Ice Cream Formulation Optimization Using "Consumer-Friendly" Hydrocolloid Stabilizers

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ABSTRACT

Ice Cream Formulation Optimization Using “Consumer-Friendly” Hydrocolloid Stabilizers

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Hydrocolloid stabilizers are commonly used in ice cream formulations to provide body and reduce ice crystal growth during storage. We conducted a retail survey of 65 different vanilla ice cream brands and found the majority of manufacturers primarily use 1 or more of 4 different hydrocolloid sources: guar gum, carrageenan, locust and carob bean gum, or cellulose gum or gel. However, many consumers view hydrocolloids as unnatural, and the presence of hydrocolloids on an ingredient declaration may negatively affect purchase intent. Our survey of 705 consumers showed significant differences in purchase intent for vanilla ice cream, based on ingredient declarations containing different hydrocolloid stabilizers. A response surface central composite design was used to optimize ice cream stability using combinations of tapioca flour, carob bean gum, and citrus fiber, 3 consumer-preferred hydrocolloid stabilizers. Instrumental evaluations considered the dependent variables mix viscosity, ice cream hardness and toughness, melt-rate, and ice crystal size. A trained sensory panel also rated iciness, melt-rate, ease of breakdown in the mouth, and vanilla intensity. Each of the dependent variables from the trained panel and instrumental analysis were measured before and after a 3-week accelerated temperature cycling test. A regression analysis of the central composite design data combined instrumental and trained-panel results to compute a response surface based on the regression equation of each attribute. Using the response surface, 3 different optimized mix formulations were determined. The 3 different mixes were optimized using: 1) all dependent variables evaluated, 2) only sensory iciness scores, and 3) ice crystal size only. An untrained consumer panel evaluated samples before and after temperature cycling test, and rated vanilla ice creams prepared from all 3 optimized mixes against a control ice cream, prepared with a natural commercial stabilizer blend. The uncycled products prepared using optimized stabilizer blend were at statistical parity with the control product for overall acceptance, purchase likelihood, preference, sweetness and vanilla intensity, rate of melting in the mouth, texture and hardness. One or more of the optimized products were rated significantly better than the control for creaminess and texture. For products subjected to temperature cycling, 1 or more of the optimized products were rated significantly better than control for all attributes except sweetness and vanilla flavor intensity. This research indicates that more consumer-preferred options for ice cream stabilization are available to the ice cream industry, with performance and sensory results equal to other commercial hydrocolloid stabilizer blends.

Keywords: clean label, tapioca flour, citrus fiber, carob bean gum, response surface central composite design
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INTERPRETIVE SUMMARY

Hydrocolloid stabilizers are commonly used in ice cream formulations to provide body and reduce ice crystal growth during storage. Many consumers view hydrocolloids as unnatural, and the presence of hydrocolloids on an ingredient declaration may negatively affect purchase intent. This research indicates that more consumer-preferred options for ice cream stabilization are available to the ice cream industry, with performance and sensory results equal to other commercial hydrocolloid stabilizer blends. Tapioca flour and citrus fiber can be used effectively as ice cream stabilizers in place of traditional stabilizers to provide a more “consumer-friendly” product.

INTRODUCTION

The body and texture of dairy-based frozen desserts are a critical part of the sensory experience and 2 of the main drivers of consumer acceptance. Consequently, most frozen dessert manufacturers include a variety of hydrocolloid stabilizers in the mix formulation to help provide smooth and creamy body and texture, and especially to minimize ice crystal growth during distribution and storage (Goff and Hartel, 2013). Hydrocolloids are high molecular weight ingredients, usually polysaccharides, which form colloidal dispersions in the aqueous phase, and are highly hydrophilic due to a large number of hydroxyl groups (Regand and Goff, 2002, Maity et al., 2018). Some of the commonly used hydrocolloid stabilizers in ice cream include natural plant derivatives such as carrageenan, guar and locust bean gums, as well as chemically modified compounds such as carboxymethyl cellulose (cellulose gel) (Goff and Hartel, 2013).

Consumer demand for so called “clean label” foods, which Aschemann-Witzel et al. (2019) defined as products free from “negatively perceived” ingredients and additives, is causing the food industry to reduce and simplify the ingredients added to food products, targeting additives that consumers deem to be more natural (Lusk, 2019). The term
“negatively perceived” is specifically referring to consumer perception, which can be confusing since consumers have varying levels of understanding and familiarity with the wide array of ingredients in food. From a technical standpoint, “clean-label” ingredients are not necessarily safer nor of higher quality than their counterparts, but the consumer is more accepting of them based on their knowledge of and attitudes towards specific declared ingredients. The food market is currently catering to consumers with limited technical understanding who demand consumer-friendly ingredients without sacrificing product quality.

While the majority of hydrocolloids used in ice cream are derived from natural sources, many consumers do not appear to understand that. Chambers V et al. (2019) evaluated whether consumers consider food ingredients like xanthan gum, seaweed gum, inulin and gelatin as “natural.” Seaweed gum was considered natural by 16% of consumers, gelatin was considered “natural by 13% of consumers, xanthan gum was considered natural by only 6% of consumers and 3% of consumers said that they perceived inulin to be “natural.” Given that many hydrocolloid stabilizers are not considered natural, even when derived from natural sources, dairy manufacturers are confused when it comes to formulating “clean label” frozen desserts (Aschemann-Witzel et al., 2019). To achieve success in the current market, new products must be developed using natural ingredients that are also likely to be perceived as “natural” by most consumers.

Consequently, considerable research has been done to evaluate novel hydrocolloids as natural stabilizers in ice cream. Bilbao-Sainz et al. (2019) studied the use of freeze-dried raspberry powder because of the current consumer demand for fewer and more familiar ingredients that are both natural and sustainable. Other natural hydrocolloid materials evaluated for their potential as stabilizers in ice cream include basil seed gum, balangu seed gum, furcellaran (a red seaweed extract), inulin, and quince seed powder (Bahramparvar et

While new stabilizers such as these could be part of the solution, there is already an abundance of commercially-available stabilizers with established supply chains, and some might be regarded more favorably than others by the consumer. Consequently, further research is needed to identify both existing and novel natural stabilizers that are not only effective but also are “consumer-friendly,” meaning that their appearance on the label has a positive effect on consumer purchase intent, when compared to alternatives. Because “friendliness” is a rather subjective term, we will hereafter use the term “consumer-preferred,” instead of “consumer-friendly,” with “preferred” referring to a quantified increase in purchase intent. Using this latter definition, “consumer-preferred” hydrocolloids can be ranked according to their impact on consumer purchase intent. The use of a broad consumer survey to rank consumer acceptance of readily available stabilizers for use in ice cream is absent from the literature. Coupling a consumer acceptance study with targeted food science research evaluating the efficacy of the most widely accepted stabilizers would address product design elements and support the development of products that will meet consumer acceptance and stability targets.

In this paper we report the results of such a study, wherein we surveyed consumer attitudes toward a wide variety of hydrocolloid stabilizers that could be used in frozen desserts, then included selected stabilizers in a response surface central composite design (CCD) statistical analysis to provide technical formulation guidance to assist in identifying optimal usage combinations and levels. A final consumer sensory panel compared the optimized stabilizer blends to a standard commercial stabilizer blend promoted as “clean label.” The objectives of this study were to identify the most consumer-preferred hydrocolloid stabilizers, determine ratios of consumer-preferred hydrocolloid stabilizers that
achieve optimal product quality, and evaluate consumer preference between optimized blends and a standard commercial blend.

**MATERIALS AND METHODS**

*Market Survey of Stabilizers Used in Retail Ice Cream*

In order to determine the type and presence of ice cream stabilizers used commercially in the current market, a survey of retail ice cream ingredient declarations was performed. Local supermarkets were visited and all of the ingredients used in every available variation of vanilla ice cream were documented. In addition, online shopping websites as well as food manufacturing websites were perused to get a larger sample size than what was available locally. In total, 65 different vanilla ice cream ingredient declarations were recorded.

*Online Survey of Consumer Attitudes Towards Ice Cream Stabilizers*

Natural stabilizers identified in published scientific literature and through communications with hydrocolloid suppliers were combined with those from the frequency-of-use data collected from the ingredient declarations market survey. The effect of each of the selected stabilizers on consumer purchase-intent was evaluated via an online consumer survey administered by the Brigham Young University (BYU) Sensory Lab using Qualtrics® (Provo, UT, USA) software.

The survey and all other human subject research was approved by the University’s institutional review board and comprised university students, faculty and other personnel, and members of the surrounding community. A total of 705 responses were received. The participants were ages 18 or older and were regular ice cream consumers who indicated that they read food ingredient declarations before making food purchases at least “sometimes,” from a list of “always,” “most of the time,” “about half the time,” “sometimes” or “never.”
Panelists provided informed consent and were compensated with a $5 gift card for their time. The survey took approximately 25 min to complete.

Survey participants were also asked about their purchase habits using various questions. Participants were asked, “How would you rate the importance of simple/clean-label ingredients in your decision to purchase ice cream?” They were also asked, “How would you rate the importance of organic ingredients in your decision to purchase ice cream?” Additionally they were asked, “How would you rate the importance of all-natural ingredients in your decision to purchase ice cream?”

The survey consisted of 2 parts. In part 1, participants were asked to compare pairs of side-by-side ingredient declarations for vanilla ice cream that were identical except for the name of 1 of 12 stabilizers. They were asked to indicate which ice cream they would purchase over the other, or select the option “no preference.” The 12 stabilizers compared in part 1 were the following non-modified hydrocolloid ingredients from natural sources: carob bean gum, carrageenan, guar gum, acacia gum, pectin, tara gum, xanthan gum, citrus fiber, arrowroot starch, tapioca flour, chicory root fiber and egg yolk.

The stabilizers carob bean gum, carrageenan and guar gum were selected for use in the paired-comparisons because they are in nearly half of all ice creams sold commercially. Acacia gum, pectin, tara gum and xanthan gum are other “natural” stabilizers that are also used in retail ice cream products, though less commonly (<10%), which accounted for their selection. Citrus fiber is naturally high in pectin, and was chosen to determine if the different nomenclature would lead to greater purchase likelihood than pectin alone. Arrowroot starch and tapioca flour were selected to explore natural root and tuber starches as stabilizers, based on the success that Fernandes et al. (2017) reported when using cassava derivatives in ice cream. Chicory root fiber—another natural root fiber, which is about 70% inulin—was
selected based on El-Nagar et al. (2002) successfully using inulin in their yogurt ice cream (Moser et al., 2014). Though not a hydrocolloid stabilizer, egg yolk is used in some “all-natural” ice creams to provide stabilization of the mix. Because it is a natural ingredient that is used commercially in ice cream, as well as in the home kitchen, egg yolk was used as a positive control. The inclusion of egg yolk allowed us to make relative comparisons to an ice cream additive that is positively regarded and has high consumer familiarity.

Participants were asked to pick the product that they would most likely purchase based on the ingredient declaration. The consumer was asked, “Assuming quality, cost and all other factors are equal – choose which of the two ice cream products you would purchase based on the ingredient declaration provided” Each of the 12 stabilizers were paired individually against each of the others for a total of 66 pair-wise comparisons. Each surveyed consumer was randomly assigned 22 of the comparisons.

Data was analyzed using a logistic regression model. A post-hoc test of all pairwise comparisons was run comparing the odds of each ingredient being chosen relative to the other ingredients. The p-values for these were based on the odds ratios between the ingredients. To adjust for the multiple comparisons a pseudo-Bonferroni adjustment was made. This led to an adjusted alpha level of 0.001 to determine statistical significance. The odds ratios for each ingredient were averaged and those averages were used to prepare a ranked-list of ingredients based on purchase intent. Higher average odds ratios indicate a higher number of preferential selections when compared against all other ingredients.

Following the pair-wise comparisons of ingredient declarations, all participants were then provided an extended list of 40 different ice cream stabilizers that comprised the twelve ingredients from the pair-wise comparison and 28 other hydrocolloids, some of which are chemically modified but commonly used in ice cream. We also included several
hydrocolloids with different names for the same ingredient and organic variations of the same
ingredient (see Table 6 in the Results section for the complete list). The consumers were
asked “If you were evaluating the ice cream ingredient declaration while shopping for ice
cream, how likely or unlikely would you be to purchase the product if it included the
following ingredients: … ” The participant answered for each of the 40 stabilizers using a
discrete Likert 1-7 scale (where 1 = very unlikely and 7 = very likely).

Based on the results of both segments of the survey, the 3 most consumer-preferred
ice cream stabilizers were selected for preliminary functionality testing and comparisons in
vanilla ice cream as described in the central composite design section.

**Ice Cream Manufacture**

*Materials.*

Ice cream was made with whole milk (3.25% fat), whipping cream (36% fat), sucrose,
non-fat dry milk, and vanilla flavor – all purchased from a local grocery store. Carob bean
gum (Locust Bean Gum POR/A) and a commercially available, natural stabilizer blend
containing gum acacia, tara gum, and guar gum (Dairyblend Natural IC 21) were sourced
from TIC gums (White Marsh, MD). Citrus fiber (Nutrava Citrus Fiber) was sourced from CP
Kelco (Atlanta, GA). Tapioca flour (Homecraft Express 390, pregelatinized) was sourced
from Ingredion (Westchester, IL).

