Research Article

Textural and Sensorial Characterization of Selected Fruit and Vegetable Purees as Impacted by the Addition of Microcrystalline Invert Sugar (MIS) as a Texturizing Agent

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Abstract | This study assesses how low concentrations of microcrystalline invert sugar (MIS) improve the perception of a better mouthfeel when added to tropical fruit and vegetable purees. The study evaluated sensory (organoleptic) attributes corresponding to the textural qualities measured by a texture analyzer. A commercial MIS (size ≤ 40 microns) was added to the puree of five arbitrarily selected fruits (strawberry, banana, and apple) and vegetables (beetroot and carrot) at three different levels (3%, 5%, 7% w/w). A Texture Analyzer determined hardness, adhesiveness, cohesiveness, gumminess, and chewiness. The difference among the treatments was analyzed using standard deviation and ANOVA ($p \leq 0.05$). To evaluate the various samples, a focus group of twelve panelists on the same day of preparation using a 9-point hedonic scale for seven attributes: viscosity, airiness, graininess, consistency, smoothness, adhesiveness, and color intensity. MIS concentrations at 3-5% were not easily detectable by panelists. However, 7% MIS products were more desirable to panelists than the control. Based on Textural Profile Analysis, MIS products required less force to masticate and swallow than the control. Overall, MIS has been shown to improve puree stability, desired viscosity levels, improved consistency, and a palatable product compared to control samples. The Principal Component Analysis (PCA) of TPA and sensory attributes showed that viscosity (F1) and airiness (F2) were the most dominating predictors, explaining the relationship by more than 80%. Subsequently, a linear correlation between actual and predicted values of sensory scores. High R^2 values of 0.73 to 0.99 confirmed the relationship between the predictors (viscosity and airiness) and the rest of the sensory attributes. It is demonstrated that MIS is potentially beneficial in preparing product formulation utilizing high moisture, high fiber, and viscous products of intermediate nature.

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Introduction

Cane sugar ($C_{12}H_{22}O_{11}$) has various functional properties besides enhancing sweetness and flavor in a food matrix. These include, but are not limited to, the interaction with starch and protein molecules during the cooking process, tenderizing by absorbing water, delaying starch gelatinization, caramelization, preservation, and delaying discoloration in frozen fruits (Annon, 2016; Carter *et al*., 2013). Sugars provide a range of characteristics, more than just sweetness. It also enhances the flavor, color, texture, structure and shelf-life of foods (Clemens *et al*., 2016). Due to sugar's various functional properties, it can achieve many desired functions in food preparation not found in other sweeteners, such as color and flavor formation, texture, fermentation, and preservation (Clemens *et al*., 2016; Goldfein and Slavin, 2015). Like sugars, sweeteners improve the palatability of food but may differ in nutritional value. Nutritive sweeteners have been shown to improve food products' palatability, like granulated and fine sugars, except they add caloric value to food products (GMA, 2014). However, inverted sugars, when incorporated with starches, increase the apparent viscosity in samples and reduce food products' water activity and humidity, thus extending their shelf life (Polypetchara and Gohtani, 2018; Naponucena *et al*., 2019).

Common types of sugars are granulated fine and extra-fine sugar, confectioner's sugar, and *invert* sugars. Specialty sugars are prepared by physical milling and blending into a second ingredient for a specific purpose. Most commercially available specialty sugars are proprietary; the US and international patents protect their formulations. The generic MIS is a mixture of very fine sugar crystals composed mainly of sucrose and *invert* sugar. Traditionally, MIS has been widely used in the baking and confectionery industries. In the bakery industry, MIS sugar reduces or entirely removes the grittiness feeling. Grittiness feeling is associated with particle size greater than 44-micron. Co-crystallization is a process used to produce MIS, comprised of 95% sucrose and 5% *invert* sugars (US Patent, 1972, No. 3,642,535; Chen and Chou, 1993).

Bakke's *et al*. (2018) findings indicate that 1.8% –2% of additional sucrose significantly reduced bitterness for multiple vegetable puree samples. Panelists preferred the purees because they masked the fruits and vegetables bitterness and had positive health effects, such as regulating glucose levels (Carter *et al*., 2013). Further studies reported desirable texture, less sedimentation, and decreased pH during storage (Ahmad *et al*., 2000; Durrani *et al*., 2010). However, Balestra *et al*. (2011) reported that purees without adding a stabilizing agent during storage will exhibit inconsistent physicochemical and rheological changes.

The inclusion of fine powdered MIS retains, holds, and evenly distributes moisture and will not sediment and separate into phases during storage. As a result, products appear smoother with creamy texture than the control samples (Chen and Chou, 1993). MIS's ability to completely dissolve in cold water also makes it an excellent flavor enhancer in water-based purees, fats, and oil emulsions (Chen and Chou, 1993).

