6.9a (0.2) |
| Light | 5.1b (0.2) | 5.0c (0.2) | 5.1b (0.2) | 4.5c (0.2) | 5.6b (0.2) |
| Non-Dairy | 4.8b (0.2) | 5.8b (0.2) | 4.7b (0.2) | 5.1b (0.2) | 5.0c (0.2) |

Means followed by different letters within a column are significantly different (P<0.05).
Scale: 1=dislike extremely, 9=like extremely.

No significant three-way interaction between lighting temperature, familiarity level, and ice cream sample was found for overall liking ($F_{3,527}$ = 1.145, $P$ = 0.475), appearance liking ($F_{3,527}$ = 1.279, $P$ = 0.281), flavor liking ($F_{3,527}$ = 0.377, $P$ = 0.769), texture liking ($F_{3,527}$ = 0.767, $P$ = 0.513), or sweetness liking ($F_{3,527}$ = 0.593, $P$ = 0.629). Further, no significant two-way interaction between 'lighting temperature and sample' or 'sample and familiarity level' for overall liking and attribute liking (P > 0.05). However, a significant two-way interaction effect of lighting temperature and familiarity level was found for overall liking and flavor liking ($F_{3,527}$ = 17.526, 10.940 for overall and flavor liking, respectively, $P$ < 0.001). As shown in Figure 2, the participants who were more familiar with ice cream samples (i.e., high Famil Lvl '1' > 6.2 on a 9-point familiarity scale; 1 = extremely unfamiliar, 9 = extremely familiar) rated overall liking and flavor liking significantly higher under warm lighting than cold lighting. The same clear trend ($P$ = 0.104) was also found in overall liking across lighting temperature for "*light*" and non-dairy samples, but not for regular and reduced carb ice creams (Figure 3). The preference for warm lighting when paired with ice cream—a cold food—does not support the hypothesis of a lighting-food temperature congruency effect. Rather, it corroborates previous findings that warm lighting improves perception of food.

Further, our hypothesis that consumers might be more susceptible to the influence of lighting temperature when evaluating products less familiar than regular ice cream was not fully supported. It is possible that the negative impact of unfamiliarity was stronger than the positive influence of warm light due to the discrepancy in expectation. Participants were informed that they would be tasting four samples of vanilla ice cream, but the identities of the samples were not disclosed. When participants who were familiar with the samples consumed them, the discrepancy between what was expected of ice cream and what they tasted would have been

minimal. For unfamiliar consumers, the experience may have been similar to those in the smoked salmon ice cream study by Yeomans et al. (2008). In the study, the group that was told they would be sampling ice cream prior to consuming the smoked salmon frozen dessert had strong negative reactions, while the group that was informed that sample was a savory frozen mousse were much more receptive (Yeomans, Chambers, Blumenthal, & Blake, 2008). Although the expectancy discrepancy in this study was theoretically not as large, it is plausible that the negative effect of consuming something unfamiliar could have overridden any positive influence of warm lighting conditions.

