HHS Public Access

Author manuscript

J Dairy Sci. Author manuscript; available in PMC 2016 June 08.

Published in final edited form as:

J Dairy Sci. 2013 August ; 96(8): 4938–4944. doi:10.3168/jds.2013-6715.

Explaining tolerance for bitterness in chocolate ice cream using solid chocolate preferences

Meriel L. Harwood[*,†], **Joseph R. Loquasto**[†], **Robert F. Roberts**[†], **Gregory R. Ziegler**[†], and **John E. Hayes**[*,1,†]

[*]Sensory Evaluation Center, The Pennsylvania State University, University Park 16802

[†]Department of Food Science, College of Agricultural Sciences, The Pennsylvania State University, University Park 16802

Abstract

Chocolate ice cream is commonly formulated with higher sugar levels than nonchocolate flavors to compensate for the inherent bitterness of cocoa. Bitterness, however, is an integral part of the complex flavor of chocolate. In light of the global obesity epidemic, many consumers and health professionals are concerned about the levels of added sugars in foods. Once a strategy for balancing undesirable bitterness and health concerns regarding added sugars has been developed, the task becomes determining whether that product will be acceptable to the consumer. Thus, the purpose of this research was to manipulate the bitterness of chocolate ice cream to examine how this influences consumer preferences. The main goal of this study was to estimate group rejection thresholds for bitterness in chocolate ice cream, and to see if solid chocolate preferences (dark vs. milk) generalized to ice cream. A food-safe bitter ingredient, sucrose octaacetate, was added to chocolate ice cream to alter bitterness without disturbing other the sensory qualities of the ice cream samples, including texture. Untrained chocolate ice cream consumers participated in a large-scale sensory test by indicating their preferences for blinded pairs of unspiked and spiked samples, where the spiked sample had increasing levels of the added bitterant. As anticipated, the group containing individuals who prefer milk chocolate had a much lower tolerance for bitterness in their chocolate ice cream compared with the group of individuals who prefer dark chocolate; indeed, the dark chocolate group tolerated almost twice as much added bitterant in the ice cream before indicating a significant preference for the unspiked (control) ice cream. This work demonstrates the successful application of the rejection threshold method to a complex dairy food. Estimating rejection thresholds could prove to be an effective tool for determining acceptable formulations or quality limits when considering attributes that become objectionable at high intensities.

Keywords

chocolate ice cream; bitterness; rejection threshold; sensory evaluation

---

[1]Corresponding author: ; Email: jeh40@psu.edu

INTRODUCTION

Chocolate is an extremely complex flavor, to which a degree of bitterness is essential for an acceptable overall flavor profile. Making a chocolate ice cream, therefore, can be complicated, as ice cream contains high levels of fat and sugar that have the ability to significantly decrease perceived bitterness. Fat can influence perceived bitterness, as bitter compounds may partition away from the aqueous phase of an emulsion and therefore become less available to act on taste receptors (Metcalf and Vickers, 2002). However, this effect may vary from compound to compound (Keast, 2008; Bennett et al., 2012), as great structural diversity exists among compounds that elicit bitterness via human bitter taste receptors (Meyerhof et al., 2010). Additionally, crystallinity of the fat can also influence the partitioning of small particles into or out of the aqueous phase (Ghosh et al., 2007).