Several researchers have reported using various forms of sugars to improve the overall stability of food products. The hypothesis is that adding sugars in low concentrations to fruit pulps of varying carbohydrate levels should improve consumers' overall perception of flavor and mouthfeel. Adding low sugar concentrations into kiwifruit and banana purees led to better flavor retention than the samples without sugar (Marsh *et al*., 2006)). Marsh *et al*. (2006) also reported adding 11 to 14% sugar into kiwifruit and banana, which retained more flavor volatiles than control samples. Ahmad *et al*. (2000) studied the effect of added sugar at various concentrations on guava pulp's storage stability. Guava pulp with 3-5% addition of granulated sugar retained better flavor, desirable texture, and less sedimentation than samples with only an organic preservative. A decrease in pH occurred during the storage of fruit pulp (apple, orange, melons, dates) was attributed to the formation of free acids and pectin hydrolysis (Ahmad *et al*., 2000; Durrani *et al*., 2010). It is important to note that fruits can vary significantly in size, color, organic acid content, and sugar concentration, even when cultivated under the same conditions (Ikegaya *et al*., 2019). Fruits like strawberries or grapes can have varying concentrations of total soluble solids. Small fruits vulnerable to dehydration around maturity will have a positive water dilution, resulting in a high soluble sugar concentration (Dai *et al*., 2016). Balestra *et al*. (2011) studied the physicochemical and rheological properties of peach, apple, and pear during storage as an intermediate product. Products showed inconsistent behavior without adding any stability agent, such as sugar.

The current literature review indicates evidence of the positive impact of added sugar in fruit puree; however, studies have yet to address textural attributes of tropical fruits and vegetables used as intermediate products in the food service and hospitality industry. Therefore, textural properties must be characterized to expand this specialty sugar (MIS) use in viscous products of varying levels of natural sugars, fiber, starch, and moisture content. Specifically, after adding MIS, the study aimed to evaluate changes in textural attributes using a sensory panel and objective assessment of selected fruits and vegetable purees.

Materials and Methods

Materials and equipment

Food grade Microcrystalline Invert Sugar (MIS), produced by Domino Foods Inc. (South Bay, FL USA) in fine powder form (size ≤ 40 microns) was obtained from a local grocery store.

Fruits and vegetables

Five types of fruit and vegetable products (strawberries, bananas, apples, beetroot, and carrots) were selected to demonstrate the effect of MIS. The samples were not intended to compare to each other. Instead, the intent was to observe the MIS interaction with the food matrix in different types of fruits and vegetables.

Preparation of spice broth

The spice broth was separately prepared using equal parts of star anise, pink peppercorn, and whole cloves wrapped in a muslin cloth and soaked in boiling water for 45 minutes.

Sous vide food processor

Sous vide processor, manufactured by Cambro®., USA, was used to heat up the water in a 20-L plastic container with a lid. An opening of about 4 inches was created by cutting the lid to insert the sous vide heater.

Sample preparation and processing steps

The MIS powder (size ≤ 40 microns) was added to the puree of 5 subjectively selected fruits and vegetables at three different levels (3%, 5%, 7% w/w). These include strawberries, bananas, apples, beetroot, and carrot. The samples were washed, peeled, cut, de-seeded, and quartered before vacuum packaging. All samples were cooked using water immersion (Sous vide, Cambro®., USA) at a constant temperature of 82.2°C until the products were soft enough to be pureed. Depending on the hardness of the raw products, immersion time varied. For example, strawberries and bananas were immersed for 15 and 20 minutes. Apples, carrots, and beetroot were immersed for 30, 60, and 90 mins. At the end of the immersion cycle, the individual contents and a spiced broth were emptied into a Vitamix Blender on 'High' for 30-60 seconds and then transferred to a clear plastic quart container. Once cooked, each sample was diluted with the spice broth utilizing a Vitamix blender on High for 30-60 seconds. After adding the MIS (3%, 5%, 7% w/w) to each sample, the samples were blended for 30 seconds with a hand immersion blender to ensure the proper distribution of MIS in the puree. A focus group of 12 panelists evaluated samples on the same day of preparation.

Sample analysis

Samples were divided into two sets. One set of the samples was stored at 4-8°C to visually monitor changes such as settling out, and phase separation changes in total soluble solids (°Brix), and pH were monitored using a refractive meter (4320 ATAGO Refractometer, USA), and a pH meter (ATAGO Digital pH meter, USA) for seven days. The other set of samples was subjected to texture measurements using a texture analyzer and sensory analysis, as depicted below.

Texture measurement

Using a Texture Analyzer (XT Plus, Stable Microsystems Inc. UK), Texture Profile Analysis, described by Bourne (2002), was developed. Briefly, a force-deformation curve in the back-extrusion cell was constructed to define the texture of the purees. The test cell filled with samples at a speed of 1 mm/sec (Figure 3A) had a 35mm plunger inserted into the samples. Two F-D compression curves (Figure 3A and B) calculate hardness (g), adhesiveness (g.sec), cohesiveness, gumminess, and chewiness (Bourne, 2002). All samples were run in triplicate.

Sensory analysis

The other set of samples was evaluated by a focus group of twelve untrained panelists on the same day of preparation. A 9-point hedonic scale for seven attributes: Viscosity (flow from a spoon);

airiness (light or dense feeling); graininess (feel of loose particles); consistency (feeling lumpy mass); smoothness (absence of all particles); adhesiveness (sticky feeling to palate); and color intensity, with 1 representing desirable mouthfeel and 9 representing undesirable mouthfeel. These attributes were perceived by a focused group discussion based on the mouthfeel, appearance of products, and consumer appeal.