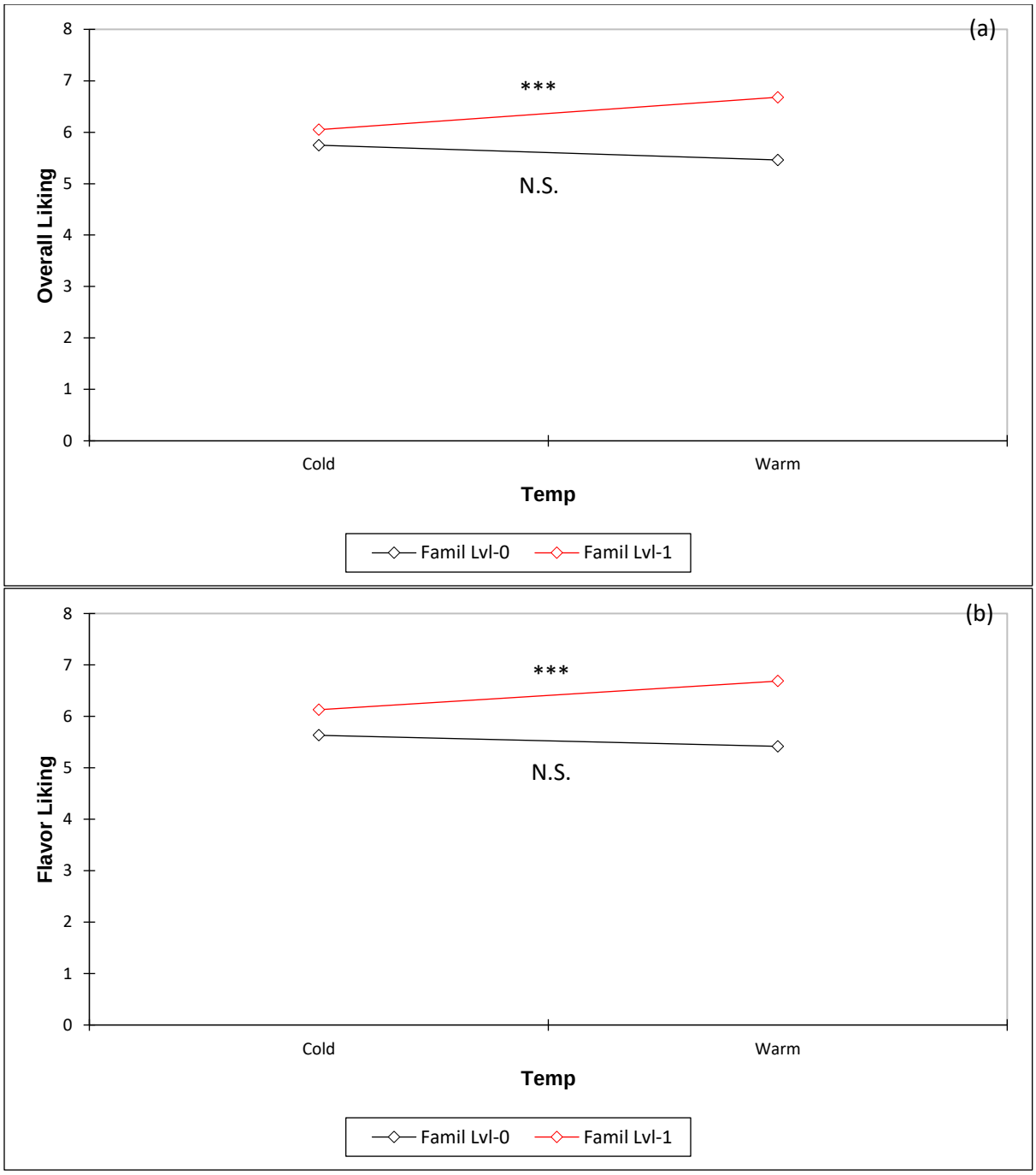


**Figure 2. A significant interaction effect of lighting temperature and familiarity level on overall liking (a) and flavor liking (b).** Famil Lvl '1' > 6.2 on a 9-point familiarity scale; 1 = extremely unfamiliar, 9 = extremely familiar. Famil Lvl '0' < 6.2. Scale: 1=dislike extremely, 9=like extremely. *** $P < 0.001$. N.S.=non-significant.