Sweetness perceptually masks bitterness in the central nervous system (Lawless, 1979). It has been shown that an optimum level for sugar in vanilla ice cream is about 13.5% (Guinard et al., 1996). In chocolate ice cream, however, sugar levels are generally increased, compared with other ice cream flavors, to compensate for the bitter compounds inherently present in chocolate (Prindiville et al., 2000; Marshall et al., 2003). It has been recommended to increase sweetener by using equal weights of sucrose (or equivalent sweetener) and cocoa in addition to the initial amount of sweetener to achieve an optimal balance of sweetness and bitterness (Marshall et al., 2003). Whereas this may seem to be an effective strategy for maintaining flavor balance, levels of added sugar in foods are of great concern in the United States, as the obesity epidemic is on the rise (Ogden et al., 2012). Moreover, consumers are becoming increasingly aware of and concerned about the amount of sugar in the foods that they choose to eat, and approximately 56% of Americans have reported trying to limit sugars in their diet (IFIC, 2011). For the production of ice cream in particular, strategies to limit sugar may be especially challenging for producers to meet consumer demand, as sugar is integral for the perceived creaminess (Stampanoni, 1993; Guinard et al., 1997), quality, and acceptance of ice cream products (Guinard et al., 1996). Additionally, several processing parameters (i.e., freezing point) are highly dependent on the sugar content of the final product, and thus the reduction of sugar can lead to manufacturing complications.

A further potentially influencing factor on the balance of bitterness in chocolate ice cream is the temperature at which ice cream is served. Both hot and cold serving temperatures, for example, have been demonstrated to have the ability to significantly enhance or decrease the perceived intensity of some sweeteners, though the effect sizes are small (Schiffman et al., 2000). A study by Paulus and Reisch (1980) investigating detection, recognition, and terminal thresholds for the 5 prototypical tastes found that, for bitter tastants (specifically quinine and caffeine), both hot and cold temperatures elevated the amount of stimulus required to be present for detection and recognition thresholds, with the effect much greater at higher temperatures. Whereas these effects may not generalize to supra-threshold concentrations or different bitter compounds, it remains possible that serving temperature may affect the perceived bitterness of ice cream.

It is important to consider that the degree of bitterness desirable in chocolate products may differ largely from consumer to consumer as dictated by preferences for milk or dark chocolate (Harwood et al., 2012a,b). That is, those who find bitterness most objectionable are likely to avoid dark chocolate, as it is typically more bitter than milk chocolate. Additionally, it is unknown whether or not preference for vanilla or chocolate ice cream is influenced by preference for milk or dark chocolate when considering individual solid chocolate preferences. Recently, we demonstrated that bitterness tolerance in chocolate-flavored fluid milk can be explained, in part, by solid chocolate preferences, as individuals who prefer dark chocolate are much more tolerant of bitterness than those who prefer milk chocolate (Harwood et al., 2012a). It seems reasonable to ask whether this pattern also generalizes to ice cream. In the current study, our main objective was to investigate if rejection thresholds (**RjT**) for added bitterness in chocolate ice cream are influenced by individual preference for milk or dark solid chocolate by estimating group RjT using a recently developed sensory method. Rejection thresholds differ from more traditional scale based acceptance (liking) tests in that they are a cognitively simpler task, and allow for direct estimation of the concentration at which an attribute becomes objectionable. Also, as we recently demonstrated, RjT are sensitive to differences between market segments, at least for chocolate-flavored fluid milk and solid chocolate.

MATERIALS AND METHODS

Treatments

In ice cream, as sugar content decreases, significant textural and flavor changes occur. After pilot testing, it became clear that, though some of these textural aspects may be overcome by the addition of bulking agents, the difference was still large enough that preferences could be affected regardless of differences in flavor. Therefore, to study how the balance of bitter flavor affects preferences in chocolate ice cream, it was decided that the most effective way to manipulate the bitterness while holding all other sensory attributes constant would be to add small amounts of a highly potent bitter compound. Sucrose octaacetate (**SOA**; SAFC, Lenexa, KS) was chosen as the added bitter ingredient because it is strongly bitter at micro molar concentrations, and generally recognized as safe as a direct and indirect food additive (21 CFR 172.515 and 21 CFR 175.105, respectively; CFR, 2012a,b). Additionally, whereas many other bitter substances may vary across individuals as a function of genetic differences (Hayes et al., 2008, 2011; Allen et al., 2013), prior work indicates little to no individual differences in SOA bitterness sensitivity in humans (Boughter and Whitney, 1993). Though individual differences in the bitterness evoked of compounds endogenous to chocolate may exist, no reports of this have been published to date. These concentrations used in the current study were based on informal bench testing as well as similar experiments involving SOA (Harwood et al., 2012a,b); concentrations were selected to range from undetectable or barely detectable (low intensity) to universally objectionable (high intensity).