Data analysis

One-way analysis of variance (ANOVA, p≤0.05) was calculated to establish a statistical difference among different treatments. XL-STAT software constructed the correlation matrix and Principal Component Analysis (PCA) plots. Briefly, a correlation matrix was developed at α = 0.05 significance level between textural attributes obtained by objective assessment using a Texture Analyzer and sensory analysis by human subjects. The resultant coefficients determined the strength and direction of the linear relationship between variables. Subsequently, the PCA was carried out to identify the principal components in all treatments that capture the most variance in the data.

Results and Discussion

Figure 1A-E summarize the changes in pH after adding MIS. There was no significant difference due to varying levels of MIS addition (p ≤ 0.05). The pH remained generally stable, indicating a stabilizing effect of MIS compared to control samples. However, the pH slightly decreased due to adding spice broth with a pH of 3.0, except for banana puree, which increased from 3 to 3.5 due to pH equilibrium dynamics. Statistical analysis revealed no significant difference between pH values among all treatments for a particular puree product (Figure 1).

Figure 2 A-E show changes in TSS (°B) after adding MIS. In most cases, TSS increased with the addition of MIS, except in strawberry, apple, and carrot puree. This is probably due to the water-binding effect of MIS being a hygroscopic agent. In statistical significance terms, there was no significant difference (p >0.05) in TSS after the addition of MIS in any sample (Figure 2).

To observe the product stability, all samples were stored at a refrigerator temperature of 6±2°C on the third day of storage; control samples started to show water leaching and a sign of phase separation.

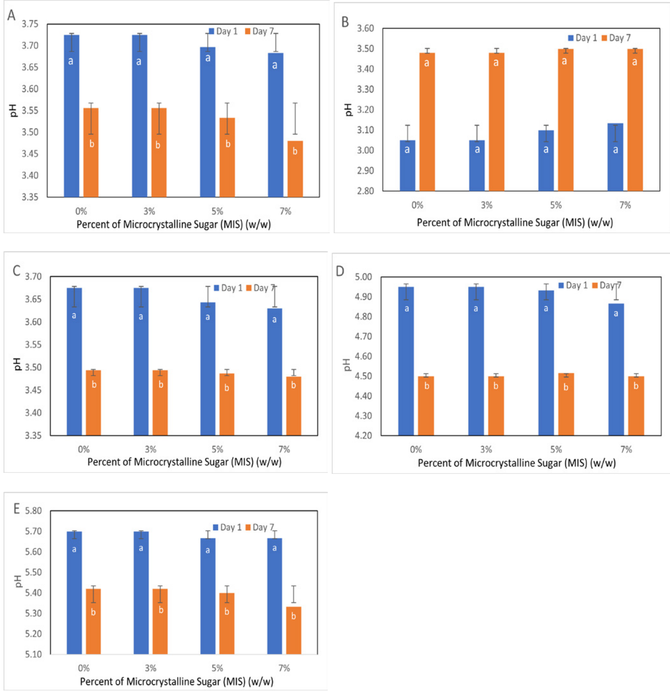

Figure 1: *Change in pH after the addition of MIS in (A) strawberry (B) banana (C) Apple (D) beetroot, and (E) carrot. A two-factor ANOVA (95% C.I) was conducted where factor 1 was MIS levels (0, 3, 5 and 7%) and factor 2 was day 1 and day 7. Factor 1 (MIS level): no significant difference was observed. Factor 2 (storage days): the statistical difference was observed in all samples except for (B) banana.*

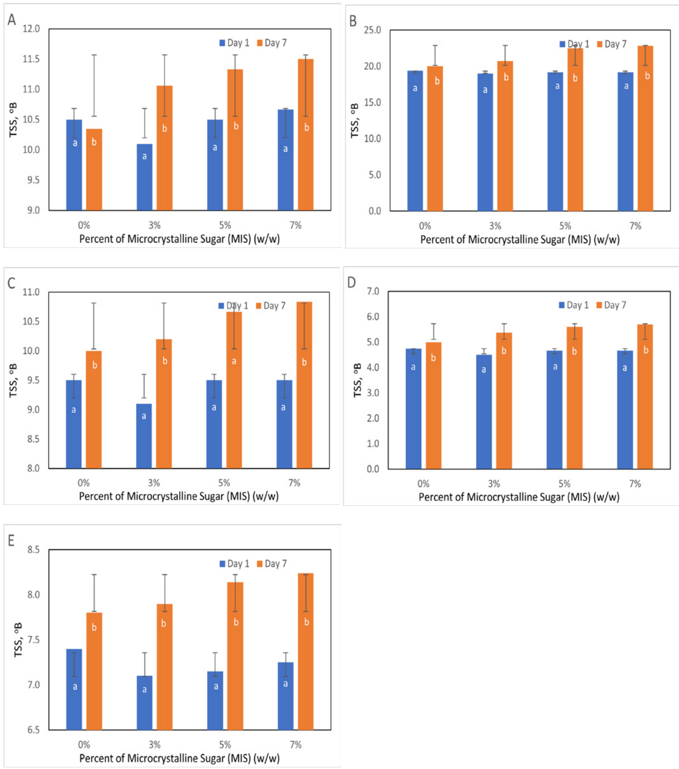

Figure 2: *Change in total soluble solids after the addition of MIS in (A) strawberry, (B) banana (C) Apple (D) beetroot, and (E) carrot. A two-factor ANOVA (95% C.I) was conducted where factor 1 was MIS levels (0, 3, 5 and 7%) and factor 2 was day 1 and day 7. Factor 1 (MIS level): no significant difference was observed. Factor 2 (storage days): the statistical difference was observed in all samples.*

