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Sensory Evaluation of Ice Cream made with Prebiotic Ingredients

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Abstract

Fructooligosaccharides (FOS) and inulin are considered prebiotic ingredients and are FDA approved for use in food for human consumption. A prebiotic is a food ingredient that benefits the host by selectively stimulating the growth and activity of the beneficial bacteria in the colon. In this project, consumer acceptability of ice cream made with 10% of the sugar substituted with either inulin or FOS was tested. Physical tests were also conducted. The texture, water activity and L and b color values did not differ significantly for the treatments (Inulin and FOS) versus the control sample. The a value for color (red/green) differed (p=0.02) for the treatment samples when compared to the control. For the sensory evaluation, 71 participants ranked the ice cream samples made with inulin and FOS equally as well liked (6.56 and 6.80, respectively) on a 17 cm hedonic scale (0 = like and 17 = dislike). However, the participants liked the control ice cream better than the ice cream with a prebiotic ingredient (P<0.001). Inulin and FOS are potential ingredients for use in ice cream.

KEYWORDS: ice cream, prebiotics, sensory, inulin, FOS, fuctooligosaccharides

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1. Introduction

A prebiotic is defined as a nondigestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon (Gibson and Roberfroid, 1995). To be classified as a prebiotic food ingredient, it must: 1) not be hydrolyzed or absorbed in the upper gastrointestinal tract; 2) serve as a selective substrate for at least one potentially beneficial bacteria in the colon, thus stimulating growth, becoming metabolically active, or both; and 3) result in a healthier colonic microflora composition (Collins & Gibson, 1999).

Claims about prebiotic ingredients reducing disease are tentative and need further scientific evaluation. These claims or potential health benefits include constipation relief, diarrhea suppression, and reduction of risks of osteoporosis, atherosclerotic cardiovascular disease due to dyslipidemia and insulin resistance, obesity, and possibly type 2 diabetes (Roberfroid, 2000).

Specific prebiotic ingredients, such as non-digestible oligosaccharides, have been shown to increase calcium absorption (Scholz-Ahrens, 2001). However, the effects vary with each non-digestible oligosaccharides and the dosage consumed (Saggiro, 2004).

Prebiotic ingredients may help to inhibit the growth of lesions in the colon, such as adenomas and carcinomas, thus reducing the risk factors involved in colorectal diseases (Ashwell, 2002). Preliminary studies also suggest that prebiotic ingredients may have a positive effect on the immune system and enhanced resistance against infection (Savendra & Tschemia, 2002; Cummings & Macfarlane, 2001).

Little data exist for the lipid lowering effects of prebiotic ingredients and come mostly from studies involving inulin and oligofructose. However, hyperlipidemic subjects have demonstrated a reduction in cholesterol from consuming prebiotics. Normal lipidemic subjects have demonstrated a reduction of serum triglycerides (Pereira & Gibson, 2002).

There are three types of fructan polysaccharides that are linked in a beta 2-1 configuration. Each type of fructan polysaccharide differs with its degree of polymerization (DP) which is the number of fructose units in the chain. The first type is inulin with DP ranging from two to greater than 60 depending on the plant source. The second type is oligofructose which has a short chain length, with a DP ranging from two to twenty. The third type is fructooligosaccharide (FOS) with the shortest chain length among the three types of fructan polysaccharides. FOS has a DP ranging from three to five (FDA, 2003).

Inulin is naturally found in significant amounts in edible fruits and vegetables. In the United States, the most commonly consumed inulin-containing foods are grains, cereals, bananas, tomatoes, garlic and onions. The average intake of inulin and oligofructose in the U.S is 2.6 grams per day, compared to the estimated amount of 10 grams per day (FDA, 2003) Most European countries officially recognize chicory inulin and oligofructose as natural food ingredients (Cummings JH, 1997). United States granted GRAS (generally recognized as safe) status to inulin, fructooligosaccharide (FOS) and oligofrucotoes in 2002 (FDA, 2003).