Here, the control samples were plain chocolate ice cream. The spiked samples contained varying amounts of SOA, with final concentrations of 10, 20, 40, 80, and 160 μ*M*. For example, to make the 160 μ*M* sample, 3.1513 g of SOA was added to 32 kg of ice cream mix (see below).

Ice Cream Processing

The ice cream formulation used was 14.1% fat (added as cream and whole milk), 10.0% nonfat milk solids (added, in part, as nonfat dry milk; Maryland and Virginia Milk Producers Association Inc., Reston, VA), 13% sugar (Good Food Inc., Honey Brook, PA), 3.7% corn syrup solids (Tate and Lyle, Decatur, IL), 3% cocoa powder (Forbes, Broadview Heights, OH), and 0.5% stabilizer or emulsifier blend (Cremodan IcePro, Danisco DuPont, St. Joseph, MO). Three samples of each treatment and control were analyzed for TS and fat on finished product using CEM Smart Trac (Mathews, NC).

Samples were formulated and manufactured to the formulation described above at the Berkey Creamery at Pennsylvania State University. Ice cream mix was batched and pasteurized at 178.5°F for 43s on an HTST pasteurizer system (APV, Charlotte, NC) and then held at 4°C until mix was frozen. Immediately before freezing, ice cream mix was weighed into separate batches and spiked with the appropriate amount of SOA (in 50 mL of ethanol for ease of dispersion) into the mix. Ice cream mix was frozen on a Gram GIF 400 continuous freezer (Gram Equipment of North America, Tampa, FL) with overrun set to 80%. Calculations from ice cream mix and finished product yielded an 82.6% overrun across all samples. Samples were packaged into 4-oz. plastic cups (Airlite Plastics, Omaha, NE) on an automatic filling system (T.D. Sawvel Co. Inc., Maple Plain, MN). All ice creams were then stored at 5°F for 1 wk before serving. Before being served to panelists, samples were tested for total coliforms and total aerobic plate count according to standard methods (Wehr et al., 2004).

Sensory Testing Procedures

Individuals were recruited from the Penn State community via email, and screened for their willingness to eat chocolate ice cream. Ninety-six reportedly healthy, nonsmokers (31 men) participated in the study. Half of the participants were between 18 and 24 yr of age and the remaining half were between 25 and 45 yr old. Recruitment aimed for an equal number of participants with a stated preference for solid milk chocolate and solid dark chocolate. Forty-six participants indicated that they preferred milk chocolate and 50 indicated that they preferred dark chocolate when asked at the conclusion of the test (Table 1). All participants provided informed consent and were paid for their time. Procedures were exempt from Institutional Review Board review by the Penn State Office of Research Protections under the wholesome foods or approved food additives exemption 45 CFR 46.101(b)(6). All sensory data were collected using Compusense Five software v5.2 (Guelph, Canada).

Rejection thresholds were measured using a series of two-alternate forced choice paired preference tests. Samples were presented as blinded pairs (a control and a sample spiked with SOA), and the participants were asked to indicate which of the 2 samples they preferred; a “no preference” option was not given (Harwood et al., 2012a). The pairs were presented in order of ascending SOA concentration (increasing bitterness). Within the pairs, the order of the samples was randomized to prevent order biases. All tests were carried out in individual testing booths at the Sensory Evaluation Center at Penn State under white lights. Each sample pair was presented as needed through a serving hatch by project staff to prevent melting of the samples and consistency of tasting temperature. Participants were instructed to rinse with room temperature (21°C) water between samples. All samples were presented between −12 and −15°C in 4-oz. plastic cups labeled with random 3-digit blinding codes. At the conclusion of the two-alternate forced choice tests, participants were asked to indicate their preference for solid milk chocolate or solid dark chocolate, chocolate or vanilla ice cream, sex, and age.