In contrast, products with added MIS exhibited no quality changes for up to 7 days. As noted in Figures 1 and 2, there was no significant difference between all treatments over 7 days regarding pH and TSS. This is important as MIS helped maintain the fresh-like attributes of purees. The fine powder of MIA has a larger surface area, which stabilizes the purees without affecting TSS, pH, and taste, such as sweetness. Such an attribute is important for intermediately products to be used in recipes such as pie filling. We noticed a mild preservation effect due to the addition of MIS. While total soluble solids (°Brix) increased initially due to MIS's addition, they remained stable afterward. In addition, pH remained stable during four days of storage compared to control samples (Figure 1). Due to the ongoing hydrolysis of dissolved components, such as pectin and natural sugars, the TSS of control samples slowly increased. However, MIS added samples with 2-3 °Brix higher solid content due to adding MIS while retaining the same TSS level during storage (Figure 2). Similarly, Balestra (2011) observed that purees with a high soluble solids content and water activity would most likely exhibit a high °Brix value.

The increase in the soluble solids content during storage observed in this work may be due to the acid hydrolysis of polysaccharides, mainly starch and pectin. Changes in pH may have been due to the combined effects of leaching and oxidation of organic acids in the biological matrix. These results are consistent with a previous study conducted on guava puree (Ahmad *et al*., 2000). One possible explanation for the increase in TSS could be a Maillard reaction, which occurs if there was an increase in pH value (Balestra *et al*., 2011).

No visible spoilage indicators were found in seven days of storage of samples with 7% added MIS at 4-8°C as compared to control samples. Significantly, it was unexpected for products to last for an extended period, according to the standard processing procedure.

MIS functions to balance flavors and mouthfeel as it increases the viscosity (thickness) of purees, which helps impart a thick, creamy mouthfeel. The fruits and vegetables with added MIS that have high sugar content and low fiber content have a higher consistency level when blended. Thus, the higher the percentage of MIS, the more consistent the puree. This study confirms the potential of MIS in improving puree stability, desired viscosity levels, improved consistency, and a palatable product compared to control samples.

Table 1: *Mean sensory score of textural attributes of selected products (n=12).*

Products	Treatments	Sensory attributes						
		Viscosity	Airiness	Graininess	Consistency	Smoothness	Adhesiveness	Color
Strawberry	0%	7.2±0.22^{a}	6.0±0.18^{b}	3.0±0.09^{a}	3.2±0.10^{a}	3.2±0.10^{a}	7.4±0.22^{b}	5.2±0.16^{a}
	3%	5.8±0.17^{a}	4.6±0.14^{a}	3.2±0.10^{a}	3.0±0.09^{a}	2.6±0.08^{a}	4.4±0.13^{a}	3.0±0.09^{b}
	5%	5.8.17^{a}	3.8±0.11^{a}	2.6±0.08^{a}	2.4±0.07^{a}	2.4±0.07^{a}	4.2±0.13^{a}	6.8±0.20^{c}
	7%	6.0±0.17^{a}	3.6±0.11^{a}	2.6±0.08^{a}	2.4±0.07^{a}	2.4±0.07^{a}	4.2±0.13^{a}	7.0±0.21^{c}
Banana	0%	4.8±0.14^{a}	5.0±0.15^{a}	5.8±0.17^{a}	4.8±0.14a	5.0±0.15^{a}	3.6±0.11^{a}	3.8±0.11^{a}
	3%	3.8±0.11^{a}	3.6±0.11^{a}	3.6±0.11^{b}	4.4±0.13a	3.2±0.10^{b}	2.6±0.08^{a}	5.8±0.17^{b}
	5%	3.2±0.10^{a}	3.4±0.10^{a}	2.6±0.08^{b}	4.2±0.13a	2.4±0.07^{b}	2.6±0.08^{a}	5.6±0.17^{b}
	7%	3.4±0.10^{a}	3.0±0.09^{a}	1.8±0.05^{c}	3.2±0.10a	2.2±0.07^{c}	2.6±0.08^{a}	5.6±0.17^{b}
Apple	0%	4.2±0.13^{a}	4.6±0.14^{a}	4.6±0.14^{a}	4.8±0.14^{a}	5.0±0.15^{a}	3.4±0.10^{a}	5.2±0.16^{a}
	3%	5.2±0.16^{a}	4.4±0.13^{a}	6.0±0.18^{b}	5.2±0.16^{a}	6.4±0.19^{a}	2.2±0.07^{a}	4.8±0.14^{a}
	5%	4.2±0.13^{a}	4.4±0.13^{a}	5.6±0.17^{b}	5.0±0.15^{a}	6.2±0.19^{a}	2.2±0.08^{a}	5.2±0.16^{a}
	7%	4.6±0.14^{a}	4.0±0.12^{a}	5.6±0.17^{b}	4.2±0.17a	5.0±0.15^{a}	3.0±0.09^{a}	6.8±0.20^{b}
Beetroot	0%	6.3±0.19^{a}	5.7±0.17^{a}	4.8±0.14^{a}	6.0±0.06^{a}	5.8±0.17^{a}	7.0±0.21^{a}	6.2±01.9^{a}
	3%	6.1±0.18^{a}	5.6±0.16^{a}	3.0±0.09^{b}	2.6±0.07^{b}	2.0±0.06^{b}	6.0±0.18^{b}	5.4±0.16^{ab}
	5%	5.8±0.17^{a}	5.4±0.17^{a}	2.8±0.08^{b}	2.6±0.18^{b}	2.2±0.07^{b}	5.6±0.17^{b}	5.2±0.14^{ab}
	7%	4.1±0.12^{b}	5.5±0.17^{a}	2.6±0.08^{b}	2.8±0.08^{b}	3.0±0.09^{b}	3.6±0.11^{c}	4.6±0.13^{b}
Carrots	0%	6.2±0.19^{a}	4.0±0.12^{a}	4.6±0.17^{a}	5.6±0.09^{a}	4.8±0.14^{a}	6.0±0.18^{a}	4.2±0.12^{a}
	3%	5±0.15^{b}	3.4±0.11^{a}	2.8±0.08^{b}	2.6±0.17^{b}	3.0±0.09^{b}	3.4±01.0^{b}	4.0±0.11^{a}
	5%	4.8±0.14^{b}	3.8±0.10^{a}	3.6±0.10^{b}	3.2±0.08^{b}	3.4±0.10^{a}	3.2±01.0^{b}	3.6±0.09^{a}
	7%	2.6±0.08^{c}	2.4±0.07^{b}	2.0±0.06^{b}	2.0±0.06^{b}	2.2±0.07^{b}	2.8±0.08^{b}	3.0±0.13^{a}

