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Influence of Flavor Solvent on Flavor Release and Perception in Sugar-Free Chewing Gum

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The influence of flavor solvent [triacetin (TA), propylene glycol (PG), medium chained triglycerides (MCT), or no flavor solvent (NFS)] on the flavor release profile, the textural properties, and the sensory perception of a sugar-free chewing gum was investigated. Time course analysis of the exhaled breath and saliva during chewing gum mastication indicated that flavor solvent addition or type did not influence the aroma release profile; however, the sorbitol release rate was statistically lower for the TA formulated sample in comparison to those with PG, MCT, or NFS. Sensory time-intensity analysis also indicated that the TA formulated sample was statistically lower in perceived sweetness intensity, in comparison with the other chewing gum samples, and also had lower cinnamon-like aroma intensity, presumably due to an interaction between sweetness intensity on aroma perception. Measurement of the chewing gum macroscopic texture by compression analysis during consumption was not correlated to the unique flavor release properties of the TA-chewing gum. However, a relationship between gum base plasticity and retention of sugar alcohol during mastication was proposed to explain the different flavor properties of the TA sample.

KEYWORDS: Flavor release; perception; flavor solvents; chewing gum; time-intensity; breath analysis

INTRODUCTION

The flavor properties of chewing gum are undoubtedly a key product attribute for consumption. Defining the mechanisms of flavor release and perception in chewing gum (or foodstuffs) can be better understood by combining analytical methods that monitor the release profiles of key flavor stimuli near the receptors in combination with sensory evaluation. Previous studies on the flavor perception of chewing gum, for example, have correlated perceived mint flavor intensity to the sucrose concentration in the saliva. Davidson et al. (*1*) monitored the temporal release profile of menthone and sucrose concentration from chewing gum while panelists recorded mint flavor intensity over time. Panelists perceived a decrease in mint flavor intensity over time which was correlated to the decrease in sucrose concentration rather than menthone release suggesting taste−aroma interactions were important for the overall mint flavor perception. Similarly, Duizer et al. (*2*) reported that a longer duration of peppermint flavor was perceived with a faster release rate of sucrose in chewing gum.

The textural properties of chewing gum have also been suggested to influence volatile flavor release properties. de Roos (*3*) varied the textural properties of flavored gum bases by varying the gum base composition or by adding a plasticizer (glycerine monostearate) and measured the residual volatile flavor concentration over time during consumption. Overall, the softer gum bases were reported to release flavor compounds at a faster rate than the harder gum bases; however, he was unable to conclude if this was due to a higher diffusivity or if the panelists chewed the softer gum at a faster rate which facilitated extraction. The gum base industry has also suggested chewing gum formulated with the flavor solvent triacetin (TA) or medium chained triglycerides (MCT) are softer than if formulated with propylene glycol (PG), and therefore the former two products would have a higher perceived flavor intensity (*4*).

A few studies have also reported a correlation between aroma/flavor perception and textural properties of solid/semisolid food systems (for example, gels, yogurt, model dessert). Baek et al. (*5*) conducted a time-intensity sensory study on gelatin gels and reported a higher maximum flavor intensity and a lower time to maximum flavor intensity for softer gels compared to harder gels which they suggested was due to a faster release of volatiles from a softer gel. Using a model mouth and in vivo analysis via Proton Transfer Reaction Mass Spectroscopy (PTR-MS), Hansson et al. (*6*) showed the release of volatiles from a pectin gel was not only dependent on the physiological properties of the mouth (mastication rate and saliva), but also on the textural properties (gel strength/structure) of the gels. In contrast, a study conducted by Weel et al. (*7*) using whey protein gels reported that the concentration of volatiles in the breath was not influenced by gel strength; however, they did indicate that the stronger gels were perceived at a lower flavor intensity. Mestres et al. (*8, 9*) attempted to explain these contradictory results based on the hypothesis of "first impression", where the perceived aroma intensity is dictated by the initial release rates rather than

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the overall amount of aroma stimulus or cognitive textural interactions. They reported that the temporal resolution of retronasal aroma perception was influence by the opening and closing of the velum-tongue border (passage way to the olfactory membrane in the oral cavity), which was controlled by the texture of the gels. For example, Mestres et al. indicated that the velum-tongue border was found to be open during the initial chewing phase prior to swallowing for hard gels while for soft gels it was only intermittently open or was closed which was further related to the panelist chewing pattern (opening and closing of the jaw versus a side-to-side chewing motion). If the velum-tongue border was closed there would be no transfer of volatiles from the oral to the nasal cavity until the sample was swallowed. These noted differences in retronasal aroma release based on the velum-tongue border indicate the challenges in investigating the influence of texture on flavor perception.