Whereas fatigue is a potential concern with a high-fat product such as ice cream, Guinard et al. (1996) previously demonstrated participants could evaluate 9 samples without experiencing significant fatigue. In this study, participants each tasted 10 different samples with a minimum of 60 s (controlled by timed delays enforced via software) between sample sets and participants were instructed to rinse with water between each sample. Additionally, all participants were informed of the large amount of samples to be tasted and instructed to only taste 1 spoonful (approximately 4 g) of each. Consequently, we believe that fatigue did not play a role in the results of our study.

Statistical Analysis

Rejection thresholds were analyzed using the procedure outlined previously (Harwood et al., 2012a), with participants separated into groups based on their self-reported preference for solid chocolate (milk chocolate or dark chocolate) and ice cream (chocolate or vanilla). Fisher's exact test was used to investigate effects of sex on preference groups, as well as stated preference for solid chocolate (milk vs. dark) and vanilla or chocolate ice cream.

RESULTS AND DISCUSSION

As expected, the group that preferred dark chocolate had a significantly higher RjT for SOA in the chocolate ice cream than the group that preferred milk chocolate, with a concentration approximately 2 times higher (Table 2). This result (both the concentration of SOA required for rejection as well as the separation between milk- and dark chocolate-preferring groups) corresponds with what has been shown previously for the same compound (SOA) in chocolate-flavored fluid milk and solid milk chocolate-flavored compound coating (Harwood et al., 2012a,b). The rejection thresholds for SOA in chocolate ice cream (Figure 1) fall approximately halfway between those observed previously for chocolate milk and compound chocolate; this was expected, as the sugar and fat content of chocolate ice cream falls between the levels in these products (Table 3).

Though we did not design this series of experiments to specifically pull apart the effects of temperature, fat, or sugar, we feel that our results are likely due to the differences in sugar content of the different sample matrices. It seems likely that the bitterness of SOA was masked by the sugar via the process of mixture suppression. Mixture suppression is a commonly observed perceptual phenomenon in taste where the sensation of a mixture is less than the sensations that would be elicited from the stimuli when experienced separately (Lawless, 1979; Keast and Breslin, 2003). Alternatively, if the RjT were a function of temperature rather than sugar content, they would be in a different order than what was observed across these experiments (present data; Harwood et al., 2012a,b). That is, if cold temperature was suppressing the bitterness, the ice cream would have the highest RjT, followed by the chocolate milk, and then, finally, the compound chocolate would have the lowest RjT.

However, this interpretation does not preclude the possibility that we are observing a physiochemical effect rather than a perceptual interaction due to partitioning into the fat phase. Specifically, increasing fat levels can decrease the bitterness of some stimuli (Metcalf and Vickers, 2002). Metcalf and Vickers (2002) demonstrated a reduction in the bitterness of quinine sulfate by oil in water emulsions with a concentration dependent effect: more fat in the system resulted in greater reduction of bitterness. Those authors hypothesized this result was due to the lipophilic nature of quinine sulfate, causing a portion of it to partition into the fat phase of the emulsion, thereby rendering it unavailable to taste receptors. Contrary to these findings, however, Keast (2008) demonstrated the opposite effect for caffeine: as milk fat level increased, so did bitterness. This might be explained by the lipophilicity hypothesis of Metcalf and Vickers (2002), as caffeine is predominantly hydrophilic, with a partition coefficient of −0.07 (Biagi et al., 1990). When considering our experiments with SOA, it seems unlikely that increasing fat would reduce the bitterness intensity; SOA has a negative partition coefficient (−0.9) according to PubChem (2013), so it would be expected to partition into the water phase. Whether this may also be influenced by pH is unknown (Bennett et al., 2012).