**Mean values with the same superscript letter among treatment groups were not significantly different at $p \leq 0.05$*

Links Researchers

Sensory analysis

MIS-added samples were visibly different from control samples. Panelists preferred the viscosity of MIS strawberry, MIS banana, and MIS carrot, and the degree of likeness increased as the concentration of MIS rose from 3% to 7%. All mean scores (n=12) were significantly different. Contrarily, MIS apple and MIS beetroot viscosity were not easily differentiated by panelists. Products appeared lighter (increased airiness) with the addition of MIS. Graininess mouthfeel improved in all products except apple, possibly due to apple's un-hydrolyzed pectin and hard starch material. Adhesiveness (undesirable sticky feeling in mouth) decreased in all samples with an increased concentration of MIS. The addition of MIS visibly increased natural color intensity, and products appeared brighter (Table 1). However, the apple appeared darker due to browning and mild sugar caramelization. It was evident that the sweetness of samples due to added MIS might have influenced panelists' ability to score textural attributes objectively, as in the case of banana and apple.

Texture profile analysis

On the other hand, the instrumental analysis yielded a significant difference among all the parameters from control and MIS-added samples ($p \leq 0.05$). Figure 3A shows a typical TPA plot, which calculates textural parameters. MIS-added products were softer, less adhesive, and required less force to swallow (calculated as total force represented by the area under the force-deformation curve). Slight variations to this trend were observed; however, products with 7% MIS appeared more desirable than control, 3%, and 5% MIS samples. The strawberry puree was an exception, which did not yield meaningful results due to too low viscosity, represented by the force-deformation behavior. The natural seed grits present in the puree may have interfered with the penetrating probe to yield inconsistent results. Control and 3% MIS added beetroot and carrot purees were not different (Table 2). Similarly, apparent differences were observed amongst management and MIS-added samples in both gumminess and chewiness. These parameters indicate that MIS samples require less force to masticate and swallow.

Regression analysis between sensory data and texture profile analysis

The related data of linear regression (slope, intercept and R^2) between actual and predicted values are shown in Table 3, depicting that 3% MIS has the highest correlation. This correlates with the study of Ahmed *et al.* (2016), in which the sapodilla jam sample with the lowest sugar concentration had the highest sensory attributes. The regression results are graphically represented in Figure 4A, B. The sensory score of the MIS concentrations (Table 4) shows that viscosity, airiness, consistency, and adhesiveness between strawberry, banana, apple, and beetroot purees are not significantly different. However, as MIS concentration increases, the purees' color differs significantly; this color is consistent in carrot purees. Compared to the textural attributes of the products. Banana, apple, beetroot, and carrot purees with 5% and 7% MIS differ significantly based on adhesiveness (Table 4). Still, panelists did not recognize the change based on the mean sensory score. For all samples, the Texture Analyzer chewiness, gumminess, and hardness levels exhibit significant changes as the concentration of MIS increases. However, these changes are not picked up by the panelists mean sensory scores, as indicated by their responses to smoothness and consistency, which do not differ significantly.