Lethuaut et al. (*10, 11*) investigated the influence of three flavor stimuli in combination on the overall flavor perception of a model dessert by varying the texture agent, sucrose, and aroma concentrations. Although the sweetness intensity was reported not to be affected by aroma concentration, both the textural properties and sucrose release rates were found to impact the perceived aroma intensity at higher aroma concentrations. However, at lower aroma concentrations, no textural effects on flavor perception were reported (*11*).

The aim of this study was to further investigate the role of flavor solvent on the release profile of volatile (aroma) and nonvolatile (sugar-alcohol) flavor compounds as well as on the textural properties and how these three stimuli influence flavor perception in chewing gum. The influence of the solvent properties of PG, TA, or MCT on the chewing gum matrix in relation to flavor perception is not well defined and therefore was investigated.

MATERIALS AND METHODS

Materials. Cinnamaldehyde, L-carvone, and jasmone were purchased from Aldrich (Sigma Aldrich, Milwaukee, WI). Piperitone was from the Penta Manufacturing (Livingston, NJ). Methanol was from Fisher Scientific (Fairlawn, NJ). Hexane and formic acid were from EMD Chemicals (Gibbstown, NJ). *N*-Caproic acid methyl ester was purchased from TCI America (Portland, OR). VH1 gum base was obtained from Hersheys Foods (Hersheys, PA). Sorbitol was from SPI polyols (Wilmington, DE). Glycerine was from Univar (Bedford Park, IL). Hydrogenated glucose syrup was from Roquette Americas (Lycasin 80/55; Keokuk, IA). Lecithin was from Solae (St. Louis, MO). Titanium dioxide was from Sensient (St. Louis, MO). Propylene glycol and triacetin were from Givaudan Flavors (Cincinnati, OH), whereas medium chain triglycerides (Neobee-80) was from Stepan Company (Northfield, IL).

Chewing Gum Models. The chewing gum ingredient formulation consisted of gum base (25.57 g/100 g), sorbitol crystals (54.48 g/100 g), hydrogenated glucose syrup (11.80 g/100 g), glycerine (2.95 g/100 g), saturated sorbitol solution (1.97 g/100 g), flavor mixture (0.98 g/100 g), flavor solvent (0.66 g/100 g; PG, TA, or MCT), titanium dioxide (0.49 g/100 g), and Lecithin (0.10 g/100 g); the gum base composition consisted of polyisobutylene (7−10 g/100 g), styrene butadiene rubber (3−5 g/100 g), polyvinyl acetate (15−20 g/100 g), wood rosin (11−15 g/100 g), polyethylene (0−2 g/100 g), filler (25−35 g/100 g; $CaCO_3$), BHT (0−0.1 g/100 g), waxes (4−8 g/100 g), emulsifier (0−2 g/100 g), and softeners (10−17 g/100 g; hydrogenated confectionery fat) (*12*). The cinnamon-like aroma mixture compositions is reported in **Table 1**. Chewing gum samples were made by initially melting the gum base (raised to 98−104 °C) in a Littleford Day gum mixer (Florence, KY). Lecithin and titanium dioxide were then added to the molten gum base during mixing, and after 2 min, the heat was shut off and the mixer was cooled by circulation of room temperature water. During cooling, the hydrogenated glucose syrup was added (mixed 2 min) followed by addition of about 50% of the sorbitol and mixed for another 2 min. At approximately 75 °C, the cinnamon-like aroma mixture (with or without flavor solvent) and the remaining sorbitol was added and mixed for 2 min. Finally, the glycerin then the remaining sorbitol syrup were added and further mixed for 1 min per each ingredient. The resultant chewing gum dough was rolled using a Rondo dough roller (Moonachie, NJ, average thickness was 0.168 cm ± 0.005) and subsequently conditioned at room temperature at 45% humidity for 12 h before being cut into commercial size sticks (Package machinery cutter, West Springfield, MA). The chewing gum samples were wrapped in aluminum foil and stored at 21 °C at 35% (±10) relative humidity prior to analysis (<4 months).

Table 1. Composition of Cinnamon-Like Aroma Mixture and Log *P* Values

compound name	flavor composition (g/100 g)	log *P* value
cinnamaldehyde	88.26	1.90[a]
L-carvone	10.16	2.87[b]
piperitone	0.79	2.85[b]
jasmone	0.79	3.55[c]

[a] Experimental value from Hansch and others (1995). [b] Experimental value from Griffin and others (1999). [c] Estimated based on the K_{ow} calculation program (Syracuse Research Corporation; http://www.syrres.com/aboutsrc/default.htm).