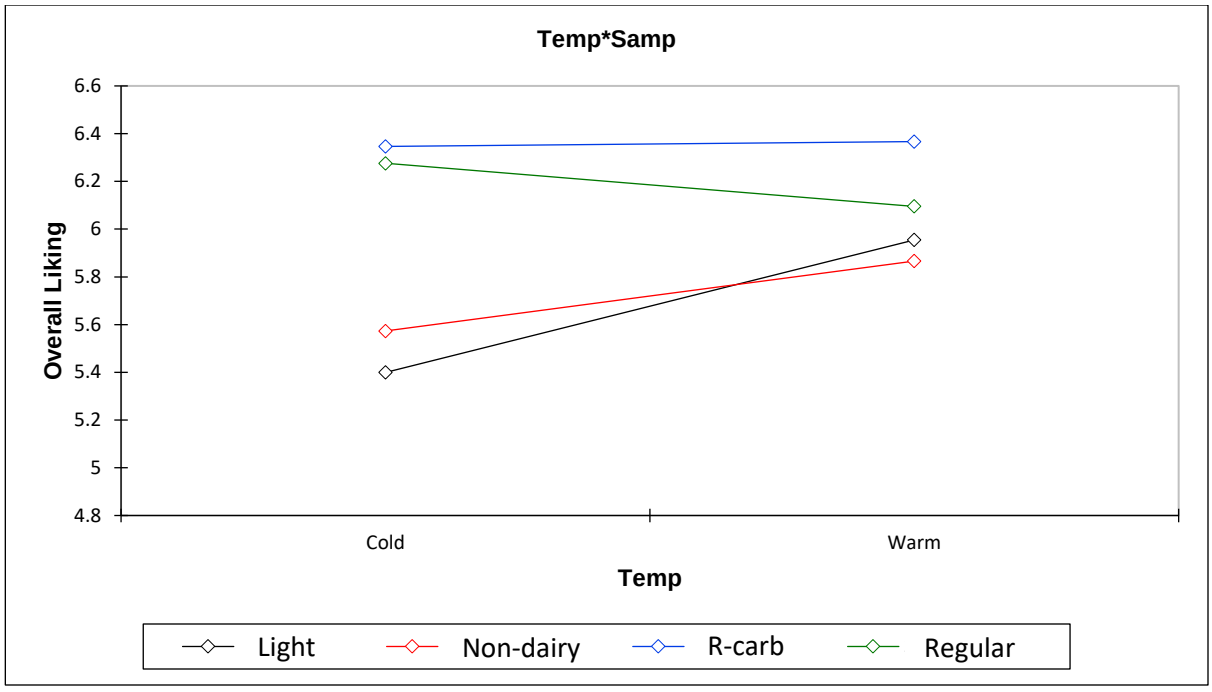


**Figure 3. A clear interaction effect of lighting temperature and sample on overall liking (*P* = 0.104).** Scale: 1=dislike extremely, 9=like extremely.

### 4.5 Conclusion

Familiar ice cream received more favorable evaluations for overall liking and flavor liking when presented under warm lighting than under cold. This finding does not support the proposed lighting-food temperature congruency hypothesis; ice cream, a food traditionally consumed cold, was preferred under incongruent lighting temperature (warm). Instead, this result supports findings that warm lighting improves perception of food in general. Further, results of this study did not support our second hypothesis that, when presented with an unfamiliar product, consumers might be more strongly influenced by an extrinsic attribute such as ambient lighting conditions to form an evaluation. Further research using other types of cold food products such as frozen desserts or frozen fruits is necessary to confirm lighting-food temperature incongruency effect on cold food.

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# CHAPTER 5: CONCLUSIONS

The findings of this work offer relevant insight toward consumer values and perceptions of ice cream. In the first study, sweetener was identified as the attribute of greatest relative importance to the average ice cream consumer, followed by claims, calories, and price. Although stevia-sweetened ice cream had poor reception compared to cane sugar, regular users of reduced sugar products were quite receptive. These consumers want low-calorie ice cream and appear open to alternative sweeteners; as such, this segment should be leveraged as opinion leaders to improve public perception of stevia.

These results further stress the importance of consumer knowledge in fostering acceptance of novel food ingredients. Consumers with greater relative knowledge of sweeteners were found to be more receptive to stevia-sweetened ice cream compared to those lacking in knowledge. There is research to suggest that improving consumer knowledge of unfamiliar food ingredients may be effective in promoting acceptance. Educational efforts to increase consumer knowledge levels of sweeteners, particularly those that utilize food package labels, may be an effective way to improve consumer understanding and promote acceptance of stevia.

Another potential avenue to improve consumer perceptions of unfamiliar ice cream may be through modification of ambient lighting conditions. While no significant effect of lighting temperature was observed overall, results indicate that consumers may be more susceptible to lighting cues when consuming a familiar ice cream. In response to growing demand for “guilt-less” desserts, ice cream manufacturers continue to churn out health-conscious ice cream alternatives that consumers may find strange. Sellers with the capacity to manipulate lighting

conditions at the point of consumption, such as ice cream parlors or restaurants, may benefit from the use of warm lighting to improve familiarity of these “atypical” ice creams.

Intrinsic sensory properties of ice cream—sweetness, richness, mouthfeel—are fundamental to consumer enjoyment. Even the most compelling labeling and optimal ambient lighting conditions cannot salvage a product that is unappealing to eat. However, when the goal is to alleviate initial hesitation to purchase or taste, extrinsic factors may prove to be a powerful tool in the hands of stevia ice cream manufacturers.