Running Title: Serving Temperature Viscosity

Serving Temperature Viscosity Measurements of Nectar and Honey-thick Liquids

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Abstract

This study reports the viscosity (thickness) of nectar- and honey-thick liquids measured at a typical serving temperature. Centipoise (cP) measurements were compared for three products (two starch and one gum-based thickener) mixed with five beverages that set for three time intervals (manufacturer recommended time to thicken, 10 and 30 minutes). The serving temperature of the cold beverages was 4º C (water, apple juice, orange juice, and milk), and the hot beverage (coffee) was measured at 70º C. Statistical analysis showed that all factors interacted with one another, meaning that the viscosity of a nectar- or honey-like liquid varies greatly depending on the type of thickening agent and beverage combination in relation to the amount of time its thickens. Simply Thick, the gum-based thickener, typically produced samples that were the least viscous but they maintained a more consistent level of thickness over time. Serving temperature results are contrasted with viscosity measurements collected at room temperature, showing variable thickening patterns especially related to the type of thickening agent.

Key Words: viscosity, thickened liquids, temperature

Complex issues surround the use of thickened liquids in dysphagia management including aspects of their preparation and service delivery. Current practice patterns suggest that many facilities make use of thickened liquids that require some type of preparation such as a powder or gel-product mixed with a beverage to produce a target level of thickness.[1] Achieving an appropriate level of consistency is complicated by a number of factors including insufficient production information on labels about thickening properties, vague guidelines about their preparation, as well as staff compliance in their service delivery.[2-4] Additionally, thickening products alter flavor and texture characteristics of the base beverage and produce different thickening patterns over time.[5-8] Variability across products and within products is of added concern since clinical judgments of thickness are not reliable.[9]

Temperature also affects thickness of liquids. Bourne[10] noted that the "viscosity of fluids is highly temperature dependent" (p. 235). The effect often is described by the Arrhenius relationship which indicates that the natural logarithm of the viscosity of most liquids shows a direct inverse relationship to temperature.[11] This inverse relationship (thickness decrease with temperature increase) has been documented with both liquid and semi-solid consistencies.[12-14] Additionally, some products (such as water) have a preferred temperature that impacts its consumption.[15] Temperature manipulation often is a consideration related to aspects of swallowing. For example, a cold bolus is applied to enhance the immediacy of a pharyngeal swallow response and recognition of the bolus in the mouth for some patients with dysphagia.[16,17] Other patients demonstrate improved esophageal function in response to hot water swallows.[18]

The viscosity measurement of a thickened liquid is influenced by a number of factors including its temperature.[19] The National Dysphagia Diet Task Force[20], recognizing the importance of a standard temperature in order to compare various measurments, used 25 degrees Celsius (similar to room temperature) and shear rate of $50s^{-1}$ in developing viscosity ranges for thin, nectar-like, honey-like, and spoon-thick liquids published in the National Dysphagia Diet (NDD). Viscosity or rheological profiling of thickened liquids commonly is reported at room temperature.[4, 5, 21] Garcia et al.[5] applied the NDD guidelines in order to compare the thickness of product/liquid combinations under standardized conditions and also to the ranges suggested by the NDD. The results showed that room temperature "thickness" was highly dependent on the type of thickening agent, the beverage it was mixed with, and the amount of time the sample was allowed to thicken. However, room temperature or a standard of 25º C is much different than the serving temperature of a many beverages that are served refrigerated (about 4º C) or hot (about 70º C for coffee). Although room temperature guidelines provide a useful comparison of products, it could result in patients being given thickened beverages that are unpleasant for reasons unrelated to thickness, such as consuming room temperature coffee or milk.