*Process Description.*

A standard vanilla base mix—formulated based on the attribute range found in
standard to premium ice cream mixes—was used to test the various hydrocolloid stabilizer
blends (Goff and Hartel, 2013). The base mix composition was 12% milk fat, 11% milk
solids-not-fat, 13% sucrose, with varying stabilizer levels between 0.32% - 2.36%. The mix
was pasteurized at 80°C for 30 seconds in a UHT/HTST Lab-25 EHVH tubular pasteurizer
(Microthermics, Raleigh, NC), homogenized using a NS2006H homogenizer (GEA Niro, Parma, Italy) at 13789 kPa (2,000 psi) and 3447 kPa (500 psi) for the first and second stages, respectively, and then aged overnight (Goff and Hartel, 2013). Batch sizes were 2.37 L and mixes were frozen after aging in a Trittico M30 4.74 L batch freezer (Bravo North America, Charlotte, NC) with an overrun of 50% (± 10%) and a draw temperature of -3.5°C (± 1). Samples (approximately 220g) were collected in 237 mL polyethylene-lined paper cups with polyethylene terephthalate lids immediately after manufacture and hardened overnight in a blast freezer at -40°C, before moving to a -20°C freezer for longer term storage. Samples for all testing were prepared and packaged as indicated here. Due to the large number of treatments (16), 4 treatments were prepared and frozen once a week. This approach allowed for different stability end times and trained panel evaluation start times. Sequence of batch preparation and freezing was randomized.

**Accelerated Stability Test**

The accelerated stability test (AST) was based on the method used by Regand and Goff (2006), which subjected the ice cream samples to cyclic temperature abuse and heat shock. Each treatment was subjected to 9 48-h freeze-thaw cycles over 3 weeks, with temperature alternating between -10°C and -20°C every 24 h (Aleong et al., 2008). Optimized samples prepared for final consumer testing were subjected to the same accelerated testing, but only received 7 48-h cycles.

**Trained Sensory Panel**

A trained sensory panel (n=13) was used to evaluate key sensory properties of the ice cream treatments prepared with the different hydrocolloid stabilizer blends, following the method of Varela and Fiszman (2013). The panel was approved by the BYU Institutional Review Board. Panelists were screened for availability and interest. Panelists provided informed consent and were compensated for their time.
The panelists evaluated iciness, melt rate, breakdown, and vanilla intensity. These attributes were selected when the ice cream lexicon was reviewed and refined over 5, h-long training sessions. During the training sessions, the panel was trained to uniformly rate each attribute by evaluating, scoring and discussing selected defective and commercial ice creams. The panelists and moderator determined the attributes to be included based on a review of similar trained panels reported in the literature (Amador et al., 2017, VanWees et al., 2020). Table 1 describes the reference sheet, adopted from this same source, which was used by the trained panelists. The table includes the definition of each attribute, how to evaluate it, the scale used to evaluate it, and the reference standards used.

The panelists evaluated between 3-6 samples during each session. Sample scores were recorded by completing a Qualtrics-hosted survey either on their phones or on their laptop. Iciness, breakdown, and vanilla intensity were ranked on a line scale of 0-15, while melt rate was defined as the number of seconds it took for the ice cream sample to completely melt inside of the panelist’s mouth. The panelist had a copy of the reference sheet and access to all reference standards during every product evaluation, and used them to achieve consistent results.

The CCD treatments were evaluated 2 d after manufacture and again at the conclusion of the AST, with evaluations staggered over 8 weeks. In preparation for the trained panel, samples were scooped into 59 mL cups, and held overnight at -20ºC. For tasting, each sample was removed from the freezer, lid removed, and allowed to temper at room temperature for 3 min. After 3 min, the panelists rated the attributes in the following order: iciness, melt rate, breakdown and vanilla intensity. A small metal teaspoon was used by each panelist to evaluate the samples, and pictures of ice cream volume in the spoon were posted for panelist
review. In addition, panelists were provided water and unsalted crackers to cleanse their palette in between samples.

**Instrumental Ice Crystal Analysis**

Ice crystal size was measured using a light microscope based on the methods of Ruger et al. (2002) and VanWees et al. (2020). Ice cream samples were held and evaluated in a -20ºC walk-in freezer. A sample of ice cream was taken from the center of the cup at least 1 inch beneath the surface. The sample was placed on a viewing slide with 2 drops of a 50:50 pentanol and kerosene solution, covered with a slip cover and observed at 200X magnification (Warren and Hartel, 2014, Amador et al., 2017). For each sample, the sizes of 240 ice crystals across 18 fields were measured at the widest point on the crystal using Fiji Image software (ImageJ 1.52t), an open-source application accessible online. A 100 µm calibration slide was used along with the software for quantitation.

**Instrumental Hardness Measurement**

Ice cream hardness was evaluated using a TA.XT2 Texture Analyzer (Stable Micro Systems Ltd, Godalming, UK) based on the methods of Smet et al. (2010) and Amador et al. (2017). A 237 mL cup of ice cream, stored at -20ºC, was held at room temperature for 10 min before testing. A 4.6cm wide, 7 cm tall, 1 mm thick plate probe penetrated the ice cream in the center of the cup at a speed of 2 mm/s to a depth of 15 mm, recording the force applied over time. Both ice cream hardness and toughness were determined. Velasquez-Cock et al. (2019) defined hardness as the peak compression force during the penetration of each sample (kg) and toughness as the compression force applied during the penetration of each sample over time (kg⋅m/s²). Four different sample cups were evaluated for each treatment.
**Evaluation of Melting Behavior**

The meltdown was assessed following the methods of Bolliger et al. (2000) and Koxholt et al. (2001). A 237 mL cup sample of each ice cream, stored at -20°C, was removed from the container, weighed and placed at ambient temperature (approximately 22°C) onto an 8-mesh sieve (8 holes per 2.54cm). A tared bowl was used to collect the melted ice cream passing through the sieve. The weight of ice cream melted was recorded in 5 min intervals for a period of 90 min. The melt rate was defined as the weight melted per min (g/min). Four different samples were evaluated for each treatment.

**Viscosity**

The apparent viscosity of each ice cream mix was measured at 4°C after ageing overnight. A Model: DV-II+ viscometer (Brookfield, Middlebury, MA) was used with a RV-02 spindle, at a speed of 2.5 rpm. The viscosity of 400 mL of ice cream mix was tested immediately upon removal from the refrigerator in a 500 mL beaker, taking 6 readings per sample.

**Central Composite Design**

Three consumer-preferred stabilizers, having distinct chemical compositions, were selected based on purchase-intent data from the consumer survey, and evaluated in a response surface central composite design. The CCD design consisted of 16 stabilizer combinations of 0, 20, 50, 80, or 100% of the maximum usage level for each hydrocolloid (Table 2). Numerous preliminary formulations were prepared and evaluated (data not shown) with varying combinations and levels of hydrocolloids to establish maximum usage levels for each of the 3 stabilizers using methods described previously. Initial maximums were based on the highest single-use addition level that did not compromise sensory properties or result in excessively viscous ice cream mixes, taking into consideration ease of flow through the pasteurizer. Additional downward adjustments to the maximum level were made to ensure
that mix viscosity was not excessive in combination with other stabilizers. A pregelatinized tapioca flour was used to ensure that the viscosity of the mix pre-pasteurization would be similar to the viscosity post-pasteurization and to minimize strain on the equipment.

For each CCD treatment, vanilla ice cream samples were prepared and subjected to AST and evaluated instrumentally and by a trained panel in order to provide data for determining which combinations performed the best and which stabilizer combinations were optimal. Based on input instrumental and trained-panel data, predicted values for each of the ice cream attributes were computed over the entire response surface, based on the regression equation from the regression analysis of each attribute, using JMP 15 software (SAS Institute, Cary, NC).

Three optimized formulas for further consumer testing were created using predictions from the CCD data. The first formulation was optimized based on the sum of all the tested ice cream attributes. The ice cream attributes were standardized and the formulation that maximized the sum of the standardized values was used. The second optimized formula was created similarly, based on the trained panel sensory iciness scores after AST. The third formulation was created based on the results of instrumental ice crystal analysis following AST.

**Untrained Consumer Sensory Analysis**

Consumers were recruited using the BYU Sensory Lab panelist database. All participants (n=60, 30 male and 30 female, 18 yrs old and older) liked both ice cream and vanilla flavor. Two panels were held on consecutive days, comprising the 3 CCD-optimized formulas and a control sample prepared with a commercial stabilizer blend (listed in materials section), promoted as being a natural or “clean label” ingredient option. The control stabilizer was added at 0.85%, which was at the higher end of the recommended use level (0.5-1.0%). Following manufacture and hardening, a subset of all 4 samples were
immediately placed in AST, as described previously. The remainder were placed in a -20°C freezer and held until the AST was complete. The AST samples were placed in the -20°C freezer for 24-h prior to consumer testing. All samples were scooped into 59 mL (2 oz) cups and held at -20°C until being moved into a -13°C freezer the night before the consumer test (Goff and Hartel, 2013). During the first panel, consumers were presented with samples that had not been subjected to AST treatment, whereas the second panel was conducted the following day using AST samples. An effort was made to use the same consumers in both panels, but new consumers were used in place of consumers who could not make it on the second day.

Ice cream samples were removed from the -13°C freezer and promptly presented to each participant side-by-side, with evaluation order balanced so that each sample was evaluated in each position an equal number of times. The participants were seated in isolated booths while participating in the sensory analysis. Saltine crackers and room temperature water were provided to each panelist to cleanse their palate in between samples. The ice cream was served in 59 mL plastic sample cups with a small plastic taster spoon. Each sample was randomly assigned a 3-digit blinding code.

The following sample attributes were evaluated using a 5-point Just-About-Right (JAR) scale. Sweetness intensity, vanilla flavor intensity, and creaminess used word anchors: 1=definitely too much, 2=slightly too much, 3=just about right, 4=slightly too little, 5=definitely too little. Word anchors for the other JAR-scale attributes were: too fast and too slow, for rate of melting in mouth; too thick and too thin for texture after it has melted in your mouth; and too hard and too soft for hardness and softness. Purchase likelihood, appearance liking, flavor, overall acceptance, texture and mouthfeel, aftertaste, and iciness level were evaluated using a 9-point hedonic scale (1=like extremely, 9=dislike extremely). Forced preference among the 4 samples was also assessed.
RESULTS AND DISCUSSION

Market Survey of Stabilizers Used in Retail Ice Cream

Our retail ice cream ingredient survey, shown in Table 3, revealed that the majority of vanilla ice cream products sold in the US include at least 1 of the top 4 ice cream stabilizers from Table 3 (guar gum, carrageenan, locust bean gum, and cellulose gum) in their formulations. While there are many different stabilizers that could be used in ice cream, these 4 are most commonly included, presumably due to cost-in-use and consistent performance of quality parameters.

Guar gum, the most frequently used stabilizer, is extracted from the endosperm of the seeds of the tropical legume *Cyamoposis tetragonolba*, also known as the guar bush (Nwokocha, 2021). Guar gum is a high molecular weight polysaccharide, composed of mannose and galactose, that functions as a thickener, gelling agent, emulsion stabilizer, film former, and texture modifier (Kapoor et al., 2013). Because of guar gum’s higher solubility compared to locust bean gum at cold temperatures, it is used more frequently in HTST pasteurization systems (Bahramparvar and Tehrani, 2011). Galactomannans like guar gum and locust bean gum are the most commonly used stabilizers specifically targeting ice crystal growth inhibition (Adapa et al., 2000). Guar gum may be used in ice cream mixes at levels up to 0.5% by weight of the mix (21 CFR 184.1339).

Carrageenan is primarily sourced from the cell walls of red algae (*Chondrus crispus*) (Tuvikene, 2021). Carrageenan is composed of alternating residues of 3-linked β-D-galactose and 4-linked α-D-galactose (Tuvikene, 2021). Kappa carrageenan and milk proteins have a synergistic relationship called milk reactivity, resulting in minimal carrageenan concentration (0.03%) required to prevent phase separation (Tuvikene, 2021). Additionally, negatively charged kappa casein and positively charged, divalent calcium ions found in milk can result in the formation of a carrageenan gel network (Tuvikene, 2021). Carrageenan functions in dairy
products by providing mouthfeel, thickness and smoothness, and stabilizing the formula matrix, preventing fat separation (Tuvikene, 2021). In the US, it may be used in ice cream at levels required to achieve the desired effect (21 CFR 172.620).

Locust bean gum, also known as carob bean gum, is sourced from the beans of the carob tree (*Ceratonia siliqua* L.) (Nwokocha, 2021). Like guar gum, locust bean gum is a galactomannan with a mannose backbone and galactose side groups (Nwokocha, 2021). Locust bean gum is a high viscosity gum that can form elastic gels when used in conjunction with other polysaccharides (Nwokocha, 2021). The maximum federally regulated use level in ice cream in the US is 0.5% of the mix weight (21 CFR 184.1343). However, locust bean gum is more than twice as expensive as guar on a wt:wt basis (personal communication, TIC gums).

Both cellulose gum and cellulose gel are commonly used in ice cream. Cellulose gum, or carboxymethyl cellulose, is the most highly processed of the 4 commonly used stabilizers and involves chemical modification steps during manufacture. In the US it can be used at levels in accordance with good manufacturing practice (21 CFR 182.1745). Carboxymethyl cellulose is composed of β-1,4 linked D-glucose units derived from the bulk components of plant fiber, but the chemical modification lessens (Goff and Hartel, 2013, Adden et al., 2021). Cellulose gel, or microcrystalline cellulose, is the other common cellulosic additive in ice cream, which is categorized by the US FDA as “generally recognized as safe.” No use limits are specified. Its manufacture involves acid hydrolysis and mechanical dispersion of cellulose fiber. Cellulose gel provides good mouthfeel and ice crystal control in ice creams (Holtzapple, 2003).