Quantification of Aroma Compounds in Chewing Gum. Twelve gum pieces per chewing gum treatment (sampled every 10th piece out of 120 pieces) were further subsampled to a 0.5 ± 0.02 g sample and dissolved in 1 mL of hexane on a vortex shaker (Vortex Genie 2, Model CG-560, NY). The hexane mixtures were then centrifuged at 11 750 rcf for 4 min (Brinkman Instruments Inc., Model no: 5415C, NY) and 0.3 mL of the supernatant was collected and added to 1 mL of methanol. The hexane−methanol extracts were then centrifuged at 11 750 rcf for 4 min and 1 mL of supernatant was collected. This step aided in the precipitation of the gum base polymers. Methanol (100 μL) containing methyl hexanoate (as internal standard; 2500 mg/L) was then added to the hexane−methanol supernatant, and subsequently analyzed by gas chromatography equipped with a flame ionization detector (GC-FID).

Gas Chromatography (GC). Analyses of aroma compounds was performed using a Hewlett-Packard 5890 Series II GC equipped with a split/splitless injector, flame ionization detector (FID), autosampler (HP 7673), and a fused-silica capillary column (DB-wax, 30 m, 0.32 mm inner dia, 0.32 μm film thickness, Agilent Technologies, CA). The GC operating conditions were as follows: 1 μL of sample was injected in split mode (1:20); inlet temperature was 200 °C, oven program was 35 °C for 2 min, then increased at 10 °C/min to 230 °C and held for 3 min; constant flow rate of 1.0 mL/min (He).

Measurement of Sorbitol/Hydrogenated Glucose Syrup Release from Chewing Gum during Mastication. The concentration of sorbitol and hydrogenated glucose syrup (HGS) were determined by HPLC from the expectorated saliva for three panelists while chewing a 2.5 g piece of chewing gum sample over a 12 min time period. The panelists were trained to follow a defined chewing and expectorate saliva (C/E) protocol: chew at 60 chews/min (used a metronome) and expectorate saliva into 20 mL cups with lids at 0, 10, 30, 50, 70, 120, 240, 420, 660 s. One-half a gram of saliva was immediately transferred into a 1.5 mL centrifuge tube and mixed with 1 mL solution of nanopure water containing 0.1 g/100 g formic acid. The samples were then centrifuged at 12 000 rpm for 3 min and the supernatant was transferred into 2 mL amber bottles with lids prior to HPLC analyses. Each chewing gum sample was analyzed in triplicate. The sugar alcohol concentration was determined using an external standard curve at 6, 13, 25, 38, 50 g/L for sorbitol and 0.16, 0.31, 0.63, 1.25, 2.5, 5, 10 mg/L for HGS plotted versus peak area ($r^2 > 0.99$).

High Performance Liquid Chromatography (HPLC). Analyses of sorbitol and HGS was performed using a Shimadzu HPLC system consisting of pump (LC-10ATvp), degasser (DGU-14A), an auto sampler (SIL-10Ai), column heater (CTO-10ACvp), and refractive index detector (RID; RID-10A). Separations were performed on a LC column Supelcogel-H (5 μm, 250 × 4.6 mm i.d.,) using an isocratic run with 0.1 g/100 g formic acid in water as the mobile phase maintained at 40 °C. The flow

rate was 0.17 mL/min, and the injection volume was 10 μL.

Measurement of Volatile Release from Chewing Gum during Mastication. Breath-by-breath analysis was performed with an atmospheric pressure chemical ionization-mass spectrometer (APcI-MS) as previously described by Schober and Peterson (*13*). Three panelists (1 male and 2 female) were trained to chew the samples using a defined chewing and swallow (C/S) protocol; chew at 60 chews/min (using a metronome) and to swallow at 0, 10, 30, 50, 70, 120, 240, 420, 660 s. The whole experiment was conducted over a 3 day period, with 4 gums per panelist per day, in random order. To minimize carry over effects and fatigue, each panelist rinsed with water and waited at least 30 min between sample analyses.

The breath from the nose was directly and continuously sampled via an interface set at 80 °C into the retrofitted Micromass ZMD 4000−mass spectrometer (Waters, Milford MA) at 0−4 min, 6−8 min, 10−12 min time intervals. The APcI operating conditions are as follows: SIM mode; sampling rate was 200 mL/min; block temperature is 100 °C; transfer line 90 °C; corona discharge was 3.5 kV, cone voltage was 15 V. Ions monitored were 133 $[M + H]^+$ for cinnamaldehdye, 151 $[M + H]^+$ for carvone, 153 for piperitone, and 165 $[M + H]^+$ for jasmone. Day to day variation in instrumental response was corrected for based on the peak heights obtained sampling a known amount of L-carvone (1 μL of 1000 mg/L solution in pentane) which was injected into an airtight water-jacketed 1.1 L deactivated glass vessel maintained at 40 °C and held for 5 min with constant stirring (200 rpm). Quantification of aroma compounds from the breath was determined via standard calibration curve methodology. Different quantities of each compound dissolved in 50 μL pentane (0.009, 0.018, 0.089, 0.179, 0.536, 0.837, 1.768 μg) were injected into the deactivated glass vessel as described above. The peak height (ion intensity) versus μg weight of each compound per L of air was plotted (all compounds reported an $r^2 > 0.99$).