Due to its longer chain length, inulin is less soluble than oligofructose and has the ability to form inulin microcrystals when added to water or milk. These microcrystals form a smooth creamy texture (Niness, 1999). In a typical ice cream, the small ice crystal size may increase 30% to 40% during hardening of ice cream. During storage, recrystallization occurs where by small ice crystals melt and large crystals grow simultaneously. Temperature fluctuations increase the rate of recrystallization leading to a higher number of large crystals; hence, giving the ice cream a coarse and grainy texture. In this respect, inulin can act as a stabilizing agent to control ice recrystallization (Akalin et al., 2002). In addition, inulin microcrystals provide a fat-like mouthfeel. Inulin has been used successfully to replace fat in table spreads, baked goods, fillings, dairy products, frozen desserts and dressings (Niness, 1999). Inulin-type fructans also help to stabilize foams (Cummings & Roberfroid, 1997).

Oligofructose has functional qualities similar to sugar or glucose syrup. Oligofructose contributes to the body of dairy products and humectancy of soft baked goods, lowers the freezing point in frozen desserts, provides crispness to low fat cookies, and acts as a binder in granola bars, similar to sugar. However, oligofructose is more soluble than sucrose and has approximately 30-50% of the sweetness of table sugar. Oligofructose can enhance fruit flavor, balance the sweetness profile and mask undesirable aftertaste (Niness, 1999). Like inulin, oligofructose can act as stabilizing agents to control ice recrystallization (Akalin et al., 2002).

Both inulin and oligofructose are used to add fiber to food products. Prebiotic ingredients are classified as fibers because they are not absorbed into the intestines but are fermented in the colon, similar to fiber (Duncan et al., 2002). Unlike fiber, they do not have off flavors and may be used to add fiber without increasing viscosity. However Akalin et al. (2008) demonstrated that the addition of prebiotic ingredients at 4% increased the viscocity of ice cream. Oligofructose is commonly used in cereals, fruit preparations for yogurt, frozen desserts, cookies and nutritional dairy products (Niness, 1999).

Inulin and oligofructose also have a lower caloric value as compared to other forms of carbohydrate due to non-digestibility of these ingredients by human enzymes. Inulin and oligofructose enter the colon where they are fermented by beneficial colonic microflora. The energy released is largely due to the production of short chain fatty acids and lactate, which are metabolized to contribute 1.5 kcal/g of useful energy (Niness, 1999). Due to their non digestibility, prebiotics can be used as sugar replacement for diabetes patients Duncan et al., 2002).

The nutritional properties of inulin and oligofructose are similar. However, each prebiotic ingredient contributes a different attribute to the finished product. For example, inulin is used when formulating a low fat table spread that has a creamy, fat like mouthfeel with no added sweetness. Conversely, oligofructose is used when formulating a low calorie fruit preparation for yogurts with high intensity sweeteners. (Niness, 1999).

Therefore, the objective of our study was to prepare ice cream with 10% of the sugar replaced with either inulin or FOS and evaluate these products for consumer acceptability.

Materials and Methods

Ice Cream Production

Ice cream was made by replacing 10% (10 g of the 100 g of sugar in a 1000 g batch of ice cream) of the sugar with either inulin or fructooligosaccharides (FOS) modifiying the University of Nebraska-Lincoln Dairy Store ice cream formulation (Table 1). A control batch of ice cream, without any addition of inulin or fructooligosaccharide was also made.

Corn syrup solids (36 DE; DRI-SWEET 36) were obtained from Germantown Summit, Roquette, IA. The stabilizer was obtained from Danisco Cultor USA Inc., New Century, KS. Inulin (Raftiline HP; DP >23) and fructooligosaccharide (FOS) (Raftilose P95; DP of 2-10) were obtained from Orafti Active Food Ingredients, Malvern, PA. The remaining ingredients were purchased from a local grocery store. Liquid ingredients (milk and cream) and dry ingredients were weighed and place in two separate containers, then the liguid and dry ingredients were mixed together. This ice cream mix was heated in a microwave for four minutes to reach a temperature of 71^0C (160^0F) to solubilize the stabilizer. In commercial ice cream production, raw milk would be used and a pasteurization process would occur at this stage. After the ice cream mix was quickly cooled on ice, each 1000 g batch was poured into the freezing chamber of a consumer ice cream maker (Hamilton Beach Ice Cream Maker). When the ice cream maker stop churning (approx. 30 min), a two ounce ice cream sample was quickly placed into a plastic container (PL2, Solo Cup Co., Il) and the containers were immediately put into a blast freezer (U.S Cooler, Il) and stored for three days.

