Sensory Evaluation of a Nutritional Beverage Containing Canola Oil/Caprylic Acid Structured Lipid

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ABSTRACT: Chocolate-flavored nutritional beverages were formulated with canola oil and a structured lipid (SL) to determine the effect of the SL on the sensory profile of the beverage. The SL was synthesized from canola oil and caprylic acid in a bioreactor packed with an *sn*-1,3-specific lipase obtained from *Rhizomucor miehei*. Differences were determined by using a triangle test panel comprising 38 members and a 7-member trained quantitative descriptive analysis (QDA) panel. Twenty-three panelists correctly identified the odd sample during the triangle testing, which corresponds to a significant difference ($P < 0.01$). QDA results indicated that substituting the SL for unmodified canola oil significantly enhanced the perception of sweet flavor and decreased bubble formation. All other attributes were unchanged when the SL was substituted for unmodified canola oil in the beverage formulations. This SL may be suitable for use by manufacturers of nutritional beverages who market their products to people on modified diets and patients who are recovering from illness or injury. The new formulation would provide consumers with a source of energy that is more readily metabolized in the body while providing essential FA.

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Structured lipids (SL) are tailor-made fats and oils with improved nutritional or physical properties because of modifications to incorporate new FA, or to change the position of existing FA on the glycerol backbone. The relationship between stereospecific FA location and lipid metabolism suggests that the process of interesterification or acidolysis could be used to improve the nutritional profile of certain TAG (1). Structured TAG that contain medium-chain FA (MCFA) may provide a vehicle for rapid hydrolysis and absorption due to their smaller molecular size and greater water solubility in comparison to long-chain TAG (2).

Numerous SL have been described in the literature, and in many cases a potential food application has been suggested for the SL. However, few researchers have taken the next step and studied how SL actually behave when used in a particular food system (1). Data are not available on the sensory properties of foods containing SL. This information is needed to stimulate acceptance and increase the use of SL by the food industry, because the sensory characteristics of a product greatly influence the performance of a product in the marketplace.

Several nutritional beverages are commercially available for supplemental use with or between meals, or as a sole source of nutrition. These beverages are manufactured for people on modified diets, at nutrition risk, or with involuntary weight loss, and for patients who are recovering from illness or injury. These products are ideal targets for canola oil replacement with a SL containing MCFA and long-chain FA on the same glycerol backbone to increase the TAG absorption rate and provide EFA. Although evidence exists that the beverage formulated with SL would safely provide consumers with a more readily metabolized energy source than the beverages currently available on the market (3–5), the sensory properties of these beverages need to be examined to determine whether there are changes in the sensory profile of the nutritional beverage when canola oil is replaced with SL.

The triangle test is a useful sensory test for determining whether product differences result from a change in ingredients, processing, packaging, or storage (6). In contrast, a quantitative descriptive analysis (QDA) uses recruited panelists who work as a group to identify key product attributes and appropriate intensity scales specific to each product. This group of panelists is then trained to identify and score product attributes reliably (7). The results are expressed on a graphical scale (6). These data are useful in understanding results from triangle tests.

The specific objectives of this study were: (i) to determine whether consumers can differentiate between chocolate-flavored nutritional beverages formulated with SL and unmodified canola oil; and (ii) to score the intensity of product attributes identified in the nutritional beverages formulated with SL and unmodified canola oil.

EXPERIMENTAL PROCEDURES

Materials. Canola oil, cocoa powder, corn syrup, sucrose, salt, vanilla extract, and chocolate-flavored nutritional beverages [Boost and Nutrament (Mead Johnson Nutritionals, Evansville, IN); Ensure (Abbott Laboratories, Columbus, OH); Kroger Complete Nutritional Drink (The Kroger Co., Cincinnati, OH); and Slim-Fast (Slim-Fast Foods Co., West Palm Beach, FL)] were purchased locally. Caprylic acid (purity >98%) was purchased from Sigma Chemical Co. (St. Louis, MO). An *sn*-1,3-specific immobilized lipase originating from

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Rhizomucor miehei (IM 60) was obtained from Novo Nordisk A/S (Bagsvaerd, Denmark). Maltodextrin was donated (AVEBE America, Inc., Princeton, NJ), as were whey protein concentrate (80%) (Davisco Foods International, Inc., Le Sueur, MN), soy lecithin (Riceland Foods, Stuttgart, AR), carrageenan (Degussa Texturant Systems, Atlanta, GA), calcium caseinate (Erie Foods International, Inc., Erie, IL), and artificial fudgy chocolate flavor (Givaudan Flavors Corporation, Cincinnati, OH).