Instrumental Texture and Gum Volume Analysis of Chewing Gum during Mastication. Three panelists (1 male and 2 female) were asked to chew the chewing gum samples using the c/s protocol described above. In two different experiments at the time intervals of 30, 60, 120, 240, 420, 720 s, the panelists expectorated the chewing gum samples for texture or volume measurement. A new piece of chewing gum was used for each time point (clock restarted at 0 s). After each sample, panelists rinsed their mouth with water to clear the palate, and at least 20 min breaks were taken between samples to minimize the effects of fatigue.

For textural analysis the chewing gum samples were placed in 3.5 mL caps (1.5 cm diameter and 1.5 cm length) and analyzed with a TA-XT2 Texture Analyzer (Godalming, Surrey, UK) equipped with a cylindrical stainless steel probe (1 cm diameter and 5 cm length). The probe penetrated the first 2 mm of the product at 2 mm/s and the total work done was recorded from the area of the force−distance curve for chewing gum chewed at a given interval. Five samples were evaluated for each treatment.

For gum volume analysis, the samples were initially placed onto a Kimwipe absorbent napkin (Kimtech, Ontario, Canada), to remove additional saliva and then placed into a 10 mL volumetric cylinder containing 10 mL of water. The volume displaced by the addition of chewing gum was then measured using a magnifying glass. Each sample was measured in triplicate.

Plasticity Index Analysis of Gum Base with Flavor solvent. Molten gum bases (100 g) containing 2.7 g of TA, PG, MCT, or NFS were poured into an aluminum weighing pan (7.5 cm diameter and 1.5 cm depth), cooled for 24 h, and analyzed with an Instron 4444 universal machine (Instron Corp., MA) equipped with a spherical probe (diameter: 12.6 mm). The probe penetrated the gum bases to distance of 1.016 mm at a speed of 2.54 mm/min. The plasticity index was calculated based on the equation listed below. Theoretical chord value was obtained from trigonometric calculations based on the dimensions of the spherical probe. After 24 h of indentation, an experimental chord value (ECV) was measured using Vernier calipers for each sample.

$$\text{Plasticity Index (PI)} = \frac{\text{Experimental chord value after 24 h (mm)}}{\text{Theoretical chord value (mm)}} \quad (1)$$

Sensory Analyses. Time-intensity analysis was conducted with a trained panel of 9 people (3 males and 6 females; age range: 21−35 years) recruited from the Department of Food Science, The Pennsylvania State University. Three attributes of the chewing gum were rated: sweetness, cinnamon-like aroma, and effort to chew. The panelists were trained on the attributes and time intensity procedures during 12 1-h sessions. References for each attribute were developed by panel consensus. Panelists used references for sweet (sucrose solutions 2, 4, 6, 9, 12 g/100 g w/w corresponding to 2, 4, 6, 9 and 12 reference value), aroma (solutions of cinnamon mixture with 4 compounds as in **Table 1**; 25, 50, 100 μg/L of water corresponding to 3, 6, and 9 reference value), and texture (Jet-Puffed marshmallows, Gaint orange slices, Swedish fish candy, Tootsie Roll chocolate corresponding to 1, 4, 7 and 9 reference values, respectively). For each attribute, a 15 point scale was used for intensity measurement. Data was collected in individual testing booths using Compusense software (Compusense Inc., Guelph, Canada). Panelists rated one attribute at a time while chewing the gum (2.5 g) for 4 min. For the aroma and effort to chew attributes, panelists were instructed to breathe normally through their nose with their mouths closed. For the sweetness attribute, panelists evaluated the samples wearing a nose-clip. For the final evaluations, 2.5 g of chewing gum was cut, wrapped in a wax paper and placed into small Ziploc bags coded by a three-digit number 1 h before each session. Four treatments were evaluated in triplicate over 12 sessions, using a complete balance block design. Two sessions were conducted per day with at least 3 h between same-day sessions. During each session, panelists evaluated all 3 attributes for a given treatment with 2 min interval between each attributes.