Prior to the taste test, the ice cream containers were transferred to a freezer (Westinghouse) set at -20 ^{0}C (0^0F).

Physical Analysis of Ice Cream

Ice cream samples were analyzed for physical characteristic (color, texture and water activity). For color, colorimeter (Minolta CR-300, Konica Minolta Sensing Americas Inc., NJ) was used. The L value signifies lightness or darkness, the b value signifies yellow or blue, and the a value signifies red or green. For texture, Texture Analyzer (TA-XT2, Texture Technologies Corp, NY) was used to measure the firmness of the ice cream samples at -10 ˚C. The force was measured in g. For color and texture measurements, a 2 oz sample was used and six replications were conducted. For water activity, Pawkit water activity meter (Decagon Devices Inc., WA) was used with a 0.5 oz sample and six replications were conducted.

Table 1. Ice cream formulation for the control and the treatments made with inulin and FOS substituted for 10% of the sugar.

Ingredients	Control (g)	Ice cream with 10% sugar replaced with Inulin (g)	Ice cream with 10% sugar replaced with FOS (g)
Whole Milk	596	596	596
Cream (36% fat)	202	202	202
Sugar	100	90	90
Non Fat Dry Milk	50	50	50
Corn Syrup Solids	45	45	45
Stabilizer	7	7	7
Inulin	-	10	-
FOS	-	-	10
Total	1000	1000	1000

Sensory Testing

After IRB approval, students, staff and faculty were recruited at University of Nebraska-Lincoln with the use of fliers and class announcements and were requested to come to the sensory laboratory in Ruth Leverton Hall at designated times. After signing the informed consent, participants were given three samples of ice cream (control, 10% inulin and 10% FOS) simultaneously. Participants rated the ice cream samples on a hedonic scale using a 17 cm line anchored with like (0 cm) and dislike (17 cm).

Statistical Analysis

Statistical analysis was conducted using SAS (version 9.1) to determine the means and standard deviation of the physical data and sensory data. An ANOVA was conducted to determine differences between means.

Results And Discussion

The results of the color, texture and water activity measurements are listed in Table 2.

For color, the L (lightness/darkness) and b (yellow/blue) values for the three samples did not differ significantly ($p \leq 0.05$). The a (red/green) value for color differed ($p = 0.02$) for the treatment samples when compared to the control. A negative a value indicates green. Since the a value for the control was greater than the treatment ice cream samples (-2.48 versus -2.23), the treatment ice cream samples (containing inulin and FOS) had less greenness than the control.

During the sensory evaluation, participants commented that one sample was “harder” than the other two samples. When we measured the texture of the samples, the mean texture measurement for firmness was statistically higher ($p = 0.05$) for the inulin treatment than for the control and FOS samples (Table 2). For our project, inulin and FOS were substituted for 10% of the sugar in ice cream. A study reported the potential benefits of using inulin and oligofructose in ice cream containing probiotic bacteria *Lactobacillus acidophilus* La-5 and *Bifidobacterium animalis* Bb-12 (Akalin & Erisir, 2002). These researchers demonstrated that probiotic ice cream containing 4% inulin and 4% oligofructose (compared to 1% inulin and 1 % oligofructose used in this project; 10 g in 1000 g batch) exhibited increased firmness throughout storage except for the 1st day. However, inulin exhibited a higher firmness than oligofructose. This is because inulin is highly hygroscopic and binds water molecules to form a gel-like network that increases the firmness of the product (Akalin & Erisir, 2002). These reserarchers also demonstrated that both inulin and oligofructose improved the melting properties of ice cream to remain firm longer at room temperature, with inulin exhibiting the lowest change in melting properties. Whereas oligofructose improved of the viability of both probiotic strains during the frozen storage time (Akalin & Erisir, 2002).