SL production. The SL was produced according to the apparatus setup and optimal conditions previously reported (8) for reacting canola oil and caprylic acid in a packed-bed bioreactor: substrate flow rate, 1 mL/min; temperature, 60°C; substrate mole ratio 1:5 (canola oil/caprylic acid); water content, 0.20% added. The product was purified by short-path distillation (UIC Inc., Joliet, IL). The oil was passed through the distillation apparatus three times under the following conditions: holding temperature, 25°C; heating oil temperature, 185°C; cooling water temperature, 15°C; pressure, <0.01 Torr.

FA analysis. The FFA content of the final product was determined using alkali titration (9). The FA compositions of canola oil and the purified SL were analyzed by GC as previously described by Fomuso and Akoh (10). FAME were prepared by methylation. The FAME were extracted with hexane and analyzed by GC. FA standards purchased from Nu-Chek-Prep, Inc. (Elysian, MN) were used to identify the peaks. FA at the *sn*-2 position on the glycerol backbone were determined by the previously described pancreatic lipase method (11). TLC analysis was done on a silica gel G plate with a developing system of hexane/diethyl ether/acetic acid (50:50:1, by vol). The MAG band was identified, scraped, methylated, and analyzed by GC as discussed above for the TAG.

Beverage formulation. The formulation for the chocolate-flavored nutritional beverages was developed based on the ingredient lists found on commercially available products, a product handbook available from Abbott Laboratories (Columbus, OH), and informal evaluation among individuals in our laboratory. The final beverage formulation used in the sensory testing is given in Table 1. Dry ingredients were premixed, dispersed with oil, and poured into the water/corn syrup mixture while stirring with a propeller blender at high shear rates for 1.5 min, as required for proper carrageenan dissolution. Two batches of the beverage were produced separately on the same day, one containing canola oil and the other SL (substituted 1:1 for the canola oil). Both beverages were stored at 4°C for 48 ± 4 h before being evaluated by sensory panelists to allow for full flavor development.

TABLE 1
Formulation for Chocolate-Flavored Nutritional Beverages

Component	wt%	Component	wt%
Water	75.92	Whey protein concentrate	1.52
Corn syrup	5.69	Salt	0.19
Sucrose	3.80	Vanilla extract	0.19
Maltodextrin	3.80	Soy lecithin	0.08
Calcium caseinate	3.41	Artificial fudgey chocolate flavor	0.05
Canola oil or SL[a]	3.41	Carrageenan	0.04
Cocoa powder	1.90		

[a]SL, canola oil/caprylic acid structured lipid synthesized at a substrate mole ratio of 1:5.

Triangle test. After obtaining approval for human subjects studies from the University of Georgia Institutional Review Board, 38 panelists were recruited from the University of Georgia campus and familiarized with the triangle testing procedure. They were required to sign a consent form indicating they had no known allergies to the beverage ingredients. The triangle test (6) was performed under normal white lighting to allow differences in appearance to be taken into account. Beverages were shaken vigorously for 10 s and poured (30 mL) immediately before each test in an attempt to imitate consumers drinking purchased nutritional beverages, which are labeled, "Shake well." Samples were presented in 90-mL white plastic cups coded with three-digit random numbers, along with water and unsalted crackers. Samples were presented at random to the panelists from the six possible presentation-order combinations. Panelists were asked to identify the odd/different sample by placing an "X" next to the corresponding sample code on the scoresheet. Panelists were allowed to retaste the samples as necessary and instructed to guess if differences were undetectable. Panelists were not asked questions about preference, acceptance, degree of difference, or type of difference after the initial selection of the odd sample in order to avoid biased responses (6).

Quantitative descriptive analysis. The descriptive analysis was performed in an attempt to identify more specifically any differences between formulations detected by the triangle test. Seven panelists (students from the University of Georgia Department of Food Science and Technology) familiar with descriptive analysis were recruited to develop sensory descriptors for chocolate-flavored nutritional beverages. Initially, the assessors sampled four commercially available chocolate beverages during a roundtable discussion. Descriptors and definitions were obtained by consensus after a group discussion of the descriptors developed by each individual assessor and are listed in Table 2.