The other ice cream stabilizers found in Table 3 are appreciably less common, each being found in less than 10% of the surveyed vanilla ice creams.
Online Survey

Demographics.

A total of 705 ice cream consumers completed the online survey. Of the respondents, 67.38% were between the ages of 18-29, 11.63% were 30-39, 10.35% were 40-49, 6.24% were 50-59, and 4.4% were 60-69 years old. Additionally, 62% of the respondents were female, and 38% were male. The majority of the respondents identified as Caucasian (86.24%), followed by Asian (8.37%), and other (5.39%). Of the respondents, 2.27% were high school graduates or less, 38.72% had some college education but no degree. 7.23% had an Associate degree, 30.50% had a Bachelor degree, 14.33% had a Master degree, 6.95% had a Doctoral or Professional degree. Of those who responded to questions about annual income, 47.37% made less than $30,000, 15.176% made $30,000 to $59,999, 16.6% made $60,000 to $99,999, 11.21% made $100,000 to $149,999, and 4.96% made $150,000 or more. 78.72% of respondents were primary shoppers for their household.

Purchase Habits.

While all participants were required to read the ingredient declaration on food labels at least “sometimes,” fewer participants read the ingredient declaration of ice cream. Among the panelists, 32.62% “never” read the ingredient declaration of ice cream, 32.91% read it “sometimes,” 10.07% read it “about half the time,” 15.32% read it “most of the time,” and 9.08% “always” read it. The data seem to indicate that respondents are less concerned about the ingredient composition of ice cream, which is typically considered an indulgent treat. The number of respondents who read ice cream ingredient labels at least half the time was 17% lower than those who read ingredient labels for all foods at least half the time. Furthermore, nearly one-third of respondents never read ice cream ingredient declarations. However, despite the lower number of consumers concerned with ice cream ingredients, the current
The results of consumer responses to a question about the importance of organic ingredients in ice cream reinforced the idea that consumers are less critical in their concern for ice cream ingredients. Nearly half of consumers responded that they did not consider organic ingredients important in ice cream. This result, along with the lower number of consumers reading ice cream ingredient declarations, is supported by other studies, which have reported a different standard for “virtue vs. vice” foods (van Doorn and Verhoef, 2011, Ellison et al., 2016, Parker et al., 2020). However, though many consumers may not attribute importance to the “organic” label, when it comes to ice cream purchasing decisions, research suggests that in application they are more likely to perceive a product labeled as “organic” to have increased taste perception (Hemmerling et al., 2013). Thus, it is likely that the “organic” label may still influence consumer perception during ice cream consumption.

By contrast, while the majority of consumer respondents did not consider organic ingredients to be important when purchasing ice cream, just over 82% considered simple or “clean-label” ingredients to be important. Further, when responding to the same question about “all-natural ingredients,” 76.88% of participants considered them to be important. Maruyama et al. (2021) stated that the naturalness of ingredients exists on a spectrum, owing to the variety of processes and modifications that might occur for a single ingredient. We believe that this spectrum is also affected by consumer understanding. In our survey, 69% of consumers did not consider themselves knowledgeable when responding to a question about their familiarity with stabilizer ingredients used in ice cream (see Figure 1). While the consumer may consider simple or “clean-label” to be more important than organic ingredients, acceptability of ingredients within both categories will vary based on consumer knowledge and perception. The results of this survey can serve as a reference for ice cream study will be of importance for manufacturers who wish to pick up the consumers represented by the 34% of respondents who read ice cream ingredient labels at least half the time.
producers seeking to give the consumer ice cream formulated with more natural or “clean label” ingredients, based on prevailing consumer understanding.

Identification of Consumer-preferred Hydrocolloid Stabilizers

Based on the purchase intent results from the ingredient pairings and extended list evaluation in the consumer survey (see Tables 4 and 5), tapioca flour, citrus fiber, and carob bean gum were chosen for additional testing. Tapioca and citrus products are widely used and present in most consumer households, lending an air of familiarity to these terms when used in food ingredient declarations. Carob products, while not as widely consumed, are nonetheless familiar due to current and past exposure to them as cocoa replacers among health-food enthusiasts (Loullis and Pinakoulaki, 2018). Consequently, it is not surprising that survey respondents would be more accepting of these terms on an ice cream ingredient declaration.

Tapioca flour had the highest purchase likelihood based on both the paired comparisons and the extended list preference. Tapioca flour was statistically preferred over every other stabilizer except egg yolk. Citrus fiber was the next best performing ingredient and was statistically preferred over every other stabilizer except egg yolk and tapioca flour. Pectin followed, but because citrus fiber was preferred by the consumer and is high in pectin, we decided to select the next most-preferred ingredient which was compositionally different. Cassava flour (another name for tapioca flour), chicory-root fiber and arrowroot starch where the next best performing ingredients, but are either compositionally or functionally (based on preliminary functionality screening trials) similar to tapioca flour. The next best compositionally-different ingredient, based on purchase intent, was carob bean gum, which is another common name for locust bean gum. Only carob bean gum was compared in the odds-ratio evaluation, whereas both locust bean and carob bean gums – as well as carob bean flour – were included in the extended list. Carob bean gum and flour both rated significantly higher
for purchase intent than locust bean gum. Carob bean gum was therefore chosen as the third and final stabilizer because of its perception compared to the other traditional stabilizers and because it is a very common and well-known option, which performed well in our preliminary screening trials. The final list of ingredients for the CCD – tapioca flour, citrus fiber, and carob bean gum – were starch-based, pectin-based, and galactomannan-based hydrocolloids, respectively.

Organic carob bean gum, organic guar gum, organic xanthan gum and organic locust bean gum did not perform significantly better in the extended list ratings than the same ingredients without the “organic” claim. While organic ingredients are a current trend among producers, consumers responding to our survey were not significantly more likely to purchase an ice cream containing organic ingredients compared to the same non-organic version. Lee et al. (2018) found that the way in which organic labels affect consumer purchase-intent is dependent on whether consumers believe their health is controlled by internal or external factors. For consumers with an internal health locus an organic label actually eliminates vice-food intake but has no effect on the intake of virtue-food, whereas the opposite is true for consumers with an external health locus. Thus, consumer attitudes towards organic ice cream labels appear to be complex.

**Formula Optimization Using Central Composite Design**

Results from the CCD analysis were used to create 3 different predicted formulas to use in subsequent consumer testing. The instrumental and sensory data that contributed to the creation of the 3 formulations can be seen in Tables 6 and 7 and the resulting predicted formulas are in Table 8.

The first formula (Overall Optimum) was created based on optimization of all attributes evaluated by instrumental and trained panel analysis. We standardized the means of
the attributes and considered them to be optimal in the statistical analysis at either highest or lowest values dependent upon which attributes were being evaluated.

The attributes that we considered optimal at lower values were viscosity, hardness and toughness, ice crystal size, sensory iciness, and sensory breakdown. We considered lower values for ice cream mix viscosity to be optimal because many of our tested formulations had high viscosities, which could potentially negatively impact pasteurization and homogenization, due to flow limitations in the equipment.

The attributes that we considered optimal at higher values were instrumental melt rate, sensory melt rate, and sensory vanilla intensity. We considered ice cream with a faster melt rate optimal because many of our preliminary and treatment samples melted much slower than traditional ice cream. According to Goff and Hartel (2013) desirable melting quality in ice cream would show definite melting within 15-20 minutes after being placed in ambient temperatures and ice cream with the defect “does not melt” retains shape after 15-20 minutes. Some of the test samples retained shape much longer than 20 minutes.

The second and third formulations both optimized around small ice crystal size, due to the negative effects of larger crystals on texture in the mouth. The second formula created from the CCD results (Sensory Optimum) was optimized based on standardized means of the lowest trained panel iciness score after AST, which would lead to a formulation with a low consumer iciness perception. The third formula (Ice Crystal Optimum) was optimized based on the lowest instrumental ice crystal size after AST, with the intention of producing ice cream with low iciness, when considered using an objective analysis.

The CCD analysis produced over 36,000 different predicted formulas, which could be sorted by dependent variable and observed for trends associated with specific hydrocolloid use. When looking at the attribute instrumental ice crystal size after AST, formulations with
more carob bean gum – and corresponding decreases in tapioca flour and citrus fiber – were predicted to have smaller ice crystals. Conversely, when looking at the attribute sensory iciness after AST, formulations with high levels of citrus fiber, mid-range levels of tapioca flour, and mid- to high-range levels of carob bean gum were predicted to have lower sensory iciness scores. The differences between instrumental and trained-panel iciness could possibly be due to the effect of different stabilizers on overall mouthfeel texture, which might have altered iciness perception. Amador et al. (2017) reported that ice creams with no difference in instrumental ice crystal size were considered less icy by trained panelists, with sensory iciness inversely correlated with fat destabilization and viscosity of the mix.

In regards to melt rate, trends among the predicted formulations would lead us to believe that tapioca flour was the ingredient that made the ice cream most resistant to melting. The formulations that were predicted to melt the slowest had the maximum level of tapioca flour and low- to no levels of citrus fiber and carob bean gum. All stabilizer ingredients contributed to mix viscosity. The CCD-predicted mix formulation with the highest mix viscosity would include all 3 stabilizers at their maximum level.

**Consumer Comparison of Final Formulations**

Samples of the 3 CCD optimized formulations and a commercial control formulation were presented to an untrained consumer sensory panel (n=60) before and after AST. Consumer responses to questions presented using a 9-point hedonic scale are shown in Table 9, whereas those presented using a 5-point “Just-about-Right” scale are shown in Table 10. In reference to questions about overall acceptance and purchase likelihood, there were no reported differences between treatments and Control before AST, but the Overall CCD had a statistically higher overall acceptance and purchase likelihood scores compared to the Control after AST (P < 0.002). Similarly, overall acceptance was not statistically significant before AST, but it was significantly higher after AST (P < 0.002) for the Ice Crystal Optimum
compared to the Control, but this did not hold true for the Sensory Optimum, which was not different from the Control. Consumer forced-preference between the 4 formulations was not statistically significant before AST, but after AST all the CCD samples were preferred compared to the Control.

According to Goff and Hartel (2013) starches can mask certain delicate flavor notes in ice cream, but conversely carob bean gum does not result in any flavor-masking in ice cream mix (Bahramparvar and Tehrani, 2011). We wanted to know if the use of tapioca flour would result in the masking of vanilla flavor or sweetness in the ice cream formulations. There was no statistical difference (P < 0.61) between sweetness intensity and vanilla intensity for any of our samples before or after AST. For the just-about-right attributes, creaminess, rate of melting in the mouth, texture, and hardness and softness, all 3 CCD samples were statistically better than the control after heat shock (P < 0.001).

The instrumental measurements for the CCD formulations can be found in Table 11. The instrumental melt rate of the control was much faster than the melt rate of the 3 CCD formulations at an average of 6.81 g/min compared to <0.17 g/min for the CCD samples. However, the slower melt-rate for the optimized products, though noted by consumers in the non-AST samples, did not result in significant differences from control. Following temperature cycling, however, the Overall Optimum was rated significantly closer to “just-about right” than the Control or the Sensory Optimum, but was not different from the Ice Crystal Optimum. Instrumental ice crystal size was not statistically different after AST for any of the samples, indicating that all 3 formulas and the control stabilizer were comparable in preventing ice crystal growth during heat shock.
CONCLUSION

More consumer-friendly ice cream mixes can be stabilized using combinations of tapioca flour, citrus fiber, and carob bean gum, without affecting stability or consumer liking and purchase intent. Tapioca flour, citrus fiber, and carob bean gum are words that are familiar to the consumer which would make them more comfortable to see on an ingredient declaration. The best performing formulation was determined to be 2% tapioca flour and 0.08% citrus fiber. Tapioca flour and citrus fiber are not currently used in any retail ice cream products according to our market survey of retail vanilla ice cream ingredient declarations. Tapioca flour is an ingredient that is widely available and could be implemented into the existing supply chain without creating any new strains. While simple or “clean label” ingredients are wanted by the consumer, organic ingredients are not as important in forming purchase decisions for ice cream. Furthermore, labeling a specific hydrocolloid as organic did not lead to greater purchase intent compared to the same ingredient without the organic label. It will be beneficial for ice cream producers to focus more on simple or “clean label” rather than organic ingredients. Survey results indicate that there are significant differences in product purchase intent based on presence of different hydrocolloids on an ice cream ingredient declaration. The dairy industry will benefit from the insights obtained from the national survey and consequent stabilizer blends which will inform “consumer friendly” formulation decisions for consumer-preferred vanilla ice creams and the consumer will benefit from the incorporation of these “clean label” ingredients.
REFERENCES


Holtzapple, M. T. 2003. HEMICELLULOSES. Pages 3060-3071.