Statistical Analysis. ANOVA and Tukeys Pairwise Comparisons using SAS statistical software (V. 8.0, SAS Institute, Cary, NC) were used to compare all treatments.

Instrumental Data. For breath analysis, evaluations were conducted on a 6 s moving average concentration values at 30, 70, and 150 s, while for sorbitol release, texture analysis, gum volume analysis, and PI values all analyses were conducted at times 30, 70, and 120 s.

Sensory Data. Time Intensity curves for each panelist were generated using Compusense software. For the attributes sweetness and cinnamon-like aroma, the parameters Maximum intensity (I_{max}) and the Time-at-Maximum intensity (T_{max}) were analyzed while for the attribute "effort to chew" the Minimum Intensity (I_{min}) and time to reach minimum intensity (T_{min}) were examined.

RESULTS AND DISCUSSION

The concentrations of the four aroma compounds in the chewing gum samples made with PG, MCT, TA, or NFS were determined prior to the analytical and sensory studies. The average quantities per gram of chewing gum for cinnamaldehyde, L-carvone, piperitone, and jasmone were reported to be 5.2, 0.5, 0.1, and 0.1 mg, respectively. No significant differences ($\alpha = 0.05$) were reported for each compound between these samples (coefficient of variation was <10%).

To investigate the influence of flavor solvent type or addition on aroma release in chewing gum, the release profiles of cinnamaldehyde, carvone, piperitone, and jasmone from samples made with PG, MCT, and TA or with NFS over a 12 min consumption period were determined. The release curves for cinnamaldehyde and carvone are illustrated in **Figure 1** (piperitone and jasmone not shown). For each compound, similar release patterns were observed among these chewing gum samples for all three panelists. No statistically differences ($\alpha = 0.05$) were reported in the concentration of each compound (based on 6 s moving average value) detected in the breath when comparing the different flavor solvent formulated chewing gums at three time points (30, 70, and 150 s); the average coefficient

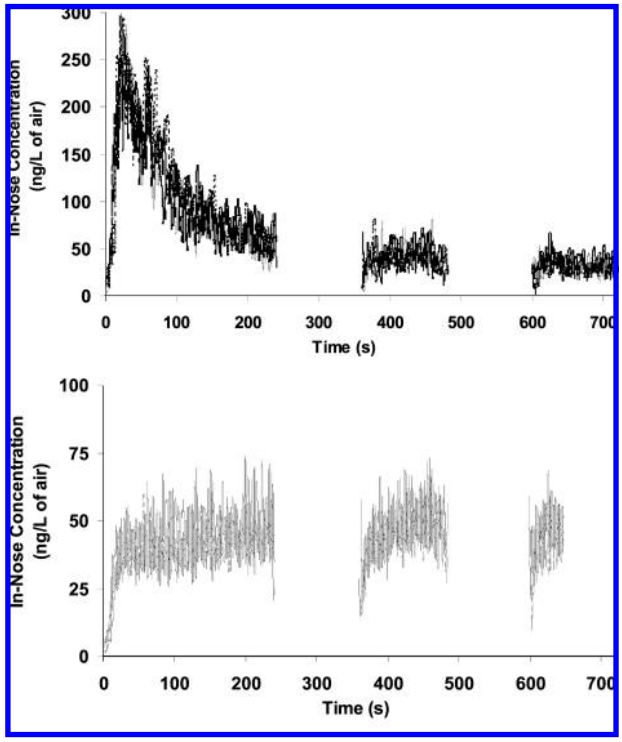

Figure 1. Cinnamaldehyde (top) and L-carvone (bottom) release profile from chewing gum samples made with NFS (—), PG (— -), TA (- - -), and MCT (— - -) consumed over 12 min; each curve represents the mean of three replicates subsequently smoothed by a 1.5 s moving average trendline for one representative panelist.

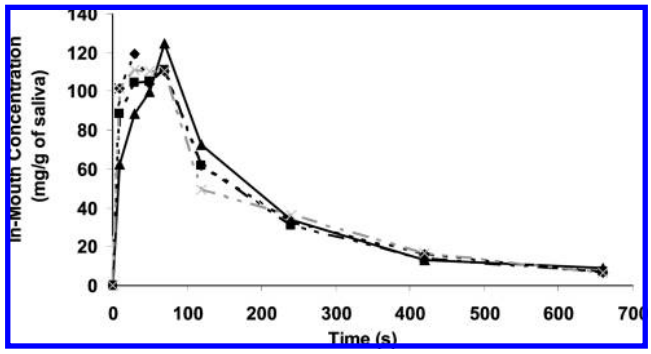

Figure 2. Sorbitol release profile from chewing gum samples made with NFS (-◆-), PG (—■—), TA (—▲—), or MCT (— × -) consumed over 8 min; average of triplicates for one representative panelist.

of variation for each panelist was <30% for each compound. Therefore, flavor solvent addition or type had no apparent affect on the release properties of the select aroma compounds (log P values ranged from 1.90 to 3.55, **Table 1**) in these chewing gum samples.