During the second session, panelists were tested on the descriptors using one beverage repeated from the first session and two other commercially available chocolate beverages. Average ratings for the group were determined for each attribute. Calibration of the panel was conducted by asking those panelists who were not within 10 points of this average rating to reevaluate the sample(s) at a third session and adjust their ratings until a consensus was reached.

Immediately before each testing session (practices and actual), the refrigerated (4ºC) beverages were shaken vigorously for 10 s and poured (60 mL) into 90-mL white plastic cups labeled with three-digit random numbers. The serving order of the two samples was alternated between panelists. Samples were evaluated in partitioned booths illuminated with white light to allow for evaluation of appearance. Panelists rated attribute intensities for each sample individually on 150-mm unstructured line scales, anchored at the 12.5 and 137.5 mm points. As shown in Table 2, the anchors on the ends of the

TABLE 2
Product Attributes Developed by Panelists for Chocolate-Flavored Nutritional Beverages and Their Corresponding QDA End Point Descriptors

Attribute	QDA end point descriptors	
Appearance	Light	Dark
Brown	Absent	Strong
Foam[a]	Absent	Strong
Aroma		
Overall intensity	Absent	Strong
Chocolate pudding-like	Absent	Strong
Flavor		
Sweet	Absent	Strong
Medicinal	Absent	Strong
Fruity	Absent	Strong
Milk shake-like	Absent	Strong
Astringent	Absent	Strong
Texture		
Viscosity[b]	Watery	Thick
Aftertaste		
Bitter	Absent	Strong
Metallic	Absent	Strong

[a]Foaminess was determined visually as bubbles on the surface of beverages.
[b]Viscosity was determined by placing product in the mouth, allowing it to flow across the tongue by moving the tongue slowly to the roof of the mouth, and measuring the rate of flow (6). QDA, quantitative descriptive analysis.

scales were absent and strong for all attributes except brown (light to dark) and viscosity (watery to thick). Panelists were allowed to retaste the sample as necessary and instructed to cleanse their mouths with water and unsalted crackers before the second sample was served.

Statistical analysis. Triangle test data were analyzed by matching the number of correct judgments from the number of trials conducted to a probability table (6,12). The QDA data were analyzed by ANOVA on each attribute after the normality assumption was checked with a normal probability plot of the ordered residuals, using an SAS software package (13). Panelists were treated as repeated measures. Differences in means were determined with Student's *t*-test. Significant differences were defined as $P < 0.05$.

RESULTS AND DISCUSSION

FA composition. After short-path distillation, the FFA content of the purified SL was 0.21%. The FA profile of the TAG (canola and SL) and at the *sn*-2 position of the canola oil and SL are given in Table 3. The acidolysis reaction successfully incorporated 37.3% caprylic acid into the canola oil TAG, mainly at the *sn*-1 and *sn*-3 positions. The 10.0% caprylic acid present at the *sn*-2 position indicates that acyl migration occurred during the acidolysis reaction, short-path distillation, or *sn*-2 positional analysis (14,15).

The caprylic acid/canola oil SL was chosen for this study because it combines rapidly absorbed MCFA and EFA into the same molecule, which is nutritionally advantageous over native oils and physical mixtures (16). Canola oil is currently the main lipid found in most commercially available nutritional beverages. Therefore, the canola oil base was selected

TABLE 3
TAG and *sn*-2 FA Composition of Canola Oil and SL[a] (mol%)

	TAG		*sn*-2	
FA	Canola oil	SL	Canola oil	SL
8:0	0.0	37.3	0.0	10.0
16:0	4.2	1.8	0.0	0.0
18:0	1.4	1.7	0.0	0.0
18:1n-9	63.1	47.3	57.9	47.9
18:2n-6	24.5	8.9	30.3	29.9
18:3n-3	6.8	3.0	11.8	12.2

[a]SL: canola oil/caprylic acid structured lipid synthesized at a substrate mole ratio of 1:5.

in an attempt to maintain much of the native oil's functionality. This is important so beverage manufacturers are not required to make other formulation changes when replacing canola oil with the SL in their products.

Triangle test. Twenty-three out of 38 panelists correctly identified the odd sample. These results correspond to a significant difference between samples ($P < 0.01$). The mean testing time for the panelists was 4 min.