### Tables

Table 1. Trained panel reference sheet for evaluating ice cream samples<sup>1</sup>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>DEFINITION</th>
<th>TECHNIQUE</th>
<th>REFERENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iciness</td>
<td>Size of ice crystals immediately detected with front teeth</td>
<td>Place sample in mouth, evaluate initial size of ice crystals in the sample by biting with the front teeth (Note: ice crystal size is determined by initial size, not size during melting).</td>
<td>0 = Jell-O</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 = Frosting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 = C&amp;H Pure Cane Sugar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15 = Private Selection Turbinado Cane Sugar</td>
</tr>
<tr>
<td>Melt rate</td>
<td>Time required for ice cream to completely melt in mouth</td>
<td>Place sample in mouth and gently press between tongue and upper palate. Count time it takes for sample to melt completely (“1−1,000” = 1 s). Time for sample to melt corresponds to the numerical score on the lexicon.</td>
<td>6 = Dreyer's Slow Churned Light Vanilla Ice Cream (moderately fast melt rate)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8 = Breyer's Natural Vanilla Ice Cream</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 = Häagen–Dazs Vanilla Ice Cream (slow melt rate)</td>
</tr>
<tr>
<td>Breakdown</td>
<td>Force required to manipulate ice cream sample between tongue and palate</td>
<td>Place sample in mouth and manipulate ice cream sample between tongue and upper palate 3–5 times. Evaluate force required to manipulate the sample.</td>
<td>1 = Kraft Cool Whip Original Whipped Topping (moderate force)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 = Daisy Original Sour Cream</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8 = Kraft Philadelphia Original cream cheese (moderately high force)</td>
</tr>
<tr>
<td>Vanilla intensity</td>
<td>Perception of vanilla flavor detected.</td>
<td>Place sample in mouth and evaluate vanilla intensity detected.</td>
<td>8 = 1% vanilla mixed with skim milk and 6% sugar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 = 2% vanilla mixed with skim milk and 6% sugar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12 = 3% vanilla mixed with skim milk and 6% sugar</td>
</tr>
</tbody>
</table>

<sup>1</sup>Taken from Amador et al. (2017) and (VanWees et al., 2020)
Table 2. Central Composite Design for 3 different ice cream stabilizers at different concentrations. Numbers represent % of maximum addition level\textsuperscript{1}

\begin{tabular}{|c|c|c|c|}
\hline
Treatment & Carob Bean Gum & Tapioca Flour & Citrus Fiber \\
\hline
1 & 80\% & 20\% & 80\% \\
2 & 20\% & 20\% & 20\% \\
3 & 20\% & 80\% & 80\% \\
4 & 0\% & 50\% & 50\% \\
5 & 20\% & 80\% & 20\% \\
6 & 80\% & 20\% & 20\% \\
7 & 50\% & 0\% & 50\% \\
8 & 50\% & 50\% & 100\% \\
9 & 20\% & 20\% & 80\% \\
10 & 80\% & 80\% & 80\% \\
11 & 50\% & 50\% & 50\% \\
12 & 100\% & 50\% & 50\% \\
13 & 50\% & 50\% & 0\% \\
14 & 80\% & 80\% & 20\% \\
15 & 50\% & 100\% & 50\% \\
16 & 50\% & 50\% & 50\% \\
\hline
\end{tabular}

\textsuperscript{1}Maximum addition levels: carob bean gum=0.32\%, tapioca flour=2\%, citrus fiber=0.4\%
Table 3. Retail ice cream hydrocolloid stabilizer usage frequency, typical usage levels, cost of use and sources used in 65 retail vanilla ice cream products sold both locally and found online

<table>
<thead>
<tr>
<th>Hydrocolloid Stabilizer</th>
<th>Frequency (n = 65)</th>
<th>Frequency% (n=65)</th>
<th>Recommended Usage Level %</th>
<th>Source¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guar Gum</td>
<td>52</td>
<td>80.00%</td>
<td>0.1%-0.2%</td>
<td>Seeds of guar beans</td>
</tr>
<tr>
<td>Carrageenan Gum</td>
<td>40</td>
<td>61.54%</td>
<td>0.01%-0.02%</td>
<td>Red edible seaweed</td>
</tr>
<tr>
<td>Locust Bean Gum and Carob Bean Gum</td>
<td>33</td>
<td>50.77%</td>
<td>0.1%-0.2%</td>
<td>Seeds of the carob tree</td>
</tr>
<tr>
<td>Cellulose Gum and Cellulose Gel</td>
<td>31</td>
<td>47.69%</td>
<td>0.2%-0.8%</td>
<td>Plant fiber, cotton</td>
</tr>
<tr>
<td>Xanthan Gum</td>
<td>6</td>
<td>9.23%</td>
<td>0.02%</td>
<td>Microbial fermentation of sugars</td>
</tr>
<tr>
<td>Tara Gum</td>
<td>4</td>
<td>6.15%</td>
<td>0.05-0.15%</td>
<td>Tara spinosa, a small leguminous tree</td>
</tr>
<tr>
<td>No Stabilizer Present</td>
<td>4</td>
<td>6.15%</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Pectin</td>
<td>3</td>
<td>4.62%</td>
<td>0.1-0.2%</td>
<td>Citrus peel, apple pomace</td>
</tr>
<tr>
<td>Acacia Gum and Gum Arabic</td>
<td>1</td>
<td>1.54%</td>
<td></td>
<td>Hardened sap of the acacia tree</td>
</tr>
</tbody>
</table>

¹Referenced from Bahramparvar and Tehrani (2011)
Table 4. Assessment of consumer willingness to purchase ice cream based on individual paired-comparisons between ice cream ingredients  (n=705)

<table>
<thead>
<tr>
<th>Stabilizer</th>
<th>Average Odds Ratio$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg Yolk</td>
<td>6.109</td>
</tr>
<tr>
<td>Tapioca Flour</td>
<td>3.486</td>
</tr>
<tr>
<td>Citrus Fiber</td>
<td>2.632</td>
</tr>
<tr>
<td>Pectin</td>
<td>1.810</td>
</tr>
<tr>
<td>Chicory Root Fiber</td>
<td>1.628</td>
</tr>
<tr>
<td>Arrowroot Starch</td>
<td>1.304</td>
</tr>
<tr>
<td>Carob Bean Gum</td>
<td>0.871</td>
</tr>
<tr>
<td>Acacia Gum</td>
<td>0.778</td>
</tr>
<tr>
<td>Xanthan Gum</td>
<td>0.600</td>
</tr>
<tr>
<td>Guar Gum</td>
<td>0.563</td>
</tr>
<tr>
<td>Carrageenan</td>
<td>0.534</td>
</tr>
<tr>
<td>Tara Gum</td>
<td>0.534</td>
</tr>
</tbody>
</table>

$^1$The odds ratios for each ingredient were averaged and those averages were used to prepare a ranked-list of ingredients based on purchase intent. A higher odds ratio indicates higher likelihood of purchase.
Table 5. Assessment of consumer likelihood to purchase ice cream based on inclusion of individual ice cream ingredients\(^1\) (n=705)

<table>
<thead>
<tr>
<th>Stabilizers</th>
<th>Mean(^2)</th>
<th>Stabilizers</th>
<th>Mean(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>6.21 ± 0.05(^a)</td>
<td>Tara Gum</td>
<td>4.04 ± 0.03(^{lnnopr})</td>
</tr>
<tr>
<td>Vanilla Extract</td>
<td>6.11 ± 0.05(^a)</td>
<td>Organic Locust Bean Gum</td>
<td>4.04 ± 0.04(^{klmno})</td>
</tr>
<tr>
<td>Egg Yolk</td>
<td>5.01 ± 0.06(^b)</td>
<td>Gum Arabic</td>
<td>4.02 ± 0.03(^{lnnopq})</td>
</tr>
<tr>
<td>Tapioca Flour</td>
<td>4.63 ± 0.04(^c)</td>
<td>Soluble Corn Fiber</td>
<td>4.00 ± 0.04(^{lnnopqr})</td>
</tr>
<tr>
<td>Tapioca Starch</td>
<td>4.50 ± 0.04(^{cd})</td>
<td>Gellan Gum</td>
<td>3.94 ± 0.03(^{mnopqrs})</td>
</tr>
<tr>
<td>Citrus Fiber</td>
<td>4.47 ± 0.04(^{de})</td>
<td>Senegal Gum</td>
<td>3.93 ± 0.03(^{nopqrs})</td>
</tr>
<tr>
<td>Pectin</td>
<td>4.35 ± 0.04(^{def})</td>
<td>Gum Sudani</td>
<td>3.92 ± 0.03(^{nopqrs})</td>
</tr>
<tr>
<td>Cassava Flour</td>
<td>4.32 ± 0.04(^{efg})</td>
<td>Locust Bean Gum</td>
<td>3.91 ± 0.04(^{npqrs})</td>
</tr>
<tr>
<td>Plant-Based Gum</td>
<td>4.31 ± 0.03(^{efg})</td>
<td>Cellulose Gum</td>
<td>3.91 ± 0.03(^{nopqrs})</td>
</tr>
<tr>
<td>Chicory Root Fiber</td>
<td>4.29 ± 0.91(^{efgh})</td>
<td>Salep</td>
<td>3.87 ± 0.03(^{pqrest})</td>
</tr>
<tr>
<td>Arrowroot Starch</td>
<td>4.27 ± 0.03(^{fgh})</td>
<td>Carrageenan</td>
<td>3.87 ± 0.04(^{pqrst})</td>
</tr>
<tr>
<td>Acacia</td>
<td>4.24 ± 0.03(^{fghj})</td>
<td>Inulin</td>
<td>3.86 ± 0.03(^{qrest})</td>
</tr>
<tr>
<td>Carob Bean Flour</td>
<td>4.21 ± 0.03(^{fghjk})</td>
<td>Seaweed Extract</td>
<td>3.81 ± 0.05(^{rest})</td>
</tr>
<tr>
<td>Organic Carob Bean Gum</td>
<td>4.21 ± 0.03(^{fghjk})</td>
<td>Sodium Alginate</td>
<td>3.79 ± 0.04(^{st})</td>
</tr>
<tr>
<td>Organic Guar Gum</td>
<td>4.18 ± 0.03(^{fghjkl})</td>
<td>Furcellaran</td>
<td>3.78 ± 0.03(^{st})</td>
</tr>
<tr>
<td>Organic Xanthan Gum</td>
<td>4.14 ± 0.04(^{fghjkl})</td>
<td>Cellulose Gel</td>
<td>3.77 ± 0.04(^{st})</td>
</tr>
<tr>
<td>Acacia Gum</td>
<td>4.13 ± 0.03(^{hijkl})</td>
<td>Microcrystalline Cellulose</td>
<td>3.72 ± 0.04(^{t})</td>
</tr>
<tr>
<td>Carob Bean Gum</td>
<td>4.10 ± 0.03(^{iklmn})</td>
<td>Tara Gum</td>
<td>4.04 ± 0.03(^{lnnoper})</td>
</tr>
<tr>
<td>Vegetable Gum</td>
<td>4.09 ± 0.03(^{iklmn})</td>
<td>Organic Locust Bean Gum</td>
<td>4.04 ± 0.04(^{klmno})</td>
</tr>
<tr>
<td>Basil Seed Gum</td>
<td>4.07 ± 0.03(^{iklmn})</td>
<td>Gum Arabic</td>
<td>4.02 ± 0.03(^{lnnopq})</td>
</tr>
<tr>
<td>Guar Gum</td>
<td>4.07 ± 0.03(^{klmno})</td>
<td>Soluble Corn Fiber</td>
<td>4.00 ± 0.04(^{lnnopqr})</td>
</tr>
<tr>
<td>Balangu Seed</td>
<td>4.06 ± 0.03(^{klmno})</td>
<td>Gellan Gum</td>
<td>3.94 ± 0.03(^{mnopqrs})</td>
</tr>
<tr>
<td>Xanthan Gum</td>
<td>4.05 ± 0.04(^{klmno})</td>
<td>Senegal Gum</td>
<td>3.93 ± 0.03(^{nopqrs})</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gum Sudani</td>
<td>3.92 ± 0.03(^{nopqrs})</td>
</tr>
</tbody>
</table>