In a parallel study, the release profile of sorbitol from the same samples over a 12 min consumption time period was monitored and is reported in **Figure 2**. Overall, the triacetin-containing chewing gum had a lower initial sorbitol release rate in the first 70 s compared to the rest of gum samples for all panelists. As anticipated, analogous release patterns were also observed with hydrogenated glucose syrup (HGS), the second most abundant sugar alcohol in the chewing gum (data not shown). Statistical analyses of the sorbitol (or HGS) concentrations in the saliva were found to be significantly lower for the triacetin gums at 30 and 70 s (see **Table 3**) but not statistically different at 120 s. Considering that the sugar alcohol phase of these samples made up approximately 65 g/100 g of the total

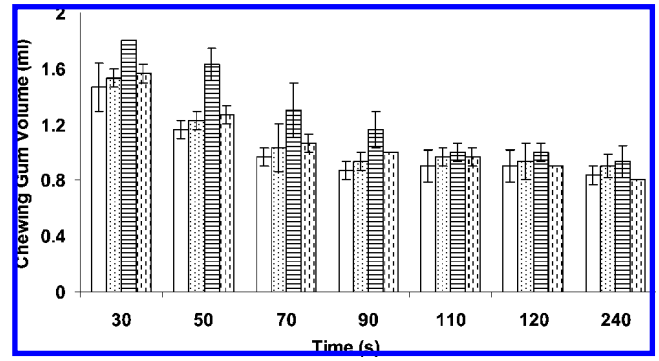

Figure 3. Time course of chewing gum volume made with NFS (□), PG (square with dots), TA (square with horizontal stripes), or MCT (square with vertical dotted lines) consumed over 4 min; average of triplicates ±95% Confidence interval for one representative panelist

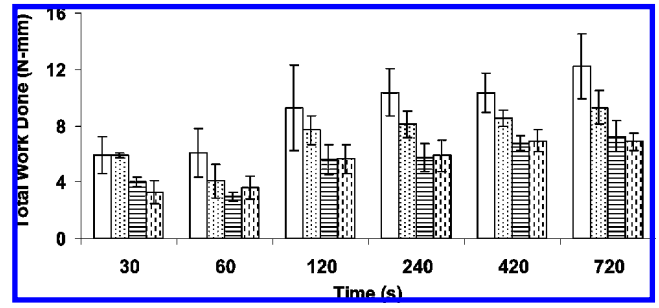

Figure 4. Time course of chewing gum compressibility made with NFS (□), PG (square with dots), TA (square with horizontal stripes), or MCT (square with vertical dotted lines) consumed over 12 min; average of five replicates ± 95% confidence interval for one representative panelist.

sample mass, the TA containing samples would also be predicted to have a higher volume during this initial time period, if the sugar alcohol phase was released at a lower rate. Time course analysis of the chewing gum volume during mastication for these samples was determined and the data for one panelist is reported in **Figure 3** (similar findings were reported for the other two panelists, data not shown). As predicted, the TA formulated chewing gum sample had the largest volume during the initial mastication period (up to 90 s).

We also observed, although not as part of the research objectives of this study, that the release profile of cinnamaldehyde was correlated to the release of the sugar alcohol phase (see **Figures 1** and **2**) which would not be anticipated based on the estimated log P value of cinnamaldehyde (see **Table 1**). In a subsequent study, Potineni and Peterson (*14*) reported that cinnamaldehyde and sorbitol generated transient hemiacetal reaction products during chewing gum manufacture/storage which were hydrolyzed back to free "cinnamaldehyde" and sorbitol in the oral cavity during mastication. Because these transient hemiacetal reaction products of cinnamaldehyde were more polar than the free "cinnamaldehyde", a more rapid release of cinnamaldehyde was observed.

To establish if the "softness" of chewing gum, as influenced by flavor solvent, was related to the unique sugar alcohol release profile of the TA-chewing gum (**Figure 2**), the compressibility of these samples over a 12 min mastication period was monitored. The data for one panelist is illustrated in **Figure 4**. Similar findings were also reported for the other two panelists, data not shown. Overall, chewing gums made with TA or MCT were found to be statistically softer (based on "total work done") than the chewing gum samples made without a solvent or with PG. There was no statistical difference in softness between the

Table 2. Plasticity Index Values of Gum Base Samples Made with PG, TA, MCT, or NFS

treatments	plasticity index (PI)[a] (range 0−1)
NFS	0.97 A
PG	0.83 B
TA	0.76 C
MCT	0.98 A

[a] Average of six replicates; different letters (A–C) indicate a statistically significant difference between samples ($\alpha = 0.05$).