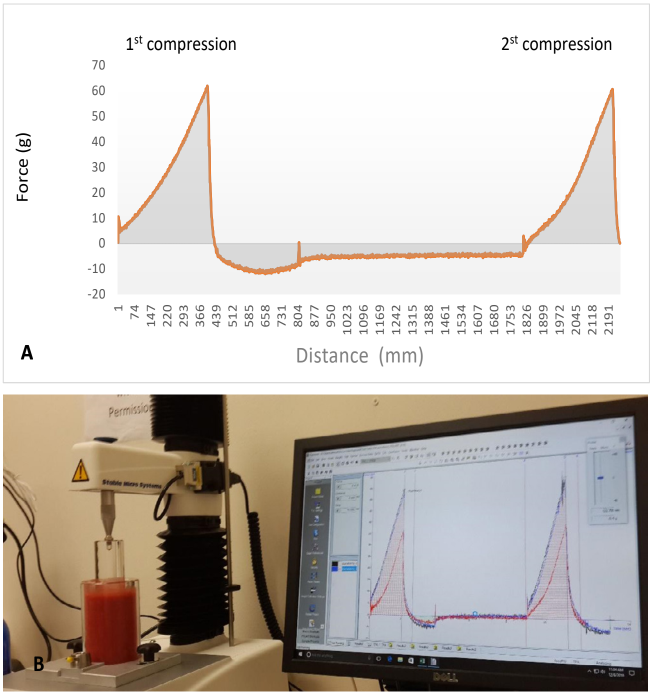

Figure 3: *A typical TPA plot to determine textural attributes using Textural Analyzer (A). Texture Analysis of Strawberry Puree (B). Hardness (g): the peak force of the first compression of the product. Adhesiveness: force * time travelled by plunger in the second compression. Cohesiveness: measured as the area of work during the second compression divided by the area of work during the first compression. (Area 2/Area 1). Gumminess: Hardness *Cohesiveness (g/mm²), Chewiness: Gumminess*Springiness (g.s).*

Table 2: *Textural attributes of selected products obtained through texture analyzer (n=30).*

		Hardness	Adhesiveness	Cohesiveness	Gumminess	Chewiness
		g	g. sec			
Strawberry	0%	0%	59.79±4.07[a]	-3.88±0.27[a]	0.94±0.06[a]	56.40±2.82[a]
	3%	3%	55.80±3.79[b]	-8.22±0.58[b]	0.92±0.06[a]	51.78±3.11[b]
	5%	5%	53.80±3.66[c]	-3.16±0.22[a]	0.93±0.06[b]	50.31±3.02[c]
	7%	7%	51.43±3.50[d]	-3.23±0.23[a]	0.92±0.06[b]	47.53±2.85[d]
Banana	0%	0%	173.77±10.43[a]	-76.78±5.37[a]	0.59±0.04[a]	102.78±6.17[a]
	3%	3%	124.46±7.47[b]	-78.27±5.48[b]	0.79±0.06[b]	98.81±5.93[b]
	5%	5%	110.48±6.63[c]	-68.89±4.82[c]	0.75±0.05[c]	82.70±4.96[c]
	7%	7%	120.84±7.25[d]	-72.77±5.09[d]	0.81±0.06[d]	97.63±5.86[d]
Apple	0%	0%	97.25±5.34[a]	-38.83±2.72[a]	0.91±0.05[a]	88.37±4.42[a]
	3%	3%	77.34±5.93[b]	-13.18±0.92[b]	0.70±0.06[b]	57.45±3.45[b]
	5%	5%	86.01±6.08[c]	-24.56±1.72[c]	0.92±0.04[a]	79.43±4.77[c]
	7%	7%	88.13±5.05[d]	-24.02±1.68[c]	0.96±0.06[a]	84.50±5.07[d]
Beetroot	0%	0%	73.15±5.34[a]	-54.66±3.83[a]	0.79±0.06[b]	57.80±3.47[a]
	3%	3%	73.65±5.38[b]	-56.13±3.93[b]	0.83±0.06[a]	61.19±3.67[b]
	5%	5%	61.92±4.52[c]	-41.94±2.94[c]	0.83±0.06[a]	51.27±3.08[c]
	7%	7%	53.43±3.90[d]	-37.53±2.63[d]	0.78±0.04[a]	41.46±2.49[d]
Carrot	0%	0%	93.00±9.34[a]	-46.81±3.28[a]	0.71±0.03[a]	65.53±3.93[a]
	3%	3%	95.50±9.55[b]	-52.78±3.69[a]	0.74±0.06[b]	70.72±4.24[b]
	5%	5%	69.53±6.95[c]	-32.80±2.30[b]	0.85±0.06[c]	59.35±3.56[c]
	7%	7%	61.54±6.15[d]	-17.82±1.25[c]	0.90±0.05[d]	55.48±3.33[d]