Another potential explanation for the differences in RjT between experiments might be differences in viscosity across the matrices. Previous work in liquids of varying viscosity suggests that the bitterness of quinine sulfate decreases as viscosity increases (Moskowitz and Arabie, 1970). The concentration of solids in the solution in the saliva would increase from chocolate milk to chocolate ice cream to compound chocolate due to an increase in viscosity across these products; if this also reduces perceived bitterness (which was not directly assessed in our tests), then we might also expect differences in hedonics. That is, as the viscosity increases, more SOA may be required to elicit the same intensity of bitterness that results in rejection of the spiked sample.

Preference for chocolate or vanilla ice cream was tested for association with preference for milk or dark chocolate (Table 4) using Fisher’s exact test, and found to be significant ($P < 0.02$). That is, people who prefer milk chocolate were over-represented in the group preferring vanilla, whereas the group preferring chocolate ice cream was comprised of 42 and 58% individuals that prefer milk chocolate and dark chocolate, respectively. Secondary analyses of rejection thresholds based on these alternative groupings reflect this distribution of preferences. The RjT for the vanilla ice cream group was 14.6 μ*M* (similar to the 14.2 μ*M* seen for the group preferring milk chocolate). The RjT for the chocolate ice cream group was 21.1 μ*M*, which is similar to what we see for the average RjT of all the participants (48% for those who prefer milk chocolate, 52% for those who prefer dark chocolate) at 20.2 μ*M*.

The estimation of group rejection thresholds for SOA in chocolate ice cream allowed us to demonstrate that excessive bitterness leads to the rejection of chocolate ice cream, which is the basis for the general recommendation to increase the amount of sweetener in chocolate ice cream mix. Additionally, the comparison of these results to previous studies evaluating

RjT for SOA in chocolate-flavored products (Harwood et al., 2012a,b) suggests that increasing levels of sugar offset the amount of SOA required to elicit rejection, as would be expected. That is, increasing sweetness suppresses the perception of bitterness in chocolate-flavored products. When practically applied, our results suggest chocolate ice cream formulated to contain lower levels of sweetener may still be acceptable to consumers who tolerate more bitterness (i.e., consumers who prefer dark chocolate), providing that the other sensory properties of the ice cream remain unchanged (i.e., texture), though this remains to be verified. That is, a market niche may exist for lower sugar chocolate ice cream that would do well among consumers of dark chocolate.

Previously, almost all studies on RjT have been applied to liquid foods, such as wine, milk, or soup (Prescott et al., 2005; Lee et al., 2008; Saliba et al., 2009). We recently demonstrated the use of this method with a solid food (Harwood et al., 2012b) and we extend this work further here, by showing this technique can be applied to an intermediate food matrix, such as ice cream. This validation should be of interest to those who work with dairy products because of the broad potential application of the RjT method in dairy products. Chocolate ice cream is a very complex stimulus that can be difficult to evaluate with consumers, and can require trained panels to profile, which are costly and labor intensive. In contrast, the RjT method is simple to carry out for both the researcher and the participant as it is based on straightforward preference tasks. As demonstrated by this experiment, this method could be used to quantify group RjT limits for an assortment of off flavors or attributes that only become objectionable at high intensities in a variety of dairy products. In addition, past and present data indicate it can also be used when considering specific market segments.

When considering acceptable concentration limits for attributes that are necessary for (or irrelevant to) preferences at low levels but become objectionable at high levels (e.g., bitterness), many benefits to using the RjT method exist. For formulations already known to be acceptable, such as the commercially successful chocolate ice cream mix used in this study, consumer acceptance tests are not required for validation. As a method of constant stimuli, spiked samples are always compared with control samples. Therefore, the standard of comparison is known. Of course, for formulations with unknown acceptability, it would be beneficial to carry out appropriate acceptance tests for the control sample before determining RjT. The RjT allows for the determination of the point at which the concentration of the attribute of interest becomes objectionable, even if it falls between the samples given, which can be difficult to determine when using acceptance tests. However, once this range is determined, it may be prudent to subsequently validate these data using traditional acceptance tests. Finally, the RjT method allows for the determination of a preference or indifference function, which illustrates the relative rate at which increasing the concentration in the spiked samples causes them to become objectionable (via the slope of the linear portion of the sigmoid function).