Table 3. Sorbitol Concentration in the Saliva during Mastication of Chewing Gum Samples Made with PG, TA, MCT, or NFS at the 30 and 70 s Time Points

	sorbitol concentration (mg/mL saliva)[a]	
treatment	30 s	70 s
NFS	103.5 A	96.8 A
PG	99.8 A	96.2 A
TA	81.0 B	120.7 B
MCT	109.6 A	101.1 A

[a] Different letters (A−B) indicate a statistically significant difference between samples ($\alpha = 0.05$); average of triplicate for all three panelists.

TA- or MCT-chewing gums during the initial phase (at the 30 or 60 s time point) for all three panelists. Consequently, a softer textured chewing gum did not necessarily result in the faster release of the sugar alcohol (e.g., the MCT formulated chewing gum; **Figure 2**). This suggested the softness of the sample as predicted by compression tests was not a good indicator of the flavor release potential of chewing gum at constant chewing rates. Based on the similar textural properties yet different sugar alcohol release rates of the TA and MCT chewing gum samples, it was hypothesized that TA was primarily plasticizing or softening the gum base polymeric continuous phase (polyvinyl acetate and so on) whereas MCT was mainly softening the lipid or discontinuous phase of the gum base material. Therefore, based on the solubility properties of these two solvents, two different mechanisms of softening the chewing gum were proposed. Triacetin would be predicted to be more soluble with polyvinyl acetate (similar structure—like dissolves like) and likewise MCT (more lipophilic) would be more soluble with the lipid/wax component of the gum base. We suspected that a more plasticized continuous phase would be softer or more flexible and would be anticipated to entrap the discontinuous phase sugar alcohol more efficiently during consumption which resulted in the delayed release of the sorbitol phase as reported in **Figure 2**.

To support the hypothesis that TA primarily softened the continuous polymeric phase, whereas MCT softened the discontinuous lipid phase of the chewing gum, the influence of flavor solvent on gum base plasticity was determined. The plasticity index value for the gum base samples mixed with an equivalent load of flavor solvent, in comparison to the chewing gum composition, are reported in **Table 2**. The TA-gum base statistically had the lowest plasticity index value indicating the addition of TA resulted in a continuous phase which was more elastic and more flexible for deformation when compared to the other solvents. In contrast, the addition of MCT did not influence the gum base plasticity as this sample was not statistically different from the plasticity value for the gum base with NFS. This supported the premise that, although both TA and MCT resulted in softer chewing gum (**Figure 4**), the mechanisms each solvent altered the chewing gum texture was unique. MCT did not plasticize the continuous polymeric phase

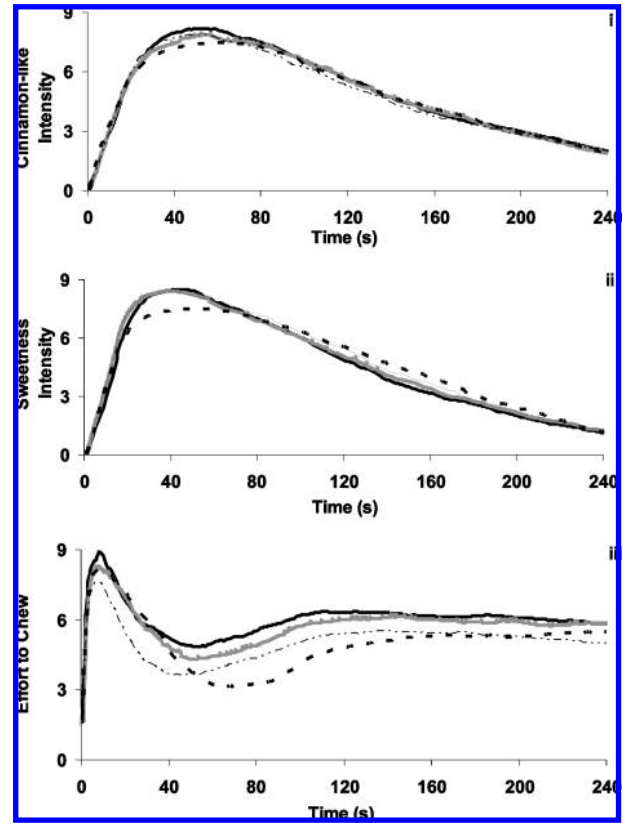

Figure 5. Sensory time-intensity analysis of (i) cinnamon-like aroma, (ii) sweetness, and (iii) effort to chew of chewing gum samples made with NFS (—), PG (zig-zag line), TA (- -), or MCT (— - - ·); scale 0−15, average of 9 panelists.

and likely is softening the lipid or discontinuous phase in the chewing gum, whereas TA softened the polymeric continuous phase of chewing gum. The more plasticized (flowable) gum base for the TA sample was therefore correlated to the slower release properties of the sugar alcohol phase during mastication in chewing gum.