The effect of serving temperature on the service delivery of thickened liquids has received less attention. Reports suggest that modified beverages (serving temperature) do not match the viscosities of barium products provided to patients during instrumental assessment of swallowing.[22, 23] Additionally, there is little information about potential differences between thickening products or variability within a product line for cold and hot thickened liquids. Although Garcia et al.[5] showed the differences in viscosity of products at room temperature, those differences may or may not be similar for thickened beverages prepared at a typical serving temperature and consumed by patients with dysphagia over the course of a meal (e.g., 30 minutes or so). Variations of this magnitude (e.g., actual serving temperatures of 4º and 70º C) are thought to impact viscosity, but it is unknown if thickened liquids prepared with a cold beverage reflect a predictable increase in viscosity and decrease in viscosity if mixed with hot beverages. This relationship may be questionable, especially for hot liquids, due to physicochemical changes in the starch used in some thickening agents. Those changes, known as gelatinization, produce swelling of the starch and are the process by which starch-based puddings or gravies thicken as they are heated.[24] The effect likely would result in thicker, rather than the expected thinner, beverages when some thickening agents are mixed with a hot beverage like coffee. The research questions for this study were:

1. Are there changes in viscosity measurements when samples prepared at their serving temperature thicken for different periods of time (manufacturer recommended time to thicken, 10 and 30 minutes) for nectar or honey-like consistencies?
2. Are there differences within a product line related to the type of liquid it is mixed with for nectar and honey-like viscosity measurements?
3. Are there differences across products in their viscosity measurements for nectar or honey-like consistencies prepared at their serving temperature?
4. How does the viscosity of thickened beverages measured at serving temperature compare to similar thickened beverages measured at room temperature?

Method

Materials

Two starch-based thickeners (Thick & Easy® and Thicken Up®) and 1 polysaccharide gum-based thickener (Simply Thick®) were tested. Although label information indicated a modified food starch (corn or maize) for the starch-based thickeners, there was no specification as to the type of modification. Maltodextrin, which provides bulk, viscosity, and a smooth mouth feel[25], was listed as a second ingredient for Thick & Easy. Xanthan gum was the thickening agent for

Simply Thick. The five beverages included water, Mussleman's apple juice, Tropicana no-pulp orange juice, 2% milk, and Folger's decaffeinated coffee.

Sample Preparation

Preparation procedures were detailed previously in Garcia, Chambers, Matta, and Clark[5] and replicated in this study in order to compare the viscosity measurements of the same product/liquid combinations and to compare the results from this study (serving temperature) to those reported at room temperature at identical thickening times. Basic procedures are restated, but more details can be found in Garcia et al.[5].

Samples were prepared in a laboratory setting using similar procedures for nectar-like and honey-like consistencies. The volumetric amount of each 4-ounce beverage was converted to weight (g) to make sure that each sample was exact in its amount of beverage. Product label information was followed in determining the amount of thickener to produce a nectar-like or honey-like consistency for a 4 fl. oz. beverage. The volumetric amount of each thickening agent was first measured in grams and averaged across five trials to ensure that the same amount of thickener was added to each beverage unless product information indicated differently (e.g., Thicken Up).

A total of three separate samples were prepared for each product and liquid combination in a 600 mL beaker. The thickening agent was slowly poured and stirred into the liquid and continuously stirred for 20 seconds using a Cimarec 2 (Barnstead/Thermolyne, Dubuque, IA) magnetic stirring device set at a constant speed. Simply Thick was shaken vigorously for the same time interval. Three timers were then set in order to measure a portion of the same sample at each of the three setting times. The first timer was set according to the manufacturer recommended time to thicken (described as "standard"). This ranged from immediate (Simply

Thick) to 3 minutes (Thicken Up). The second timer was set for 10 minutes and the third timer for 30 minutes.

Instrumentation & Measurement Procedures

Viscosity measurements were made with a Brookfield RVDV-II+ viscometer (Brookfield Engineering, Middleboro, MA), meeting the American Society for Testing and Materials (ASTM) standards for evaluating the properties of thickened liquids in the shear rate range from 0.1 to $50s^{-1}$. [26] Temperature was controlled using a Brookfield water bath. The serving temperature of thickened liquids prepared with water, apple juice, milk, and orange juice was 4 degrees Celsius (±2º C), a typical temperature for refrigerated products, and the serving temperature of coffee was 70 degrees Celsius (±2º C), a temperature representative of coffee that has been allowed to cool slightly for drinking after brewing. A different portion of the same 4 oz. sample was measured at the 3 designated time periods and calculated for a shear rate of $50s^{-1}$. Because the amount of setting time was an important factor to control, some minor temperature variations were anticipated. Preliminary tested showed that temperature variations of ± 1 and 2 degrees Celsius did not appreciably affect the measured viscosity of the samples as the resulting measurements were within the instrument's accuracy (± 1%) and repeatability (± 2%).