\(^{a}\)\(^{2}\)\(^{3}\)Mean values with different superscripts signify statistical difference in consumer purchase intent
\(^1\)=very unlikely to purchase, \(7=\) very likely to purchase
Table 6. Trained panel sensory scores for central composite design ice cream formulations (n=13)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Iciness (AST)</th>
<th>Iciness (AST)</th>
<th>Melt Rate (AST)</th>
<th>Melt Rate (AST)</th>
<th>Breakdown (AST)</th>
<th>Breakdown (AST)</th>
<th>Vanilla Intensity (AST)</th>
<th>Vanilla Intensity (AST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.42 ± 0.19</td>
<td>1.24 ± 0.14</td>
<td>9.38 ± 0.59</td>
<td>8.76 ± 0.45</td>
<td>9.75 ± 0.36</td>
<td>9.5 ± 0.35</td>
<td>9.75 ± 0.48</td>
<td>10.21 ± 0.27</td>
</tr>
<tr>
<td>2</td>
<td>1.02 ± 0.15</td>
<td>1.74 ± 0.13</td>
<td>8.08 ± 0.52</td>
<td>7.63 ± 0.32</td>
<td>9.05 ± 0.43</td>
<td>8.21 ± 0.45</td>
<td>10.53 ± 0.37</td>
<td>10.56 ± 0.37</td>
</tr>
<tr>
<td>3</td>
<td>1.07 ± 0.11</td>
<td>1.78 ± 0.20</td>
<td>7.95 ± 0.41</td>
<td>7.43 ± 0.43</td>
<td>9.32 ± 0.33</td>
<td>8.26 ± 0.30</td>
<td>10.23 ± 0.33</td>
<td>9.85 ± 0.29</td>
</tr>
<tr>
<td>4</td>
<td>0.74 ± 0.09</td>
<td>1.48 ± 0.17</td>
<td>9.28 ± 0.36</td>
<td>8.29 ± 0.34</td>
<td>9.53 ± 0.27</td>
<td>8.95 ± 0.41</td>
<td>10.25 ± 0.34</td>
<td>10.28 ± 0.30</td>
</tr>
<tr>
<td>5</td>
<td>1.2 ± 0.15</td>
<td>1.43 ± 0.15</td>
<td>9.8 ± 0.46</td>
<td>9.33 ± 0.44</td>
<td>10.31 ± 0.27</td>
<td>9.71 ± 0.25</td>
<td>10 ± 0.39</td>
<td>9.87 ± 0.28</td>
</tr>
<tr>
<td>6</td>
<td>1.32 ± 0.13</td>
<td>1.2 ± 0.21</td>
<td>10.21 ± 0.30</td>
<td>9.52 ± 0.35</td>
<td>10.5 ± 0.32</td>
<td>10.24 ± 0.36</td>
<td>9.79 ± 0.34</td>
<td>9.5 ± 0.34</td>
</tr>
<tr>
<td>7</td>
<td>0.98 ± 0.12</td>
<td>1.05 ± 0.11</td>
<td>8.65 ± 0.47</td>
<td>9.92 ± 0.44</td>
<td>9.52 ± 0.37</td>
<td>9.89 ± 0.39</td>
<td>10.03 ± 0.32</td>
<td>10.35 ± 0.36</td>
</tr>
<tr>
<td>8</td>
<td>1.1 ± 0.17</td>
<td>1.23 ± 0.11</td>
<td>9.5 ± 0.41</td>
<td>10.12 ± 0.45</td>
<td>10.36 ± 0.28</td>
<td>9.98 ± 0.25</td>
<td>9.58 ± 0.26</td>
<td>9.81 ± 0.24</td>
</tr>
<tr>
<td>9</td>
<td>1.5 ± 0.17</td>
<td>1.46 ± 0.23</td>
<td>8.94 ± 0.30</td>
<td>9.03 ± 0.31</td>
<td>9.43 ± 0.18</td>
<td>9.28 ± 0.25</td>
<td>9.85 ± 0.32</td>
<td>9.89 ± 0.34</td>
</tr>
<tr>
<td>10</td>
<td>1.6 ± 0.18</td>
<td>1.43 ± 0.16</td>
<td>8.74 ± 0.29</td>
<td>8.99 ± 0.24</td>
<td>9.42 ± 0.30</td>
<td>9.82 ± 0.24</td>
<td>10.25 ± 0.31</td>
<td>10.02 ± 0.27</td>
</tr>
<tr>
<td>11</td>
<td>1.41 ± 0.22</td>
<td>1.27 ± 0.17</td>
<td>8.38 ± 0.34</td>
<td>9.5 ± 0.41</td>
<td>9.24 ± 0.29</td>
<td>9.74 ± 0.21</td>
<td>10.25 ± 0.30</td>
<td>10.56 ± 0.33</td>
</tr>
<tr>
<td>12</td>
<td>0.89 ± 0.11</td>
<td>0.92 ± 0.11</td>
<td>8.64 ± 0.34</td>
<td>9.17 ± 0.47</td>
<td>9.55 ± 0.20</td>
<td>9.83 ± 0.18</td>
<td>10.2 ± 0.25</td>
<td>10.54 ± 0.41</td>
</tr>
<tr>
<td>13</td>
<td>1.41 ± 0.12</td>
<td>0.8 ± 0.08</td>
<td>9.94 ± 0.32</td>
<td>9.65 ± 0.49</td>
<td>9.83 ± 0.27</td>
<td>9.73 ± 0.25</td>
<td>10.11 ± 0.25</td>
<td>10.47 ± 0.43</td>
</tr>
<tr>
<td>14</td>
<td>0.93 ± 0.16</td>
<td>1.30 ± 0.25</td>
<td>7.24 ± 0.34</td>
<td>8.44 ± 0.65</td>
<td>8.24 ± 0.38</td>
<td>8.94 ± 0.50</td>
<td>10.25 ± 0.28</td>
<td>10.86 ± 0.51</td>
</tr>
<tr>
<td>15</td>
<td>1.12 ± 0.16</td>
<td>1.08 ± 0.20</td>
<td>9.15 ± 0.45</td>
<td>10.42 ± 0.45</td>
<td>9.96 ± 0.29</td>
<td>10.20 ± 0.60</td>
<td>9.72 ± 0.33</td>
<td>11.00 ± 0.88</td>
</tr>
<tr>
<td>16</td>
<td>1.3 ± 0.11</td>
<td>1.30 ± 0.25</td>
<td>9.83 ± 0.41</td>
<td>8.70 ± 0.20</td>
<td>9.34 ± 0.23</td>
<td>9.14 ± 0.10</td>
<td>9.7 ± 0.24</td>
<td>11.20 ± 0.58</td>
</tr>
</tbody>
</table>

1AST = Samples from accelerated stability test. Evaluated following 3 weeks of temperature cycling. All other samples were evaluated after storage in -20ºC freezer for 3 days after manufacture.
Table 7. Instrumental hardness (Kg), melting behavior (g/min), and ice crystal size (µm) in central composite design ice cream formulations (n=13)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Hardness (Kg)</th>
<th>Toughness (Kg/sec)</th>
<th>Viscosity (cP)</th>
<th>Melting rate (g/min)</th>
<th>Ice Crystal</th>
<th>Ice Crystal (AST$^1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17.27 ± 313.92</td>
<td>63.70 ± 1387.39</td>
<td>3072 ± 126.46</td>
<td>2.71 ± 0.70</td>
<td>56.26 ± 1.19</td>
<td>58.56 ± 1.27</td>
</tr>
<tr>
<td>2</td>
<td>13.95 ± 906.02</td>
<td>50.09 ± 3615.68</td>
<td>83 ± 4.92</td>
<td>2.50 ± 0.46</td>
<td>54.13 ± 1.25</td>
<td>67.47 ± 1.76</td>
</tr>
<tr>
<td>3</td>
<td>13.54 ± 1304.17</td>
<td>51.23 ± 5452.15</td>
<td>403 ± 2.67</td>
<td>3.25 ± 0.52</td>
<td>55.69 ± 1.09</td>
<td>56.08 ± 1.52</td>
</tr>
<tr>
<td>4</td>
<td>15.08 ± 1052.22</td>
<td>57.78 ± 4251.44</td>
<td>2867 ± 80.04</td>
<td>0.92 ± 0.19</td>
<td>53.87 ± 1.04</td>
<td>60.12 ± 1.64</td>
</tr>
<tr>
<td>5</td>
<td>17.81 ± 947.50</td>
<td>72.07 ± 4450.70</td>
<td>2583 ± 33.27</td>
<td>3.08 ± 0.97</td>
<td>53.90 ± 1.30</td>
<td>60.48 ± 1.30</td>
</tr>
<tr>
<td>6</td>
<td>21.58 ± 1249.43</td>
<td>84.06 ± 5725.79</td>
<td>9739 ± 236.15</td>
<td>2.33 ± 0.80</td>
<td>65.79 ± 1.34</td>
<td>62.09 ± 1.49</td>
</tr>
<tr>
<td>7</td>
<td>14.42 ± 1017.17</td>
<td>53.32 ± 4749.88</td>
<td>3469 ± 96.13</td>
<td>0.03 ± 0.014</td>
<td>58.86 ± 1.65</td>
<td>65.06 ± 1.77</td>
</tr>
<tr>
<td>8</td>
<td>18.27 ± 1385.59</td>
<td>67.04 ± 7678.00</td>
<td>8475 ± 83.51</td>
<td>0.97 ± 0.29</td>
<td>53.60 ± 1.77</td>
<td>60.70 ± 1.97</td>
</tr>
<tr>
<td>9</td>
<td>12.86 ± 1541.42</td>
<td>46.63 ± 8376.38</td>
<td>1205 ± 5.33</td>
<td>1.73 ± 0.37</td>
<td>53.96 ± 1.40</td>
<td>54.70 ± 1.21</td>
</tr>
<tr>
<td>10</td>
<td>17.37 ± 999.71</td>
<td>65.15 ± 6556.63</td>
<td>4480 ± 42.93</td>
<td>3.90 ± 1.10</td>
<td>65.57 ± 1.41</td>
<td>70.33 ± 1.95</td>
</tr>
<tr>
<td>11</td>
<td>21.63 ± 615.88</td>
<td>85.78 ± 2768.46</td>
<td>4019 ± 292.22</td>
<td>0.01 ± 0.01</td>
<td>59.71 ± 1.55</td>
<td>62.43 ± 1.57</td>
</tr>
<tr>
<td>12</td>
<td>14.84 ± 2350.49</td>
<td>54.99 ± 10224.44</td>
<td>3320 ± 114.17</td>
<td>2.24 ± 0.72</td>
<td>60.17 ± 1.54</td>
<td>68.30 ± 1.80</td>
</tr>
<tr>
<td>13</td>
<td>19.31 ± 357.34</td>
<td>72.32 ± 3106.48</td>
<td>8112 ± 203.52</td>
<td>0.0 ± 0.0</td>
<td>53.16 ± 1.15</td>
<td>58.54 ± 1.51</td>
</tr>
<tr>
<td>14</td>
<td>15.34 ± 642.12</td>
<td>59.58 ± 2323.45</td>
<td>132 ± 0.99</td>
<td>1.05 ± 0.26</td>
<td>46.78 ± 1.14</td>
<td>67.63 ± 1.75</td>
</tr>
<tr>
<td>15</td>
<td>23.00 ± 1854.76</td>
<td>99.07 ± 16493.45</td>
<td>6805 ± 71.87</td>
<td>0.01 ± 0.00</td>
<td>49.19 ± 1.21</td>
<td>61.98 ± 1.40</td>
</tr>
<tr>
<td>16</td>
<td>21.07 ± 469.09</td>
<td>83.53 ± 4602.60</td>
<td>2453 ± 13.49</td>
<td>0.31 ± 0.10</td>
<td>47.19 ± 1.76</td>
<td>60.70 ± 1.97</td>
</tr>
</tbody>
</table>

$^1$AST = Samples from accelerated stability test. Evaluated following 3 weeks of temperature cycling test. All other samples were evaluated after storage in -20°C freezer for 3 days after manufacture.
Table 8. Control and optimized vanilla ice cream formulations determined by central composite design results

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Control</th>
<th>Overall Optimum&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Sensory Iciness Optimum&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Ice Crystal Optimum&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carob Bean Gum (%)</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
<td>0.32</td>
</tr>
<tr>
<td>Tapioca Flour (%)</td>
<td>0</td>
<td>2</td>
<td>0.92</td>
<td>0</td>
</tr>
<tr>
<td>Citrus Fiber (%)</td>
<td>0</td>
<td>0.08</td>
<td>0.26</td>
<td>0</td>
</tr>
<tr>
<td>Standard Commercial Blend (%)</td>
<td>0.85</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>1</sup>Overall Optimum formulation was created based on the sum of all tested ice cream attributes. The ice cream attributes were standardized and the formulation that maximized the sum of the standardized values was used.

<sup>2</sup>Sensory Optimum was created from the lowest standardized value based on the trained panel iciness analysis following AST.

<sup>3</sup>Ice Crystal Optimum was created from the lowest standardized values based on the results of instrumental ice crystal analysis following AST.
Table 9. Consumer panel ratings for control and optimized ice cream formulations evaluated after 2 weeks in -20ºC storage and after accelerated stability testing (AST)\(^1\) (n=60)

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Purchase Likelihood</th>
<th>Purchase Likelihood (AST)</th>
<th>Overall Acceptance</th>
<th>Overall Acceptance (AST)</th>
<th>Preference</th>
<th>Preference (AST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.4 ± 0.24(^a)</td>
<td>6.27 ± 0.25(^b)</td>
<td>7.18 ± 0.14(^a)</td>
<td>7.22 ± 0.13(^b)</td>
<td>153(^a)</td>
<td>191(^a)</td>
</tr>
<tr>
<td>Overall Optimum(^2)</td>
<td>7.12 ± 0.19(^a)</td>
<td>7.37 ± 0.20(^a)</td>
<td>7.52 ± 0.13(^a)</td>
<td>7.75 ± 0.12(^a)</td>
<td>136(^a)</td>
<td>137(^b)</td>
</tr>
<tr>
<td>Sensory Optimum(^3)</td>
<td>6.92 ± 0.27(^a)</td>
<td>6.88 ± 0.25(^ab)</td>
<td>7.42 ± 0.14(^a)</td>
<td>7.5 ± 0.14(^ab)</td>
<td>144(^a)</td>
<td>149(^b)</td>
</tr>
<tr>
<td>Ice Crystal Optimum(^4)</td>
<td>6.92 ± 0.23(^a)</td>
<td>6.78 ± 0.22(^ab)</td>
<td>7.53 ± 0.16(^a)</td>
<td>7.27 ± 0.15(^b)</td>
<td>167(^a)</td>
<td>123(^b)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.084</td>
<td>0.001</td>
<td>0.123</td>
<td>0.002</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