Water activity was not affected by the addition of either inulin or FOS (Table 2).

Table 2. Color, Texture and Water Activity of Ice Cream made with Inulin and FOS substituted for 10% of the sugar.

	Color			Texture (g) n = 6	Water Activity n = 6
	L (Lightness/ darkness) n = 6	a (red/green) n = 6	B (yellow/ blue) n = 6		
Control	84.42 ± 0.37	-2.48 ± 0.17^{b}	6.71 ± 0.53	862.80 ± 45.40^{a}	0.93 ± 0.03
Ice cream with 10% sugar replaced with Inulin	84.58 ± 0.49	-2.23 ± 0.17^{a}	6.30 ± 0.60	1849.70 ± 456.51^{b}	0.91 ± 0.02
Ice cream with 10% sugar replaced with FOS	84.58 ± 0.49	-2.23 ± 0.17^{a}	6.30 ± 0.60	608.00 ± 6.79^{a}	0.90 ± 0.02

^{a,b} Superscripts that are different in each column show significantly different outcomes from each other at $P \leq 0.05$. Data without superscript indicates no significant differences.

Table 3: Sensory Evaluation of Ice Cream made with Inulin and FOS.

Ice Cream Treatments	Scale (cm) * n = 71
Control	4.89 ± 3.59^{a}
Ice cream with 10% sugar replaced with Inulin	6.56 ± 3.84^{b}
Ice cream with 10% sugar replaced with FOS	6.80 ± 3.99^{b}

[a,b] Superscripts that are different show significantly different outcomes from each other at $P \leq 0.05$.
[*] Measured on a 17 cm hedonic scale, anchored with like and dislike; 0 cm = like, 17 cm = dislike.

Seventy-one participants evaluated the ice cream samples made with either 10% of the sugar substituted with inulin or FOS and compared these treatments with the control sample of ice cream. Results of the sensory evaluation are listed in Table 3. Participants liked the ice cream made with inulin (6.56 on a 17 cm scale) or FOS (6.80 on a 17 cm scale) equally well (not statistically different, $p > 0.05$). However, the participants like the control sample better than the ice cream with 10% of the sugar substituted with either inulin or FOS ($p < 0.001$). Since the hedonic scale was a 17 cm line, a value of 6.56 or 6.80 is still within the like region of the scale (8.5 would indicate neither like or dislike).

Conclusion

Inulin and FOS are potential ingredients for use in ice cream. Our sensory results indicated that the ice cream made with 10% of the sugar substituted with either inulin or FOS was acceptable. Continued research needs to be conducted to determine the ideal amount of prebiotic ingredients to add to ice cream.

Prebiotic ingredients may improve the quality of the ice cream by increasing the firmness and improving the melting properties (Akalin and Erisir, 2002). Hence, ice cream with the prebiotic ingredient may have a longer storage period and a higher sustainability of texture.

Ice cream has the image of being high-fat, high-sugar and high-calorie. Adding prebiotic ingredients into ice cream may create a healthier product that is lower in fat, lower in sugar, lower in calorie and contains fiber. Inulin and FOS can act as fat replacers, while retaining a creamy texture and a fat-like mouthfeel. In addition, a prebiotic ingredient, such as inulin or FOS, has the functional qualities similar to sugar or glucose syrup. Part of the sugar used to make ice cream can be substituted with a prebiotic ingredient, thus lowering the sugar content of ice cream. Inulin and FOS have a lower caloric value as compared to other forms of carbohydrate, due to its non-digestibility by the human colon. The energy released by both prebiotic ingredients are 1.5 kcal/g of energy, compared to 4 kcal/g of carbohydrate and 3.4 kcal/g for sucrose. The addition of inulin and FOS add fiber to food products because they are not absorbed into the intestines but are fermented in the colon. The addition of a prebiotic ingredient has the potential to increase calcium absorption. Therefore, adding prebiotic ingredients has the potential to positively change the nutritional composition of ice cream.

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