Statistical Analysis

Serving temperature data were analyzed using analysis of variance with Product and Liquid as the two between factors and Time as the repeated within subject factor. Samples prepared to nectar and honey-like levels were analyzed separately, both using viscosity measurement (in centipoise, cP) as the dependent variable. The Fisher's protected least significant difference (LSD) procedure was applied using an alpha level of .05 to determine statistically significant differences.

Results

Statistical analysis of serving temperature data showed a significant three-way interaction for both nectar-like consistency ($p < .0001$) and honey-like consistency ($p < .0001$). The interaction of factors indicates that any comparison of thickening product depends on the beverage it is mixed with and time it thickens, the effect of time depends on the product/beverage combination, and comparison of beverage depends on the type of thickening product and thickening time. Figure 1 illustrates the mean viscosity of each product/liquid combination at standard (T1), 10 minutes (T2), and 30 minutes (T3) of setting time for each level of thickness. High values represent more viscous samples and low values represent thickened liquids that measured less viscous.

<<Figure 1 about here>>

Nectar-like Samples at Serving Temperature

Comparisons within thickening products (time & liquids considerations). Each product was compared for changes in viscosity measured at the three time periods and in relation to its base beverage. Thick & Easy and Thicken Up (starch-based products) showed a tendency to produce samples that thickened from standard to 10 minutes of setting time (Figure 1). Significant contrasts, contained in Table 1, verified this pattern statistically. The exceptions were Thick & Easy water and Thicken Up water and apple juice samples. The starch-based products mixed with orange juice, milk, and coffee remained significantly more viscous at 30 minutes compared to standard. One sample, Thicken Up mixed with milk, continued to thicken given a longer setting time (significantly more viscous at 30 minutes compared to 10 minutes). Simply Thick showed no statistically significant change in viscosity for any beverage across the three setting times with the exception of 2% milk. In that case, the mean measurement at 10 minutes (111 cP) was less ($p < 0.05$) than the mean measurement at the standard thickening time (165 cP).

Previous research[5] showed that some thickening products do not provide the same degree of thickening across a variety of beverages at room temperature. Thus, another aspect of the current study was to determine if a product provided consistent thickening when mixed with different types of liquids at serving temperatures. The differences are highlighted in Figure 1, with statistically significant contrasts reported in Table 2. Simply Thick showed the fewest differences in viscosity measurements across beverages at any time interval, with no statistically significant differences at 10 and 30 minutes of setting time. Thick & Easy and Thicken Up reflected a number of differences across liquid type. For the two starch-based thickeners, orange juice, milk, or coffee resulted in the most viscous measurements at each time to thicken.

<<Tables 1 & 2 about here>>

Comparisons among thickener products for each thickening time. Product samples for each liquid combination were compared to one another at standard, 10-minutes, and 30-minutes of setting time, with significant differences ($p < 0.05$) reported in Table 3. The three products showed some similarity in viscosity measurements for apple juice, yielding no significant differences at the standard thickening time. Product differences were most apparent when comparing the results for orange juice, milk, and coffee. Although the most viscous were associated with the starch-based products, their pattern of thickening varied across hot and cold beverages. Thicken Up resulted in more viscous samples of nectar milk and coffee; whereas, Thick & Easy samples of orange juice were thicker than Thicken Up samples at each time. Simply Thick yielded the least viscous samples across the three time periods.