CONCLUSIONS

In conclusion, RjT for SOA in chocolate ice cream are influenced by preference for solid milk or dark chocolate. Existing preferences for solid chocolate appear to generalize to chocolate-flavored ice cream, as might be expected. Specifically, those who prefer solid dark chocolate to milk chocolate tolerate substantially higher levels of an added bitterant. This difference in RjT agrees with previous studies on RjT for SOA in other chocolate-flavored products. This approach could be used to make chocolate ice cream with less added sugar to be marketed for dark chocolate lovers, though this remains to be verified. Rejection thresholds also have the potential to be applied to other dairy foods in quality control or product optimization applications as a means to determine specific concentration limits associated with preferences.

Acknowledgments

The authors thank the staff of the Berkey Creamery at Penn State, especially Bonnie Ford, Todd Gantt, and Emily Furumoto for their assistance in sample preparation. We also thank Rachel Primrose and the Sensory Evaluation Center staff for their assistance with data collection, and our participants for their time and participation. This manuscript was completed in partial fulfillment of the requirements for a Master of Science degree at the Pennsylvania State University by the first author (MLH). This work was partially supported by funds from the Pennsylvania Manufacturing Confectioners' Association, who were not involved in the study design or the decision to publish these data. The corresponding author receives support from USDA Hatch Project PEN04332 funds and a National Institutes of Health grant from the National Institute of Deafness and Communication Disorders (DC010904).

References

Allen AL, McGeary JE, Knopik VS, Hayes JE. Bitterness of the non-nutritive sweetener acesulfame potassium varies with polymorphisms in TAS2R9 and TAS2R31. Chem Senses. 2013; 38:379–389. http://dx.doi.org/10.1093/chemse/bjt017. [PubMed: 23599216]

Bennett SM, Zhou L, Hayes J. Using milk fat to reduce the irritation and bitter taste of ibuprofen. Chemosens Percept. 2012; 5:231–236. [PubMed: 23527314]

Biagi GL, Guerra MC, Barbaro AM, Barbieri S, Recanatini M, Borea PA, Pietrogrande MC. Study of the lipophilic character of xanthine and adenosine derivatives: I. RM and log P values. J Chromatogr A. 1990; 498:179–190.

Boughter JD, Whitney G. Human taste thresholds for sucrse octaacetate. Chem Senses. 1993; 18:445–448.

CFR (Code of Federal Regulations). [Accessed Jun. 6, 2013] 21CFR 172.515. Synthetic flavoring substances and adjuvants. 2012a. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=172.515

CFR (Code of Federal Regulations). [Accessed Jun. 6, 2013] 21CFR 175.105. Adhesives. 2012b. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=175.105

Ghosh S, Peterson D, Coupland J. Aroma release from solid droplet emulsions: Effect of lipid type. J Am Oil Chem Soc. 2007; 84:1001–1014.

Guinard JX, Zoumas-Morse C, Mori L, Panyam D, Kilara A. Effect of sugar and fat on the acceptability of vanilla ice cream. J Dairy Sci. 1996; 79:1922–1927.

Guinard JX, Zoumas-Morse C, Mori L, Uatoni B, Panyam D, Kilara A. Sugar and fat effects on sensory properties of ice cream. J Food Sci. 1997; 62:1087–1094.