To further investigate the role of the instrumental findings in this study on flavor perception, a time-intensity sensory analysis profile was determined for the sweetness, cinnamon-like aroma, and "effort to chew" attributes from the different solvent-type formulated chewing gum samples. The results are shown in **Figure 5**. The perceived sweetness of the TA chewing gum was significantly lower in maximum intensity (I_{max}) whereas the time to maximum intensity (T_{max}) was found to be significantly higher (**Table 4**) in comparison to the other chewing gum samples. This is in agreement with the slower sorbitol release profile reported from the instrumental analysis (**Figure 2**). However, the maximum concentration of sorbitol released from the TA chewing gum was not observed to be lower than other chewing gum samples (**Figure 2**), which indicated the lower rate of sorbitol release was related to the decreased sweetness perception and not to the absolute concentration of the sorbitol reported in the mouth. The I_{max} for the cinnamon-like aroma of the TA chewing gum sample was statistically lower than the other samples, whereas the T_{max} for the TA chewing gum sample was significantly higher than the MCT chewing gum. These findings are in contrast to the instrumental breath analysis which found flavor solvent-type or addition did not influence the aroma release profile these samples (**Figure 1**). This indicated that for the TA chewing gum, the noted slower sugar alcohol release profile was correlated to the suppression of the cinnamon-like aroma

Table 4. Sensory Parameters of Chewing Gum Samples Made with PG, TA, MCT, or NFS

	sensory parameters[a]					
	sweetness		cinnamon-like aroma intensity		effort to chew	
treatments	max. intensity (I_{max})[b]	time to max. intensity (T_{max}) [s]	max. intensity (I_{max})[b]	time to max. intensity (T_{max}) [s]	min. intensity (I_{min})[b]	time to min. intensity (T_{min}) [s]
NFS	9.06 A	39.56 A	8.83 A	49.44 AB	4.43 A	62.11 A
PG	9.06 A	37.41 A	8.67 A	50.04 AB	3.76 B	68.89 A
TA	8.34 B	47.74 B	8.15 B	59.44 A	2.69 C	69.11 A
MCT	9.07 A	39.11 A	8.69 A	43.85 B	3.15 C	48.85 B

[a] Different letters (A–C) indicate a statistically significant difference between samples ($\alpha = 0.05$); average of nine panelists [b] a 15 cm line scale was used for evaluations (0 = none, 15 = very high).

perception. This observation was consistent with previous research that reported the perception of mint flavor intensity in a minted flavored chewing gum was correlated to the sucrose concentration, suggesting taste-aroma interactions or that sweetness level influenced the perception of the aroma intensity (*1*).

The influence of flavor solvent-type on the perceived chewing gum textural properties (effort to chew, **Figure 5**) was also analyzed and was in general agreement with the analytical textural measurements (**Figure 4**). Overall, chewing gum with TA and MCT were found to be softer or required less effort to chew versus with PG or NFS (I_{min} and T_{min}, **Table 4**). Although the analytical textural measurements reported that the chewing gum samples made with TA and MCT were comparable in softness (**Figure 4**), the sensory data showed the level at which the softness was perceived in the first 2 min were statistically different ("effort to chew" in **Figure 5**). Gums with MCT had the lowest ratings for "effort to chew" around 40 s whereas for the gums with TA had the lowest ratings around 70 s, again suggesting different plasticizing affects of these flavor solvents on the gum base (**Table 4**). The "effort to chew" analysis was not, however, correlated to the perceived cinnamaldehyde flavor intensity.

In summary, the flavor properties of chewing gum were influenced by the addition of TA but not by the addition of the other flavor solvents, PG or MCT. The TA formulated chewing gum had a lower sugar alcohol release rate during mastication and likewise was reported to have a suppressed sweetness and aroma intensity. Although both TA and MCT resulted in softer chewing gum, the TA sample uniquely plasticized the continuous phase of the gum base. Therefore, the influence of flavor solvent on the flavor properties of chewing gum was not correlated to the chewing gum softness but rather to plasticization of the polymeric phase of the gum base.

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