<<Table 3 about here>>

Honey-like Consistency

Comparisons within thickening products (time & liquid considerations). Viscosity measurements for honey-like samples are illustrated in Figure 1 for each product/liquid combination at each time to thicken. The significant contrasts over time are contained in Table 4. Simply Thick did not appreciably change in thickness across the three time intervals ($p > 0.05$). A similar pattern occurred with Thicken Up honey-like samples of water and apple juice. In contrast, milk and coffee were more viscous by 10 minutes and orange juice became significantly more viscous by 30 minutes of setting time. Thick & Easy showed a consistent pattern of thickening. All of the samples measured at 10 minutes were thicker than portions of the same sample measured at their standard preparation time ($p < 0.05$). Additionally, four of the five beverages (all but apple juice) were significantly more viscous at 30 minutes than they were at 10 minutes of setting time.

Different patterns emerged within a product line, especially for the gum versus starch-based thickeners at 10 and 30 minutes (Table 5). Simply Thick (gum-based) viscosity measurements of water, apple juice, orange juice, milk, and coffee were statistically similar to one another at 10- and 30-minute intervals. Product variability was more apparent for the two starch thickeners. Thick & Easy samples prepared with orange juice, milk, and coffee were more viscous than water and apple juice at 10 and 30 minutes of setting time. Thicken Up samples prepared with milk or with coffee were the most viscous by time 3 (30 minutes).

<<Tables 4 & 5 about here>>

Product comparisons for each thickening time. Table 6 contains product comparisons and significant differences, if any, at each time interval for honey-like consistencies. Thick & Easy produced the most viscous samples at 10- and 30 minutes in comparison to Thicken Up and

Simply Thick, with the magnitude of difference (increase in viscosity) depending of the particular beverage. Although Thicken Up measured similar to Simply Thick for honey-like samples of water, apple juice, and coffee, the products varied from one another with milk and coffee viscosity measurements.

<<Table 6 about here>>

Comparison of Serving and Room Temperature Viscosity Measurements

The same preparation procedures made it possible to compare the serving temperature results from this study to values previously reported for these same three products at room temperature.[5] The averages (in centipoise) are contrasted in Figure 3 for nectar- and Figure 4 for honey-like consistencies for each product. The results showed that the starch-based thickeners mixed with hot coffee (70º C) resulted in a much more viscous sample than with the sample prepared at room temperature (25º C), especially by 30 minutes of setting time. Simply Thick showed the opposite pattern, in that nectar and honey-thick liquids prepared with hot coffee were less viscous than the mean values of thickened coffee measured at room temperature. Most of the thickened liquids prepared with water, orange juice, apple juice, or milk (cold beverages maintained at 4º C) were more viscous at the cold versus room temperature; however, there were exceptions such as nectar-thick orange juice (Thick & Easy) and honey-like orange juice (Thick & Easy) and 2% milk (Thicken Up).

<<Figures 3-4 about here>>

Discussion

Any time a patient's diet is modified such as with the use of thickened liquids, there are a number of factors that may influence its implementation. This study examined the impact of two serving temperatures (4º C for water, apple juice, orange juice, or milk and 70º C for coffee) for three products (two starch-based and one gum-based thickening agent) mixed with beverages that thickened for varying lengths of time (manufacturer recommended time to thicken, 10 and 30 minutes). The method of preparation and measurement was replicated in order to compare changes, if any, to the viscosity values reported at 25º C (room temperature).[5]

The results from this study reflected distinct differences in the thickening properties of some starch- and gum-based products, particularly when the setting time of a thickened liquid was extended to 10 or 30-minutes at its serving temperature. Simply Thick (gum-based product) nectar- and honey-like samples generally maintained a consistent level of thickness across a 30-minute time interval, which suggests that patients who may not drink the product immediately would still consume the beverage at a reasonably constant thickness. The two starch-based thickeners, especially Thick & Easy, showed a tendency to thicken over time, especially for honey-like product liquid combinations. This result was consistent with room temperature data, which also showed a tendency for some starches to continually absorb liquid (thicken) with time.[5] Although Thicken Up samples increased in thickness, the pattern was not as common as what occurred with Thick & Easy. In comparing product label information, the primary distinction in ingredients was that Thick & Easy listed maltodextrin, while Thicken Up did not identify it as an ingredient. The specific impact of maltodextrins in the tested products is unknown, but it is logical that products containing maltodextrin may behave differently than other products. Maltodextrins often are used to provide bulk and to ensure more even dispersion of ingredients[27-29] and some types have limited thickening capacity and can form weak gels.[30] There was no other product information shared by the manufacturers that clarified ingredients or specifics about the nature of starch modification that might shed light on the results. Lack of product label information is a concern when analyzing the effects of thickening agents and aspects of their service delivery.[4]