**Mean values with the same superscript letter among treatment groups were not significantly different at $p \leq 0.05$*

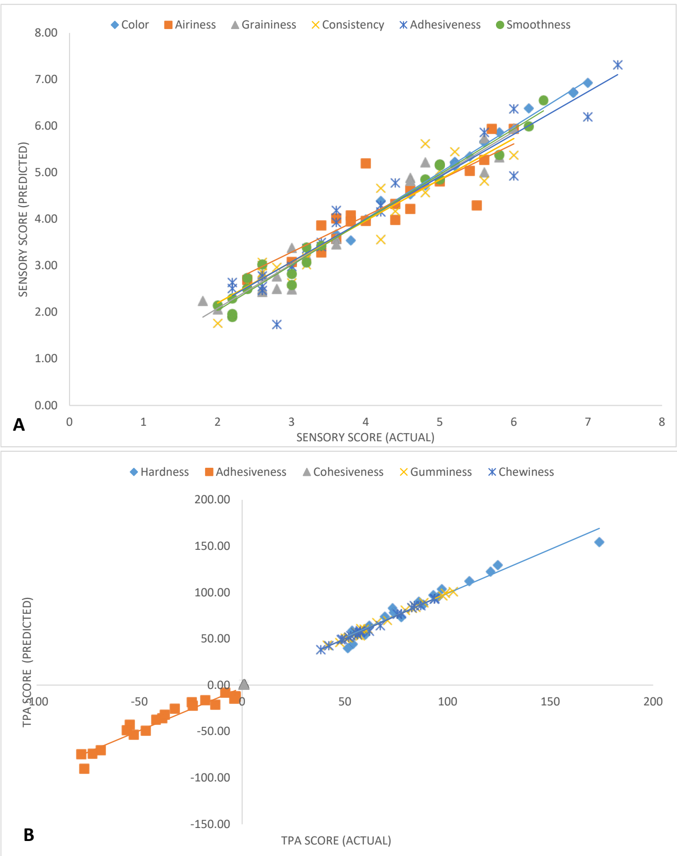

Figure 4: *Correlation between actual vs. predicted sensory score (A) an TPA Score (actual) (B).*

Table 3: *Slope and coefficient of determination (R^2) between actual vs. predicted sensory score.*

Sensory	Slope	y-Intercept	R^2
Viscosity	0.795	1.011	0.795
Airiness	0.735	1.141	0.735
Graininess	0.919	0.296	0.919
Consistency	0.873	0.469	0.873
Smoothness	0.931	0.248	0.931
Adhesiveness	0.789	0.841	0.788
Color	0.992	0.037	0.992
TPA			
Hardness	0.948	4.331	0.948
Adhesiveness	0.925	-2.802	0.925
Cohesiveness	0.967	0.026	0.967
Gumminess	0.991	0.556	0.992
Chewiness	0.993	0.455	0.993

Note: $y = ax + b$

Principal component analysis

Figure 5A and B show the projection of the principal components of the texture profile and sensory analysis of MIS variables. All MIS variables showed a strong positive correlation between sensory graininess, smoothness, and consistency. Overall, as the concentration of MIS increased the percentage of variance (POV) decreased. The sensory analysis showed that panelists could easily detect the difference between control and MIS-added samples. However, differences among samples were not detectable in banana and apple samples at any MIS level. PCA plots also revealed that 3% and 5% MIS samples exhibited the highest correlation between sensory and subjects' preferred TPA. Yet, the 7% samples have the lowest correlation.