\(^{a-c}\)Mean values with different superscripts signify significant difference.
\(^1\)AST = Samples from accelerated stability test. Evaluated following 3 weeks of temperature cycling. All other samples were evaluated after storage in -20ºC freezer for 3 days after manufacture.
\(^2\)Overall Optimum formulation was created based on the sum of all tested ice cream attributes. The ice cream attributes were standardized and the formulation that maximized the sum of the standardized values was used.
\(^3\)Sensory Optimum was created from the lowest standardized value based on the trained panel iciness analysis following AST.
\(^4\)Ice Crystal Optimum was created from the lowest standardized values based on the results of instrumental ice crystal analysis following AST.
Table 10. Consumers “Just-About-Right” ratings for control and optimized ice cream formulations evaluated after 2 weeks in -20ºC storage and after accelerated stability testing (AST)1 (n=60)

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Creaminess (AST)</th>
<th>Creaminess (AST)</th>
<th>Rate of Melting in the mouth</th>
<th>Rate of Melting in the mouth (AST)</th>
<th>Texture (AST)</th>
<th>Texture (AST)</th>
<th>Hardness and Softness (AST)</th>
<th>Hardness and Softness (AST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.45 ± 0.10c</td>
<td>2.27 ± 0.09b</td>
<td>3.02 ± 0.09a</td>
<td>3.4 ± 0.10a</td>
<td>2.70 ± 0.08c</td>
<td>2.45 ± 0.10b</td>
<td>3.20 ± 0.09a</td>
<td>2.78 ± 0.10b</td>
</tr>
<tr>
<td>Overall</td>
<td>2.87 ± 0.06ab</td>
<td>2.82 ± 0.07a</td>
<td>2.92 ± 0.08a</td>
<td>3.02 ± 0.07b</td>
<td>3.07 ± 0.06ab</td>
<td>2.93 ± 0.07a</td>
<td>3.37 ± 0.08a</td>
<td>3.07 ± 0.06a</td>
</tr>
<tr>
<td>Sensory</td>
<td>2.94 ± 0.09a</td>
<td>3.10 ± 0.09a</td>
<td>2.78 ± 0.08 a</td>
<td>2.73 ± 0.09c</td>
<td>3.23 ± 0.06a</td>
<td>3.20 ± 0.09a</td>
<td>3.20 ± 0.07a</td>
<td>3.17 ± 0.09a</td>
</tr>
<tr>
<td>Ice Crystal</td>
<td>2.62 ± 0.09bc</td>
<td>2.82 ± 0.09a</td>
<td>3.02 ± 0.06a</td>
<td>2.90 ± 0.08bc</td>
<td>2.85 ± 0.07bc</td>
<td>3.00 ± 0.08a</td>
<td>3.18 ± 0.08a</td>
<td>3.20 ± 0.07a</td>
</tr>
<tr>
<td>P-Value</td>
<td>0</td>
<td>0</td>
<td>0.087</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.182</td>
<td>0</td>
</tr>
</tbody>
</table>

Mean values with different superscripts signify significant difference.

1AST = Samples from accelerated stability test. Evaluated following 3 weeks of temperature cycling. All other samples were evaluated after storage in -20ºC freezer for 3 days after manufacture.

2Overall Optimum formulation was created based on the sum of all tested ice cream attributes. The ice cream attributes were standardized and the formulation that maximized the sum of the standardized values was used.

3Sensory Optimum was created from the lowest standardized value based on the trained panel iciness analysis following AST.

4Ice Crystal Optimum was created from the lowest standardized values based on the results of instrumental ice crystal analysis following AST.
Table 11. Mix viscosity, melting behavior, instrumental hardness, and ice crystal size for control and optimized ice cream formulations evaluated after 2 weeks in -20°C storage and after accelerated stability testing (AST)\(^1\)

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Mix Viscosity (cP)(n=6)</th>
<th>Melt rate (g/min)(n=4)</th>
<th>Hardness (Kg)(n=4)</th>
<th>Toughness (Kg/sec)(n=4)</th>
<th>Ice Crystal (n=240)</th>
<th>Ice Crystal (AST)(n=240)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>400.45 ± 1.78</td>
<td>6.81 ± 2.00</td>
<td>8.50 ± 406.03</td>
<td>32.32 ± 1883.95</td>
<td>45.40 ± 1.05</td>
<td>66.00 ± 1.28</td>
</tr>
<tr>
<td>Overall Optimum(^1)</td>
<td>435.12 ± 3.21</td>
<td>0.01 ± 0.011</td>
<td>13.03 ± 899.78</td>
<td>49.74 ± 2943.15</td>
<td>51.30 ± 1.12</td>
<td>66.10 ± 1.15</td>
</tr>
<tr>
<td>Sensory Optimum(^2)</td>
<td>6725.33 ± 214.21</td>
<td>0.0 ± 0.0</td>
<td>15.70 ± 856.05</td>
<td>61.59 ± 5361.92</td>
<td>53.00 ± 1.08</td>
<td>66.00 ± 2.10</td>
</tr>
<tr>
<td>Ice Crystal Optimum(^3)</td>
<td>881.4 ± 25.11</td>
<td>0.17 ± 0.07</td>
<td>11.96 ± 383.52</td>
<td>47.31 ± 2195.89</td>
<td>54.60 ± 1.07</td>
<td>60.20 ± 1.45</td>
</tr>
</tbody>
</table>

\(^1\)AST = Samples from accelerated stability test. Evaluated following 3 weeks of temperature cycling. All other samples were evaluated after storage in -20°C freezer for 3 days after manufacture.

\(^2\)Overall Optimum formulation was created based on the sum of all tested ice cream attributes. The ice cream attributes were standardized and the formulation that maximized the sum of the standardized values was used.

\(^3\)Sensory Optimum was created from the lowest standardized value based on the trained panel iciness analysis following AST.

\(^4\)Ice Crystal Optimum was created from the lowest standardized values based on the results of instrumental ice crystal analysis following AST.
Figures

Figure 1. Frequency with which consumers read ice cream ingredient declarations as compared to declarations on other food products (n=705)
Figure 2. Consumer-rated importance of organic and clean-label ingredients when making ice cream purchase decisions (n=705)
The term “natural” does not currently have an official definition in the United States. The United States Department of Agriculture (USDA) gave guidance for the use of the voluntary claim “natural” in meat and poultry products, in the Standards and Labeling Policy Memorandum 055 on November 22, 1982. The memo explains that no artificial flavor or coloring ingredient, chemical preservative, or artificial or synthetic ingredient can be used, with only minimal processing (FSIS, 1982). The memo stated that exceptions may be made on a case-by-case basis, further complicating the issue. Because there is no official definition, consumers cannot be positive that the product they are purchasing is natural, and producers do not want to risk lawsuits resulting from a “natural” claim.

Like “natural,” “clean label” is an undefined term, but it is generally understood to be products which do not contain negatively perceived ingredients, namely allergens, additives, processed ingredients, and ingredients perceived as sounding unfamiliar or chemical (Aschemann-Witzel et al., 2019). Aschemann-Witzel et al. (2019) mentioned that research on consumer categorization of food ingredients as “natural” or “clean label” is lacking. Generally, food producers base their assumptions on their own perceptions and categorizations when making “clean label” products. It was also found that consumers associate the word “stabilizer” with the words “unknown,” “unnatural,” “unnecessary,” and even “unhealthy” (Aschemann-Witzel et al., 2019). Asioli et al. (2017) discussed the finding that “clean label” is a subjective term and is dependent on the consumer familiarity with food ingredients, production methods used, and the inferences resulting from that knowledge. One of the conclusions reached is that the “clean label” trend is driven by health motivations and concerns (Asioli et al., 2017).
Based on a preliminary review of 65 retail ice creams conducted to assist with my study design, the most commonly used hydrocolloid stabilizers in ice cream are guar gum, carrageenan, locust bean gum, cellulose, and xanthan gum. These hydrocolloid stabilizers are all naturally sourced, although cellulose is chemically modified, but that does not mean that they are considered “natural” by the consumer. Chambers V et al. (2019) developed a questionnaire to evaluate whether certain ingredients were considered “natural.” Concerning ice cream and hydrocolloids, the ingredients xanthan gum, seaweed gum, inulin, and gelatin were evaluated, and some were considered to be more “natural” than others. Sixteen percent of participants said that they perceived seaweed gum to be “natural,” 13% of participants said they perceived gelatin to be “natural,” 6% of participants said that they perceived xanthan gum to be “natural,” and 3% of participants said that they perceived inulin to be “natural” (Chambers V et al., 2019). According to the participants, the main factor for assessing that something is not “natural” is because it is unknown. Moreover, out of all the ingredients evaluated, the only ingredient that was perceived to be “natural” by more than 55% of consumers was sea salt (Chambers V et al., 2019). If naturally sourced ingredients are not considered “natural” by the consumer, they almost certainly would not be considered “clean label” by the consumer either.

Guar gum—the most commonly used hydrocolloid stabilizer in ice cream—is extracted from the seeds of the tropical legume Cyamoposis tetragonolba, also known as the guar bush (Goff and Hartel, 2013). The other most commonly used hydrocolloids in ice cream follow the same trend, as all of them are naturally sourced as well. Carrageenan is primarily sourced from a red algae, Chondrus crispis (Goff and Hartel, 2013). Locust bean gum, also known as carob bean gum, is sourced from the beans of the tree Ceratonia siliqua (Goff and Hartel, 2013). Xanthan gum is a bacterial exopolysaccharide that is produced by the growth of Xanthomonas campestris.
in culture (Goff and Hartel, 2013). Carboxymethyl cellulose is derived from the bulk components of plant material or from soluble fiber, but is chemically modified, which would lessen its suitability for “clean label” products (Goff and Hartel, 2013).

Although the individual impact of hydrocolloids in limiting recrystallization and affecting freezing properties has been extensively studied, the mechanisms are not fully understood nor is there agreement throughout the scientific community (Goff et al., 1999, Bahramparvar and Tehrani, 2011). Three mechanisms are used to explain the cryoprotective effect of hydrocolloid stabilizers on ice cream: viscosity and molecular mobility, cryo-gel formation, and phase separation (Hagiwara and Hartel, 1996, Soukoulis et al., 2008, Goff and Hartel, 2013). While these mechanisms may partially explain the effects of hydrocolloid stabilizers in ice cream, the effects cannot be attributed to 1 particular factor, but rather to several interaction effects (Herrera et al., 2007).

Viscosity and molecular mobility are some of the mechanisms used to explain the cryoprotective effect, although there is no definitive correlation between viscosity and inhibition of water recrystallization in ice cream (Bahramparvar and Tehrani, 2011). Additionally, different stabilizers have varying degrees of effectiveness in slowing ice crystal growth at the same viscosity level (Regand and Goff, 2003).

Another mechanism used to explain the cryoprotective effects is cryo-gel formation. According to a study by BahramParvar et al. (2013), the addition of kappa-carrageenan provides cryo-protective functions in ice cream by acting as a gelling agent and decreasing water mobility through water retention. It was concluded that in formulations including kappa-carrageenan as a secondary stabilizer, there was a significant decrease in hardness and iciness (BahramParvar et
al., 2013). Thaiudom and Goff (2003) also found that a gel-like structure formed when kappa-
carrageenan was used above 0.05% of the formulation. Gelatin, carrageenan, and locust bean
gum are gelling stabilizers, and xanthan gum, cellulose, and alginate are non-gelling gums
(Buyong and Fennema, 1988, Goff et al., 1999, Regand and Goff, 2003, Spagnuolo et al., 2005,
Fernández et al., 2007). However, those non-gelling stabilizers can be more effective at limiting
ice recrystallization than gelling stabilizers. Through inhibition of solute transport, non-gelling
stabilizers can cause the water to melt and regrow, rather than melt, diffuse, and then regrow
(Regand and Goff, 2003).

The third mechanism used to explain the cryoprotective effect is phase separation.
Kappa-carrageenan is used to control phase separation between hydrocolloids and milk proteins.
Thaiudom and Goff (2003) evaluated the phase separation of locust bean gum, xanthan gum, and
guar gum both in the presence and absence of kappa-carrageenan. In the absence of kappa-
carrageenan, xanthan gum showed the greatest incompatibility with milk proteins, followed
closely by guar gum and locust bean gum, but with carrageenan present, there was no phase
separation found at the macroscopic level (Thaiudom and Goff, 2003).

Chang and Hartel (2002) found that hydrocolloid stabilizers, specifically carrageenan,
guar gum and cellulose, significantly decrease the mean air cell size during the first 6 minutes of
ice cream freezing in a batch freezer. This is directly correlated with the fact that the ice cream
mixes without stabilizer had a significantly lower apparent viscosity. However, as ice crystals
form while freezing, the apparent viscosity increases and the maximum air cell size decreases
due to shear forces disrupting the air cells (Chang and Hartel, 2002). The ice crystals formed also
function to stabilize the air cells (Dickinson, 1992). The main destabilization mechanism in ice
cream is coalescence (Pelan et al., 1997, Rohenkohl et al., 1999). According to Chang and Hartel
(2002), the addition of hydrocolloid stabilizers inhibited air cell coarsening, or coalescence, in ice cream. Maity et al. (2018) found that combinations of hydrocolloids can be used for desired properties, but hydrocolloid effectiveness will vary based on the system it is added too.

**PROPOSED EXPERIMENTAL DESIGN**

Initially, a national survey will be conducted to assess consumer attitude toward specific hydrocolloid stabilizers and to determine the 3 most “consumer-friendly.” Those 3 hydrocolloid stabilizers will be included in an RSD statistical analysis to evaluate how ingredient and process variables interact to produce optimized formulations. The response-surface-design (RSD)–with 16 different treatment combinations–will be used to determine the blends of hydrocolloid stabilizers to be tested. The RSD will factor in low, middle, and high range-of-use for up to 3 hydrocolloid stabilizers, and optimized blends will be created for testing, based on those ranges. The hydrocolloid stabilizers will be evaluated individually and in combination.