One important consideration for any thickening product is repeatability. That is, its ability to produce a similar level of nectar- or honey-like thickness for serving temperature beverages consumed by patients with dysphagia (e.g., thickened water vs. thickened juice). Simply Thick produced the most repeatable level of thickness across beverages. Although Thicken Up, the only product to include a specific beverage usage chart, recommended the same amount of thickener (1 tablespoon, 1 teaspoon) for nectar-like milk, water, and coffee, viscosity results at serving temperature showed that milk and coffee samples were always more viscous than water. Moreover, by 10 and 30-minutes of setting time, milk was more viscous than coffee. Orange juice always resulted in the most viscous nectar- or honey-thick sample for Thick & Easy by 10- and 30 minutes of setting time. Orange juice contains pectins, ions, acids, and solids, [31, 32] which may enhance its bonding characteristics with the particular starch modifications of these products in a way that results in more significant thickening over time.

An essential aspect of this study was that thickened liquids were tested at serving temperature, which meant that four thickened beverages (water, apple juice, orange juice, & milk) were measured at a temperature similar to refrigeration (4º C), while thickened coffee was measured "hot" (70º C). In relation to the starch-based thickeners, starch suspensions usually follow the Arrhenius relationship in that an increase in temperature generally causes fully gelatinized starch suspensions to decrease in viscosity.[11] In contrast, the heating of starch dispersions usually causes the starch granules to swell and further gelatinize and viscosity increases as demonstrated in the viscosity measurements of thickened coffee. The mean values of nectar- and honey-thick coffee were statistically similar or more viscous than some cold beverages (thickened water, apple juice) especially at 10 and 30-minute test intervals. Most gum solutions also decrease in viscosity when temperature is increased. Xanthan gum is an exception with little change in viscosity occurring in temperature ranges between 0º C and 100º C, [33] which would help explain the statistical similarity of coffee measurements to the other beverages prepared with Simply Thick.

The effect of temperature also was apparent in comparing serving to room temperature findings from previous research[5] (Figures 3-4). Thickened coffee at the serving temperature was less viscous in comparison to room temperature (as predicted by the inverse relationship between temperature and liquids) for Simply Thick. A much different pattern for coffee occurred with the starch-based products where the mean measurements at serving temperature reflected samples that were quite viscous. The viscosity of starch dispersions increases dramatically once it reaches its gelatinization temperature, [34] which helps explain the magnitude of increase in viscosity when hot coffee was mixed with starch products. In this study, the difference between serving and room temperature was 45º C (70-25 degrees). A similar effect for a starch product was reported for an 8-degree difference in temperature (37 vs. 25 degrees C)[35] where thickened apple juice at 37º C was more viscous and the rate of change (increase in viscosity) was greater for the higher temperature over an extended period of time.

With regard to “cold” thickened liquids, almost all of the gum-based and the majority of starch-based samples were more viscous in comparison to similar beverages measured at room temperature; however, there did not appear to be a characteristic pattern in the amount of increase across temperatures. The instances in which the serving temperature sample was less viscous (reflecting a percentage decrease) typically occurred with 2% milk and in comparing “standard” thickening times across temperatures. Overall, viscosity measurements for orange juice and milk produced the most viscous samples of thickened liquids for the starch-based products regardless of temperature (25 or 4 degrees C), reaffirming the importance of the base liquid and how its various components such as ions, proteins, and acids interact with thickening agents.[5] The 2% milk in this study behaves somewhat differently from other liquids because it contains fat, which can interfere with the uptake of liquids into starch granules. This is especially true at cold temperatures where milk fat molecules are close to their solid state and may physically block gaps in the starch structure, which would result in reduced swelling of the starch granule and lower viscosity. The effect would be expected to increase with higher fat milk or dairy products and, in theory, could be almost eliminated with the use of skim or non-fat milk. However, those products were not studied in this research.