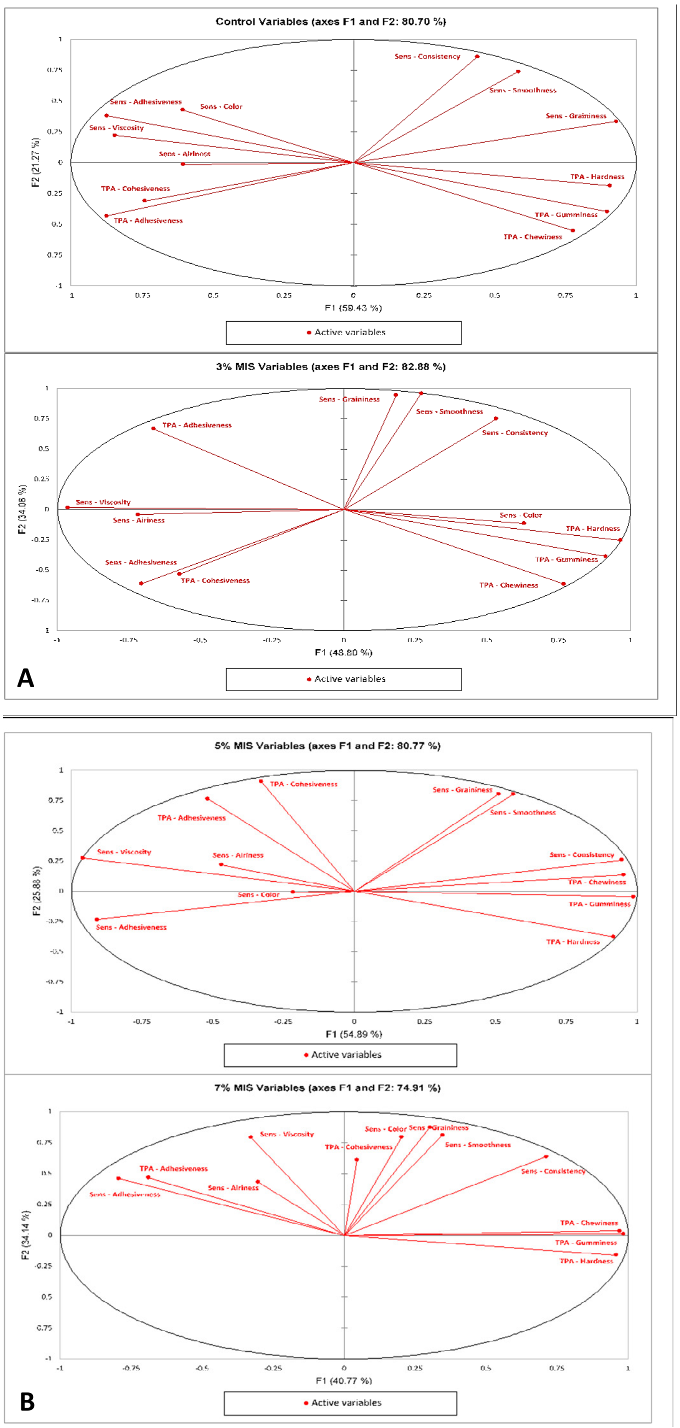

Figure 5: *From top to bottom: control 3% MIS (A) and 5% MIS (B) variables. Sens: sensory and TPA: Textural Profile Analysis.*

For the sensory score, F1 (viscosity) and F2 (airiness) explained >80% of the relationship at all levels except for the 7% MIS, which yielded about 75% relationship. Nevertheless, the predictors had enough prediction ability. The loading factors were used to predict the sensory score and further validated. Figure 4A shows a linear correlation between actual and predicted values of sensory scores. High R^2 values in the range of 0.73 to 0.99 and a slope close to 1.00 confirmed the relationship between F1 (viscosity) and F2 (airiness) and the rest of the sensory attributes.

Similarly, Hardness and Adhesiveness were the main predictors of TPA. Figure 4B shows a high correlation between predicted vs. actual TPA score (>0.99) and slope close to 1.

Table 4: *Correlation matrix of textural and sensory attributes of selected products.*

Variables	**Sensory Attributes**		
Control	**Sens - Viscosity**	**Sens- Graininess**	**Sens- Adhesiveness**
TPA - Hardness		0.829	-0.765
TPA - Adhesiveness	0.573	-0.989	
TPA - Cohesiveness		-0.829	
TPA - Gumminess	-0.882	0.723	-0.953
TPA - Chewiness	-0.927	0.524	-0.98
3% MIS			
TPA - Hardness	-0.918	-0.671	0.661
TPA - Adhesiveness	0.566		-0.717
TPA - Cohesiveness			
TPA - Gumminess	-0.901	-0.595	0.645
TPA - Chewiness	-0.794	-0.549	
5% MIS			
TPA - Hardness	-0.977	0.79	-0.71
TPA - Adhesiveness	0.684		
TPA - Cohesiveness	0.551		
TPA - Gumminess	-0.955	0.943	-0.851
TPA - Chewiness	-0.883	0.932	-0.912
7% MIS			
TPA - Hardness		0.572	-0.738
TPA - Adhesiveness			0.631
TPA - Cohesiveness	0.627		
TPA - Gumminess		0.663	-0.728
TPA - Chewiness		0.649	-0.708

**Values in bold are different from 0 with a significance level alpha =0.05. Sens = sensory data and TPA = Texture Profile Analysis.*

Correlation matrix

The correlation matrix compared sensory and textural attributes. As shown in Table 4, the viscosity was most negatively, but strongly, correlated against gumminess, chewiness, and hardness (r= -0.977, r= -0.955), seen through control (r= -0.882) and 5% MIS samples (Table 4). Textural adhesiveness is negatively correlated with graininess. Consistency is significant regarding gumminess and chewiness, which are positively correlated. Gumminess and chewiness show a negative correlation against sensory adhesiveness. Sensory graininess was positively correlated against gumminess and chewiness (r= 0.943, r= 0.932) for 5% MIS samples and is negligible for all other MIS variables. For sensory adhesiveness and TPA chewiness, 5% MIS samples were also negatively correlated (r= -0.912).

Conclusions and Recommendations

The results provide sufficient evidence that MIS functions to balance flavors and improve mouthfeel as it increases the viscosity (thickness) of purees, which helps impart a thick and creamy mouthfeel. When blended, the fruits and vegetables with added MIS with high sugar and low fiber content have a higher consistency level. Thus, the higher the percentage of MIS, the more consistent the puree. This study confirms the potential of MIS in improving puree stability, desired viscosity levels, improved consistency, and a palatable product compared to control samples. This research explored possible uses of MIS as a texturizing agent in puree products. While it was clear that MIS has a noticeable impact on textural parameters, low concentrations of 3% and 5% were only sometimes detectable through panelists subjective assessment. Similarly, MIS concentration at 7% was the most desirable formulation; however, sweetness influenced the likeness's degree. This potential subjective evaluation discrepancy was removed by instrumental analysis that yielded reproducible results confirming MIS's role in texture improvement. This study's results confirm a potential use of MIS in preparing product formulation of high moisture, high fiber, and viscous products of intermediate nature. Future studies could expand on establishing MIS concentration in other food products, according to the product's final usage and consumer preference.

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Human subjects were recruited after the approval of the Institutional Review Board (IRB). The authors declare no conflict of interest. There is no financial interest involved in this study. The author agrees to the terms and conditions of the Sarhad Journal of Agriculture.

Novelty Statement

This study finds microcrystalline invert sugar (MIS) enhances mouthfeel in tropical fruit and vegetable purees, with 7% concentration proving most desirable to panelists, while improving texture and stability.

Conflict of interest

The authors have declared no conflict of interest.

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