The sensory properties of the optimized formulations will be assessed by a trained panel of 6-12. The physical properties will be measured using multiple laboratory instruments, evaluating mix viscosity, hardness, melt rate, and ice crystal size.

Up to 3 optimized hydrocolloid stabilizer blends from the RSD, determined based on preliminary data and literature defining optimal ice cream properties, will be compared against each other and to a standard commercial blend (SCB) in a hedonic ranking consumer sensory panel following accelerated storage. The best performing blend in the consumer sensory panel will be the optimal ice cream hydrocolloid stabilizer formulation to satisfy the increasingly label-conscious consumer.
STANDARD BASE MIX

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<thead>
<tr>
<th>Ingredient</th>
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<tbody>
<tr>
<td>Milk</td>
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</tr>
<tr>
<td>Cream</td>
<td>28.76%</td>
</tr>
<tr>
<td>Sugar</td>
<td>12.58%</td>
</tr>
<tr>
<td>NFDM</td>
<td>5.08%</td>
</tr>
<tr>
<td>Vanilla</td>
<td>2.5%</td>
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</table>

DETAILED METHODS

Ice Cream Process Description

A standard vanilla base mix—formulated based on the attribute range found in standard to premium ice cream mixes—was used to test the various hydrocolloid stabilizer blends (Goff and Hartel, 2013). The base mix composition was 12% milk fat, 11% milk solids-not-fat, 13% sucrose, with varying stabilizer levels between 0.32% - 2.36%. Dry and wet ingredients were thoroughly mixed separately and then combined. After combination, the mix was pasteurized at 80°C for 30 seconds in a continuous tubular pasteurizer (Development Series MicroThermics model: UHT/HTST Lab-25 EHVH), homogenized (MicroThermics Laboratory In-Line model: NS2006H) at 2,000 psi and 500 psi for the first and second stages, respectively, and then aged overnight in a standard refrigerator. Instructions for pasteurizer and homogenizer are given below. Batch sizes were 2.37 L and mixes were frozen after aging in a 4.74 L batch freezer (Bravo North America model: Trittico 30) located at the BYU Culinary Support Center with an overrun of 50% (± 10%) and a draw temperature of -3.5°C (± 1). The batch freezer was cleaned and sanitized before use. A priming batch was made first with extra ice cream mix to cool the barrel. Ice cream was frozen in the barrel for 7 minutes. Barrel was scraped clean by hand in between batches. Samples (approximately 220g) were collected in 237 mL polyethylene lined paper cups with polyethylene terephthalate lids immediately after manufacture and hardened overnight in the Culinary Support Center blast freezer at -40°C, before moving to a -20°C freezer.
located in the Eyring Science Center for longer term storage. Samples for all testing were prepared and packaged as indicated here.

Due to the large number of treatments (16), 4 treatments were prepared and frozen once a week. Each treatment required two batches in order to get enough samples for testing. This approach allowed for different stability end times and trained panel evaluation start times. Sequence of batch preparation and freezing was randomized.
Microthermics Operating Instructions

1. Turn on “cold water” and “hot water” for the pasteurizer using knobs behind it on its left side. Turn on (left) “cold water” for homogenizer using knob behind it on its right side. Connect pipes. Make sure hoses are connected Inlet to Outlet and Outlet to Inlet. Make sure green knobs underneath are set to fill (NOT Running). Turn on “Single Phase Disconnect” on pasteurizer and “Main Disconnect” on homogenizer (large red knob on each).

2. Touch key button on the pasteurizer’s screen and press “Caps” for lowercase, and enter “user” as User ID and “mtinow” as password.

3. Fill the product inlet tubes with water using a graduated cylinder. Ensure that the product inlet tubes are submerged in water. Open the product inlet knob. Set product pump flow to 1.5 L/min and turn on by pressing the adjacent red button. Then press Auto. Watch the pressure pump to make sure the first one gets to 90. If the second one does not go up much, turn on and off the homogenizer.

4. Set back-pressure to ~69 psi by rotating big blue knob labeled “Back pressure.”

5. On the lower left panel (the front face of the unit), open PH feed and PH drain. Be sure to turn the handles on the same level at the same time.

6. Set final heat setpoint to 85°C.

7. Check for water under the pistons in the homogenizer.

8. Set the preheat temperature to 50°C.

9. Allow the unit to heat up. Tap “auto” on the three columns (pump, preheat, final heat) to turn on auto.

10. On the homogenizer, adjust stage 2 to 500 psi, then adjust stage 1 to a cumulative 2000 psi. Use caution when adjusting the stages.

11. Prepare to run sanitizer.

Miscellaneous tips.

Never allow the pump to run dry. At least one tube should always be submerged in a bucket of water in the sink.

Allow the unit to warm for 30 minutes before running product and adjusting the final temperature.

The preheat pressure and final heat pressure should never exceed 20 psi. Opening the feed valves raises the pressure and opening the drain valves reduces the pressure. Try to maintain a constant pressure of 20 psi for each when the unit is running. As heat is applied the pressure will naturally increase, so you will need to open the drain valves more often than the feed valves.

Tear down the homogenizer to clean between usages.

The homogenizer is a timing pump; it should be set at least 0.5L/min slower than the pasteurizer.
Pressure 1 (P1) should read at least 60 psi when the homogenizer is running.

When cleaning the pasteurizer, the back pressure should be periodically increased above 73 psi for 5-10 seconds to force the release loop to open.

P1 should read higher than P2 because P1 is read at the source of the pressure generator.

Run sanitizer before running product. (See cleaning instructions sheet for sanitizer info).

Running Product.

1. Grab timers from lab bench, product, one empty container and lid, whisk, and large cylinder (2000 mL).

2. Turn off the water hose and fill it with water. Put a glove on and hold your thumb over the end of the hose. Submerge in ice cream mix.

3. Have someone flip the switches so the hose turns on. Take your thumb off when you feel suction.

4. Set a timer for 4.5 minutes.

5. When the timer goes off, put the end hose into the cylinder and wait for 1 min or fill it to 1100 mL.

6. Fill the empty mix container with the end hose. Be sure not to let any of the hoses touch the crates.

7. After the beginning container begins to empty, flip the hose switches again and set a timer for 3:30 min.

8. Wash the beginning container and lid and wash out the mix tube.

9. Dry and repeat for the next product containers.
Panelist,

Thank you for evaluating this week’s samples. You will be evaluating samples aaa, bbb and ccc one at a time and in that order. If you feel that the sample you selected is not representative, feel free to take a different one with the same number (then text Ben at 509-492-1595 to let him know). Please follow the instructions below:

1. Use QR code below or link in email to record responses
2. Remove the first test sample from freezer and remove lid
3. Start timer for 3 minutes
4. Get metal testing spoon from table to the right of the refrigerator and freezers
5. Collect reference standards that you will use from marked refrigerator to the right of the freezer
6. After three minutes are up:
   a. Evaluate attributes in the order they are listed
   b. Use references to make a conscientious review
7. Repeat steps 2-6 with the next sample and then again with each of the following samples until done
8. Wash spoon and place in sanitizer bowl

Contact Ben Woodward at 509-492-1595 with any questions or concerns
TRAINED PANEL REFERENCE PHOTOS
TRAINED PANEL EVALUATION

xx/xx/xx Evaluation – aaa, bbb, ccc

Start of Block: Default Question Block

Q1 Trained Panel Evaluation Week x - xx/xx/xx

You will be evaluating samples aaa, bbb, ccc

Q2 What is your name?

Page Break
Q3 Sample aaa

1. Remove the test sample from freezer and remove lid
2. Start timer for 3 minutes
3. Get metal testing spoon from table to the right of the refrigerator and freezers
4. Collect reference standards that you will use from marked refrigerator to the right of the freezer
5. After three minutes are up:
   a. Evaluate attributes in the order they are listed
   b. Use references to make a conscientious review

Q4 Iciness (scale of 0-15)

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Q5 Melt Rate ("1-1,000"= 1 sec)

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</tbody>
</table>

Q6 Breakdown (scale of 0-15)

Breakdown ()

Q7 Vanilla Intensity (scale of 0-15)

Vanilla Intensity ()
Q8 Sample bbb

1. Remove the test sample from freezer and remove lid
2. Start timer for 3 minutes
3. Collect any new reference standards that you will use from marked refrigerator to the right of the freezer
4. After three minutes are up:
   a. Evaluate attributes in the order they are listed
   b. Use references to make a conscientious review

Q9 Iciness (scale of 0-15)

| Iciness () | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |

Q10 Melt Rate ("1-1000"= 1 sec)

| Melt Rate () | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
Q11 Breakdown (scale of 0-15)

Breakdown ()

Q12 Vanilla Intensity (scale of 0-15)

Vanilla Intensity ()
Q13 Sample ccc

1. Remove the test sample from freezer and remove lid
2. Start timer for 3 minutes
3. Collect any new reference standards that you will use from marked refrigerator to the right of the freezer
4. After three minutes are up:
   a. Evaluate attributes in the order they are listed
   b. Use references to make a conscientious review

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Q14 Iciness (scale of 0-15)

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Q15 Melt Rate ("1-1,000"= 1 sec)

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57
Q16 Breakdown (scale of 0-15)

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Breakdown ()

---

Q17 Vanilla Intensity (scale of 0-15)

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Vanilla Intensity ()
CONSUMER SENSORY PANEL

Vanilla Ice Cream with Consumer-Friendly Stabilizers Consumer Test

Name_________________________  Signature_________________________

Welcome to the Food Science Sensory Laboratory. A copy of the form titles “Consent to Be a Research Subject” is posted in each booth. Please read it carefully before continuing. By signing your name above, you acknowledge that you have read and understand the consent form, and desire of your own free will and volition to participate in this study and accept the benefits and risks relating to the study. You may withdraw at any time without penalty. Please inform the receptionist if you wish to withdraw.

In this session, you will evaluate FOUR samples of VANILLA ICE CREAM side-by-side. You will receive FOUR SPOONS, one per sample, so please use the same spoon for each sample. You will taste the samples for ELEVEN CHARACTERISTICS so conserve enough ice cream to evaluate each category. Please read all the instructions and questions carefully. Before you get the samples, please answer these questions by checking the appropriate boxes.

* What is your age category?
  A. Younger than 18 years
  B. 18 - 29 years
  C. 30 - 39 years
  D. 40 - 49 years
  E. 50 - 54 years
  F. 55 years or older

* What is your gender?
  o Female
  o Male
* What is your attitude towards **ICE CREAM**?

A. I like it  
B. I neither like nor dislike it  
C. I dislike it  

* What is your attitude towards **VANILLA FLAVOR**?

D. I like it  
E. I neither like nor dislike it  
F. I dislike it  

* How often do you consume ice cream?

   o Daily  
   o About once a week  
   o At least every two weeks  
   o At least once a month  
   o At least once every 3 months  
   o Almost never/never

Locate the set of lights to the right of the computer screen and press the red button next to the green “READY” light to indicate that you are ready to receive your samples. Please be patient; they should arrive shortly.

Evaluate the samples from **LEFT TO RIGHT** as they are arranged on your tray.

When the samples arrive, **DO NOT** taste them until instructed to do so. **Double check the sample numbers** to make sure they match the numbers on the screen. Press the button by the “HELP” LIGHT to the right of the screen if your sample numbers do not match or if you need other help. You will first evaluate **APPEARANCE**. Keep in mind that you will be asked to **RANK** the samples in order of preference at the end.
* How much do you like or dislike the APPEARANCE of each sample?

Sample #’s

* * *

Like extremely [ ] [ ] [ ] [ ]
Like very much [ ] [ ] [ ] [ ]
Like moderately [ ] [ ] [ ] [ ]
Like slightly [ ] [ ] [ ] [ ]
Neither like nor dislike [ ] [ ] [ ] [ ]
Dislike slightly [ ] [ ] [ ] [ ]
Dislike moderately [ ] [ ] [ ] [ ]
Dislike very much [ ] [ ] [ ] [ ]
Dislike extremely [ ] [ ] [ ] [ ]

NOW TASTE THE SAMPLES.

Use a bite of cracker and sip of water between samples to refresh your sense of taste between samples.

* EVERYTHING CONSIDERED, how do you feel about the OVERALL ACCEPTANCE of each sample?

Sample #’s

* * *

Like extremely [ ] [ ] [ ] [ ]
Like very much [ ] [ ] [ ] [ ]
Like moderately [ ] [ ] [ ] [ ]
Like slightly [ ] [ ] [ ] [ ]
Neither like nor dislike [ ] [ ] [ ] [ ]
Dislike slightly [ ] [ ] [ ] [ ]
Dislike moderately [ ] [ ] [ ] [ ]
Dislike very much [ ] [ ] [ ] [ ]
Dislike extremely [ ] [ ] [ ] [ ]

* How much do you like or dislike the OVERALL FLAVOR of each sample?

Sample #’s

Like extremely [ ] [ ] [ ] [ ]
Like very much [ ] [ ] [ ] [ ]
Like moderately [ ] [ ] [ ] [ ]
Like slightly [ ] [ ] [ ] [ ]
Neither like nor dislike [ ] [ ] [ ] [ ]
Dislike slightly [ ] [ ] [ ] [ ]
Dislike moderately [ ] [ ] [ ] [ ]
Dislike very much [ ] [ ] [ ] [ ]
Dislike extremely [ ] [ ] [ ] [ ]

* How much do you like or dislike the TEXTURE/MOUTHFEEL of each sample?