QDA. Mean ratings by panelists of attribute intensities for appearance, aroma, flavor, texture, and aftertaste are listed in Table 4. All data were normally distributed and the SD were relatively low, indicating a well-calibrated panel. Significant differences ($P < 0.05$) between formulations were found only for the foam/bubbly appearance and sweet flavor attributes. This amount of variation among foamy appearance and sweet flavor attributes was also seen when commercially available beverages were evaluated during training sessions (data not shown). The mean values obtained for both test beverages were within the range of products currently on the market. Panelists did not detect an increase in astringency when canola oil was replaced with SL, although the FFA content was 0.03 and 0.21%, respectively.

The fact that significant differences did exist in the sweet flavor attribute between formulations suggests that the SL

TABLE 4
Mean Ratings of Panelists ($n = 7$) of Chocolate-Flavored Nutritional Beverages Formulated with Canola Oil and SL[a]

Descriptive attribute[b]	Canola oil[c]	SL[c]
Brown color	64.3 ± 8.6	56.6 ± 7.9
Foam (bubbles)	15.6 ± 10.6[A]	3.0 ± 3.1[B]
Overall aroma intensity	64.1 ± 14.6	51.4 ± 13.9
Chocolate pudding-like aroma	35.6 ± 11.0	37.5 ± 11.9
Sweet flavor	48.0 ± 18.3[A]	80.3 ± 17.8[B]
Medicinal flavor	56.4 ± 16.9	68.1 ± 16.5
Milk shake-like flavor	21.3 ± 6.9	29.5 ± 11.5
Astringent flavor	31.6 ± 6.0	30.0 ± 8.6
Viscosity	32.6 ± 7.7	35.9 ± 7.7
Bitter aftertaste	39.4 ± 18.2	41.2 ± 20.3
Metallic aftertaste	41.4 ± 11.4	41.6 ± 13.1

[a]SL: canola oil/caprylic acid structured lipid synthesized at a substrate mole ratio of 1:5.
[b]Attributes were rated on 150-mm unstructured line scales, anchored at the 12.5- and 137.5-mm points.
[c]Means within the same row (attribute) with different superscripts are significantly different ($P < 0.05$).

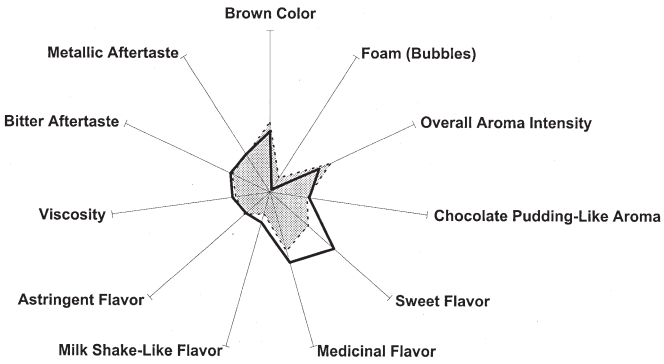

FIG. 1. Sensory profiles of chocolate-flavored nutritional beverages formulated with canola oil and canola oil/caprylic acid structured lipid (SL). Individual attributes are positioned like the spokes of a wheel around a center point (zero, not detected), with the spokes representing attribute intensity scales, with higher (more intense) values radiating outward. Open area: SL beverage; stippled area, canola oil beverage.

either increased the sweet flavor perceived in chocolate beverages or masked other flavors that decreased the perceived sweet flavor in the canola oil beverage. Currently, medium-chain TAG (MCT) are used by the food industry as flavor carriers (17). Therefore, the presence of MCFA on the SL glycerol backbone may enhance its ability to transport flavor components and be responsible for the increased sweetness in the SL beverage.

Differences in foaminess also may be a result of the changes in FA on the glycerol backbone. Studies on beer showed that lipids have a negative, a positive, or little effect on foam formation and stability, depending on their M.W. (18). More specifically, Pueyo *et al.* (19) found that wines containing greater amounts of linolenic acid and palmitic acid form more foam than wines with lower concentrations of these compounds. During the acidolysis reaction, a portion of the linolenic and palmitic acids were removed from the canola oil TAG molecule (Table 3), and may explain the decreased foaminess observed in the beverage formulated with the SL.

To create a visual profile or "fingerprint" of product attributes, spider plots were created by plotting average intensity values on each scale and then joining the points (7). Figure 1 shows attributes of the test beverages formulated with canola oil and SL. This plot illustrates that brown color, sweet flavor, medicinal flavor, and aroma intensity are the most prominent characteristics of the beverages. Sweet flavor was the only prominent attribute significantly influenced when SL was substituted for canola oil in the nutritional beverage formulation.

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