Harwood ML, Ziegler GR, Hayes JE. Rejection thresholds in chocolate milk: Evidence for segmentation. Food Qual Prefer. 2012a; 26:128–133. [PubMed: 22754143]

Harwood ML, Ziegler GR, Hayes JE. Rejection thresholds in solid chocolate-flavored compound coating. J Food Sci. 2012b; 77:S390–393. [PubMed: 22924788]

Hayes JE, Bartoshuk LM, Kidd JK, Duffy VB. Supertasting and PROP bitterness depends on more than the TAS2R38 gene. Chem Senses. 2008; 33:255–265. [PubMed: 18209019]

Hayes JE, Wallace MR, Knopik VS, Herbstman DM, Bartoshuk LM, Duffy VB. Allelic variation in *TAS2R* bitter receptor genes associates with variation in sensations from and ingestive behaviors toward common bitter beverages in adults. Chem Senses. 2011; 36:311–319. [PubMed: 21163912]

IFIC. Food and Health Survey: Consumer Attitudes Toward Food Safety, Nutrition and Health. International Food Information Council Foundation; Washington, DC: 2011.

Keast RSJ. Modification of the bitterness of caffeine. Food Qual Prefer. 2008; 19:465–472.

Keast RSJ, Breslin PAS. An overview of binary taste-taste interactions. Food Qual Prefer. 2003; 14:111–124.

Lawless HT. Evidence for neural inhibition in bittersweet taste mixtures. J Comp Physiol Psychol. 1979; 93:538–547. [PubMed: 479396]

Lee YM, Prescott J, Kim KO. PROP Taster status and the rejection of foods with added tastants. Food Sci Biotechnol. 2008; 17:1066–1073.

Marshall, RT.; Goff, HD.; Hartel, RW. Ice Cream. 6. Kluwer Academic/Plenum Publishers; New York, NY: 2003.

Metcalf KL, Vickers ZM. Taste intensities of oil-in-water emulsions with varying fat content. J Sens Stud. 2002; 17:379–390.

Meyerhof W, Batram C, Kuhn C, Brockhoff A, Chudoba E, Bufe B, Appendino G, Behrens M. The molecular receptive ranges of human TAS2R bitter taste receptors. Chem Senses. 2010; 35:157–170. [PubMed: 20022913]

Moskowitz HR, Arabie P. Taste intensity as a function of stimulus concentration and solvent viscosity. J Texture Stud. 1970; 1:502–510.

Ogden, CL.; Carroll, MD.; Kit, BK.; Flegal, KM. Prevalence of Obesity in the United States, 2009–2010. U.S. Department of Health and Human Services Centers for Disease Control and Prevention; Atlanta, GA: 2012.

Paulus K, Reisch AM. The influence of temperature on the threshold values of primary tastes. Chem Senses. 1980; 5:11–21.

Prescott J, Norris L, Kunst M, Kim S. Estimating a “consumer rejection threshold” for cork taint in white wine. Food Qual Prefer. 2005; 16:345–349.

Prindiville EA, Marshall RT, Heymann H. Effect of milk fat on the sensory properties of chocolate ice cream. J Dairy Sci. 2000; 83:2216–2223. [PubMed: 11049061]

PubChem. NCBI. Sucrose Octaacetate–Compound Summary. Vol. 2013. U.S. National Library of Medicine; Bethesda, MD: 2013.

Saliba AJ, Bullock J, Hardie WJ. Consumer rejection threshold for 1,8-cineole (eucalyptol) in Australian red wine. Food Qual Prefer. 2009; 20:500–504.

Schiffman SS, Sattely-Miller EA, Graham BG, Bennett JL, Booth BJ, Desai N, Bishay I. Effect of temperature, pH, and ions on sweet taste. Physiol Behav. 2000; 68:469–481. [PubMed: 10713286]

Stampanoni CR. Influence of acid and sugar content on sweetness, sourness and the flavour profile of beverages and sherbets. Food Qual Prefer. 1993; 4:169–176.

Wehr, HM.; Frank, JF. A. P. H. Association. Standard Methods for the Examination of Dairy Products. 17. American Public Health Association; Washington, DC: 2004.