Sample #’s
* How much do you like or dislike the **AFTERTASTE** of each sample?

Sample #’s

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<td>Dislike extremely</td>
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* How much do you like or dislike the **ICINESS LEVEL** of each sample?

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<td>Dislike extremely</td>
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* How do you feel about the **SWEETNESS INTENSITY** in each sample?

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<td>Just about right</td>
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<tr>
<td>Slightly too little</td>
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<td>Definitely too little</td>
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* How do you feel about the **VANILLA FLAVOR INTENSITY** of each sample?

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<th>Sample #’s</th>
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<tr>
<td></td>
<td>Definitely too much</td>
<td>Slightly too much</td>
<td>Just about right</td>
<td>Slightly too little</td>
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<tr>
<td>CREAMINESS</td>
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<tr>
<td>Sample #'s</td>
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* How do you feel about the CREAMINESS of each sample?

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<thead>
<tr>
<th></th>
<th>Definitely too much</th>
<th>Slightly too much</th>
<th>Just about right</th>
<th>Slightly too little</th>
<th>Definitely too little</th>
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<tbody>
<tr>
<td>RATE OF MELTING IN THE MOUTH</td>
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<td>Sample #'s</td>
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</tbody>
</table>

* How do you feel about the RATE OF MELTING IN THE MOUTH of each sample?
<table>
<thead>
<tr>
<th>Question</th>
<th>Scale</th>
<th>Options</th>
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</thead>
<tbody>
<tr>
<td>* How do you feel about the <strong>TEXTURE</strong> of each sample of ice cream <strong>AFTER</strong> it has <strong>MELTED IN YOUR MOUTH</strong>?</td>
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<tr>
<td>Sample #’s</td>
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<td>Slightly too slow</td>
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<td>Definitely too slow</td>
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<tr>
<td>How do you feel about the <strong>HARDNESS/SOFTNESS</strong> of each sample?</td>
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<tr>
<td>Sample #’s</td>
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<tr>
<td>Definitely too thick</td>
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<tr>
<td>Slightly too thick</td>
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<td></td>
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<tr>
<td>Just about right</td>
<td>[ ] [ ] [ ] [ ]</td>
<td></td>
</tr>
<tr>
<td>Slightly too thin</td>
<td>[ ] [ ] [ ] [ ]</td>
<td></td>
</tr>
<tr>
<td>Definitely too thin</td>
<td>[ ] [ ] [ ] [ ]</td>
<td></td>
</tr>
</tbody>
</table>

**66**
How likely or unlikely would you be to **PURCHASE** each sample?

<table>
<thead>
<tr>
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<th>#_____</th>
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<tbody>
<tr>
<td>Extremely likely</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<td>Very likely</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>Moderately likely</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<td>Slightly likely</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<tr>
<td>Neither likely nor unlikely</td>
<td>O</td>
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<td>O</td>
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<td>Slightly unlikely</td>
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<td>Moderately unlikely</td>
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<tr>
<td>Very unlikely</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Extremely unlikely</td>
<td>O</td>
<td>O</td>
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</tbody>
</table>
RANK the samples in order of PREFERENCE by writing the sample codes in the appropriate spaces below.

_________                __________                ---_________                  _________
  Liked best                    Liked 2nd best              Like 3rd best                Liked least

* Please share any comments or suggestions about the samples here. Please refer to the sample number in your comments.

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

You are finished. Please place the samples and tray in the pass-through compartment and PRESS THE BUTTON BY THE “FINISHED” LIGHT. Please give this questionnaire to the receptionist. THANK YOU!
ICE CREAM STABILIZER ONLINE SURVEY

Start of Block: Demographic Questions

Q1.1 Informed Consent  My name is Laura Jefferies, PhD, I am a faculty member in the Department of Nutrition, Dietetics & Food Science at Brigham Young University. I am conducting this research with my colleagues Michael Dunn, PhD, Brad Taylor, PhD, and graduate student Benjamin Woodward. You are being invited to take part in an online survey that will ask you a series of questions about ice cream and ice cream stabilizers.  Your participation requires completing this survey only. This should take approximately 20 minutes of your time. Your participation will be anonymous. This survey involves minimal risk to you. You will be reimbursed for your time upon survey completion at the dollar amount or point value quoted to you prior to completing this survey. There are no direct benefits in taking part in this study. However, the results of this study will help us measure public attitude and behavior regarding ice cream stabilizers. You do not have to be in this study if you do not want to be. You do not have to answer any question that you do not want to answer for any reason.  We will be happy to answer any questions you have about this study. If you have further questions about this project or if you have a research-related problem you may contact me, Laura Jefferies, PhD at 801-422-9290 or laura_jefferies@byu.edu. If you have any questions about your rights as a research participant you may contact the IRB Administrator:  A-285 ASB, Brigham Young University, Provo, UT 84602; irb@byu.edu; (801) 422-1461.  The IRB is a group of people who review research studies and whose jobs are to protect the rights and welfare of research participants. The completion of this survey implies your consent to participate. If you choose to participate, please click next to begin the survey. Thank you!  IRB NUMBER: IRB2020-078
IRB APPROVAL DATE: 02/17/2020  Please select the box below to indicate an understanding of your rights and consent to participate:

☐ Select to continue
Q1.2 What is your age in years?

- Under 18 years
- 18 - 29
- 30 - 39
- 40 - 49
- 50 - 59
- 60 - 69
- Older than 70 years

Q1.3 What is your sex?

- Male
- Female
- I prefer not to answer
Q1.4 How do you identify your ethnicity?

- White or Caucasian
- Black or African American
- American Indian or Alaska Native
- Asian
- Native Hawaiian or Pacific Islander
- Other

Q1.5 What is your current marital status?

- Single or never married
- Married
- Widowed
- Divorced
- Separated
Q1.6 What is the highest level of school you have completed or the highest degree you have received?

- Less than high school degree
- High school graduate (high school diploma or equivalent including GED)
- Some college but no degree
- Associate degree in college (2-year)
- Bachelor's degree in college (4-year)
- Master's degree
- Doctoral degree
- Professional degree (JD, MD)
Q1.7 Information about income is very important to understand. Would you please give your best guess? Please indicate the answer that includes your entire household income in 2019 before taxes.

- Less than $10,000
- $10,000 to $19,999
- $20,000 to $29,999
- $30,000 to $39,999
- $40,000 to $49,999
- $50,000 to $59,999
- $60,000 to $69,999
- $70,000 to $79,999
- $80,000 to $89,999
- $90,000 to $99,999
- $100,000 to $149,999
- $150,000 or more
- I prefer not to answer

End of Block: Demographic Questions

Start of Block: Purchasing Habits
Q2.1 Are you responsible for 50% or more of the shopping for your household?

○ Yes

○ No

Q2.2 How healthy/unhealthy would you consider your dietary/eating habits?

○ Extremely healthy

○ Moderately healthy

○ Slightly healthy

○ Neither healthy nor unhealthy

○ Slightly unhealthy

○ Moderately unhealthy

○ Extremely unhealthy
Q2.3 Which of the following dietary lifestyles do you follow? Check all that apply:

☐ Dairy-free
☐ Keto
☐ Paleo
☐ Vegan
☐ Vegetarian
☐ None
☐ Other (please specify) ________________________________________________

Q2.4 How often do you read the ingredient declaration of a food product before purchasing it?

☐ Always
☐ Most of the time
☐ About half the time
☐ Sometimes
☐ Never
Q2.5 How often do you read the ingredient declaration of an ice cream product before purchasing it?

- Always
- Most of the time
- About half the time
- Sometimes
- Never

End of Block: Purchasing Habits

Start of Block: Ice Cream Habits
Q3.1 On average, how frequently does your household purchase ice cream?

- [x] Daily
- [ ] 4-6 times a week
- [ ] 2-3 times a week
- [ ] Once a week
- [ ] 2-3 times a month
- [ ] Once a month
- [ ] Every other month
- [ ] Every 3-6 months
- [ ] Every 6-12 months
- [ ] Never
Q3.2 On average, how frequently do you consume ice cream?

- Daily
- 4-6 times a week
- 2-3 times a week
- Once a week
- 2-3 times a month
- Once a month
- Less than once a month
- Never

Q3.3 How loyal are you to a specific ice cream brand?

- Extremely loyal
- Moderately loyal
- Slightly loyal
- Not loyal
Q3.4 How knowledgeable do you consider yourself to be when it comes to ice cream stabilizers?

- Extremely knowledgeable
- Very knowledgeable
- Moderately knowledgeable
- Slightly knowledgeable
- Not knowledgeable at all

Q3.5 How would you rate the importance of all-natural ingredients in your decision to purchase ice cream?

- Extremely important
- Very important
- Moderately important
- Slightly important
- Not at all important
Q3.6 How would you rate the importance of simple/clean-label ingredients in your decision to purchase ice cream?

- [ ] Extremely important
- [ ] Very important
- [ ] Moderately important
- [ ] Slightly important
- [ ] Not at all important

Q3.7 How would you rate the importance of organic ingredients in your decision to purchase ice cream?

- [ ] Extremely important
- [ ] Very important
- [ ] Moderately important
- [ ] Slightly important
- [ ] Not at all important
Q3.8 Of the following brands, which do you regularly purchase/consume? Select all that apply:

☐ Store-brand ice cream (e.g. Kroger, Western Family, Food Club, Great Value, Blue Ribbon)

☐ Standard ice cream (e.g. Turkey Hill, Dreyer's, Edy's, Meadow Gold)

☐ Premium ice cream (e.g. Tillamook, Blue Bell, Alden's Organic, Blue Bunny, Cold Stone, Private Label)

☐ Ultra-premium ice cream (e.g. Haagen-Dazs, Ben and Jerry's, Magnum)

End of Block: Ice Cream Habits

Start of Block: Comparisons a

Q4.1 The following questions show two sets of ingredients that may appear on an ice cream container. Read them carefully.

Q4.2 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

☐ Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan

☐ Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum

☐ No preference
Q4.3 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- No preference

Q4.4 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- No preference

Q4.5 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- No preference
Q4.6 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- No preference

Q4.7 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- No preference

Q4.8 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- No preference
Q4.9 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- No preference

Q4.10 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- No preference

Q4.11 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- No preference
Q4.12 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- No preference

Q4.13 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- No preference

Q4.14 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- No preference
Q4.15 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- No preference

Q4.16 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- No preference

Q4.17 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- No preference
Q4.18 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- No preference

Q4.19 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- No preference

Q4.20 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- No preference
Q4.21 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- No preference

Q4.22 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- No preference

Q4.23 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- No preference
Q4.24 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- No preference

Q4.25 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- No preference

Q4.26 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- No preference
Q4.27 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- No preference

Q4.28 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- No preference

Q4.29 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- No preference
Q4.30 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- No preference

Q4.31 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- No preference

Q4.32 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- No preference
Q4.33 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- No preference

Q4.34 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- No preference

Q4.35 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- No preference
Q4.36 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- No preference

Q4.37 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- No preference

Q4.38 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- No preference
Q4.39 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- No preference

Q4.40 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- No preference

Q4.41 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- No preference
Q4.42 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- No preference

Q4.43 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- No preference

Q4.44 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- No preference
Q4.45 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- No preference

Q4.46 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- No preference

Q4.47 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- No preference
Q4.48 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- No preference

Q4.49 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- No preference

Q4.50 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- No preference
Q4.51 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- No preference

Q4.52 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- No preference

Q4.53 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- No preference
Q4.54 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- No preference

Q4.55 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- No preference

Q4.56 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Arrowroot Starch
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- No preference
Q4.57 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- No preference

Q4.58 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- No preference

Q4.59 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- No preference
Q4.60 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carob Bean Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- No preference

Q4.61 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- No preference

Q4.62 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tapioca Flour
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Acacia Gum
- No preference
Q4.63 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Egg Yolk
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Xanthan Gum
- No preference

Q4.64 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Chicory Root Fiber
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Tara Gum
- No preference

Q4.65 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Carrageenan
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- No preference
Q4.66 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Guar Gum
- No preference

Q4.67 Assuming quality, cost and all other factors are equal - choose which of the two ice cream products you would purchase based on the ingredient declaration provided:

- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Pectin
- Ingredients: Milk, Cream, Sugar, Nonfat Dry Milk, Vanilla Extract, Citrus Fiber
- No preference

End of Block: Comparisons a

Start of Block: Likert List
Q5.1 If you were evaluating the ingredient declaration while shopping for ice cream, please rate how likely or unlikely you would be to purchase the product if it included the following ingredients:
<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Very unlikely</th>
<th>Unlikely</th>
<th>Neither likely nor unlikely</th>
<th>Likely</th>
<th>Very likely</th>
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<tr>
<td>Acacia Gum</td>
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<tr>
<td>Organic Xanthan Gum</td>
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<tr>
<td>Tapioca Flour</td>
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<tr>
<td>Carrageenan</td>
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<tr>
<td>Senegal Gum</td>
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<tr>
<td>Pectin</td>
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<td>Arrowroot Starch</td>
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### End of Block: Likert List

### Start of Block: Block 7

Q6.1 We have your email stored. You should expect to receive the gift card next week. If you would **not** like to receive an Amazon gift card, check the button below to **opt out**. Otherwise, the survey is complete.

- [ ] Opt me out of receiving an Amazon gift card

### End of Block: Block 7

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