Clinical Implications, Considerations, & Limitations

The challenges faced by clinicians who recommend thickened beverages for their patients are numerous. Simply stated, thickening agents vary in their thickening properties and additional variability is created by the base liquid (components like pectins, ions, and acids), especially when mixed with starch products. Although the viscosity of Simply Thick (gum-based product) remained fairly stable across beverages and thickening times, nectar and honey-like samples were typically less viscous, which may contribute to different concerns about swallowing safety. These thickened beverages may not achieve the patient's target level of thickness; a concern further heightened by suggestions that service delivery providers may be inattentive to the amount of beverage (add more than the recommended amount) or mixing procedures (stir it vs. vigorously shake it) resulting in thickened beverages that are even less viscous.[37] In this situation, the benefit of a product's repeatability may be negated if samples are consistently too thin for safe swallowing.

Another important clinical implication from this study is the interaction of thickening agents (starch vs. gum-based) with the temperature of beverages. Although a common assumption is that “cold” thickened liquids are more viscous than hot or room temperature beverages, this was not the case for coffee samples prepared with the two starch-based products (Thick & Easy and Thicken Up), which also represent the most commonly applied thickening agents in a recent survey of practice patterns.[1] The starch-based products mixed with coffee always produced more viscous samples than coffee samples prepared at room temperature (25º C). It is reasonable that some patients with dysphagia may be provided thickened coffee that is much more viscous than intended, especially as it sits for 10 or more minutes.

Conversely, there are limitations to the clinical application of these findings. One such factor is that samples were measured at the same temperature (4º or 70º C) across the three setting times in order to compare the mean viscosity values to one another using experimental controls. In a typical mealtime setting, this would not be the case as a thickened liquid could naturally “warm” or “cool” during the course of its consumption. Subtle gradations in temperature were not examined in this study, but should be a consideration for future investigations. Another consideration is that the test results are based on single point viscosity measurements at one shear rate, whereas, the natural flow of a thickened beverage in the mouth may be quite variable.[36] The three products measured in this study were previously submitted to extensive sensory analysis testing for both nectar and honey-thick liquids for similar beverages.[7] A highly trained sensory analysis panel rated a number of attributes including perceptions about the viscosity of each beverage/product combination at its standard preparation. The product/liquid combinations perceived by the sensory panel as the most viscous, also reflected the highest physical measurements of viscosity in this study, suggesting some relationship between viscometer data to actual human perception. Using trained panelists is a common sensory technique and offers another means (in addition to perceptions of patients and physical measurements) of evaluating the added effects of thickening agents to flavor, texture, and viscosity of thickened beverages.

The results from this study support the need for standardization in thickening products and label information for their clinical application. The differences in viscosity measurements documented across products and within a product line in this study occurred in a controlled test environment in which the amount of thickener and beverage were carefully measured and mixed in a consistent manner. The results do not account for the variability that might be introduced by products that are more difficult to prepare given limited product label information (e.g., becomes lumpy when mixed with certain beverages or should be shaken and not stirred), nor the variability by caregivers who are not formally trained in the preparation of thickened liquids or are noncompliant in some aspect of their service delivery. [1-4] For example, a tendency for staff to add too much thickener is only complicated by using starch products that naturally thicken with more setting time. Clinicians must consider all of these factors in their decision-making about products in the absence of standardization and additional research to know how, if at all, these results relate to practice practices in their own patient care environment. The combination of factors may help explain the substantial percentage of speech-language pathologists (about 67%) who report some use of prethickened products in their practice patterns, [1] even though there is limited information about the viscosity of prethickened products or their ability to produce a repeatable level of thickness across beverage type.