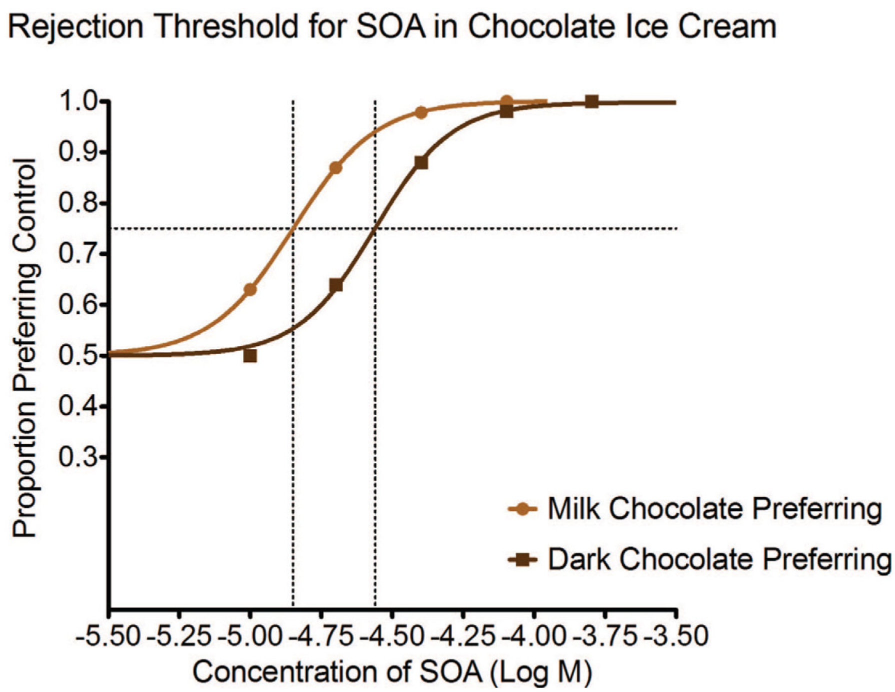

Figure 1.

Rejection thresholds for sucrose octaacetate (SOA) in chocolate ice cream for groups that prefer milk and dark chocolate. Color version available in the online PDF.

Table 1

Breakdown of participants by sex and solid chocolate preference

Item	n	Men	Women
All participants	96	31	65
Milk chocolate preference	46	18	28
Dark chocolate preference	50	13	37

Table 2

Group rejection thresholds for sucrose octaacetate (SOA) in chocolate ice cream

Preference group	**Concentration of SOA (μ*M*)**	**Fold difference**	***P*-value**
Milk chocolate	14.17	1.93×	0.0002
Dark chocolate	27.42		
Vanilla ice cream	14.6	1.45×	0.0039
Chocolate ice cream	21.1		
All participants	20.2	NA[1]	NA

[1]NA = not applicable.

Table 3

Sugar and fat content of stimuli in past and present experiments and corresponding rejection thresholds (RjT)

Item	Sugar (%)	Fat (%)	Milk chocolate preference RjT (μ*M*)	Dark chocolate preference RjT (μ*M*)
Chocolate-flavored fluid milk[1]	10	2	3.9	9.0
Chocolate ice cream[2]	13	14.1	14.2	27.4
Solid milk chocolate-flavored compound coating[3]	55	31	43.9	113.5

[1]Results from Harwood et al. (2012a); n = 70, 38 preferred dark chocolate and 32 preferred milk chocolate.

[2]Results of current study; n = 96, 50 preferred dark chocolate and 46 preferred milk chocolate.

[3]Results from Harwood et al. (2012b); n = 85, 42 preferred dark chocolate and 43 preferred milk chocolate.

Table 4

Contingency table for preference group distributions (Fisher's exact test)

Item	Milk chocolate	Dark chocolate	Total
Chocolate ice cream	32	45	77
Vanilla ice cream	14	5	19
Total	46	50	*

*$P = 0.02$.