Acknowledgements. This research was supported by a grant from the Kansas Health and Nutrition Fund.

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Table 1

Significant differences ($p < .05$) in viscosity for product/beverage combinations at each time interval for nectar-thick consistency

	Thick & Easy	Thicken Up	Simply Thick
Water	--	--	--
Apple Juice	10 Minutes > Standard	--	--
Orange Juice	10 Minutes > Standard 30 Minutes > Standard	10 Minutes > Standard 30 Minutes > Standard	--
Milk	10 Minutes > Standard 30 Minutes > Standard	10 Minutes > Standard 30 Minutes > Standard 30 Minutes > 10 Minutes	Standard > 10 Minutes
Coffee	10 Minutes > Standard 30 Minutes > Standard	10 Minutes > Standard 30 Minutes > Standard	--

Table 2

Significant contrasts ($p < .05$) within each product at each time to thicken for nectar-thick beverages

	Time 1 (Standard)	**Time 2 (10 Minutes)**	**Time 3 (30 Minutes)**
Thick & Easy			
	OJ > Water, Coffee	OJ > Water, Coffee, Apple Juice, Milk	OJ > Water, Apple Juice, Milk, Coffee
	Milk > Water, Coffee	Milk > Water, Apple Juice	Milk > Water
		Coffee > Water, Apple Juice	Coffee > Water, Apple Juice
Thicken Up			
	Water > Apple Juice, OJ	Water > Apple Juice	OJ > Apple Juice
	Milk > Water, Apple Juice, OJ	Milk > Water, Apple Juice, OJ, Coffee	Milk > Water, Apple Juice, OJ
	Coffee > Water, Apple Juice, OJ	Coffee > Water, Apple Juice, OJ	Coffee > Water, Apple Juice, OJ, Milk
Simply Thick			
	Milk > Water, Apple Juice, Coffee	--	--

Table 3

Product comparisons for nectar-thick beverages at each time to thicken ($p < .05$)

Beverage	***Time 1***	***Time 2***	***Time 3***
Water	Thicken Up > Thick & Easy Thicken Up > Simply Thick	Thicken Up > Simply Thick	Thicken Up > Simply Thick
Apple Juice	--	Thick & Easy > Simply Thick Thick & Easy > Thicken Up	
Orange Juice	Thick & Easy > Simply Thick Thick & Easy > Thicken Up	Thick & Easy > Simply Thick Thick & Easy > Thicken Up Thicken Up > Simply Thick	Thick & Easy > Simply Thick Thick & Easy > Thicken Up Thicken Up > Simply Thick
Milk	Thicken Up > Thick & Easy Thicken Up > Simply Thick	Thicken Up > Thick & Easy Thicken Up > Simply Thick Thick & Easy > Simply Thick	Thicken Up > Thick & Easy Thicken Up > Simply Thick Thick & Easy > Simply Thick
Coffee	Thicken Up > Thick & Easy Thicken Up > Simply Thick	Thicken Up > Thick & Easy Thicken Up > Simply Thick Thick & Easy > Simply Thick	Thicken Up > Simply Thick Thick & Easy > Simply Thick

Table 4

Significant differences ($p < .05$) in viscosity for product/beverage combinations at each time interval for honey-like consistency

	Thick & Easy	Thicken Up	Simply Thick
Water	10 Minutes > Standard	--	--
	30 Minutes > Standard		
	30 Minutes > 10 Minutes		
Apple Juice	10 Minutes > Standard	--	--
	30 Minutes > Standard		
Orange Juice	10 Minutes > Standard	30 Minutes > Standard	--
	30 Minutes > Standard		
	30 Minutes > 10 Minutes		
Milk	10 Minutes > Standard	10 Minutes > Standard	--
	30 Minutes > Standard	30 Minutes > Standard	
	30 Minutes > 10 Minutes	30 Minutes > 10 Minutes	
Coffee	10 Minutes > Standard	10 Minutes > Standard	--
	30 Minutes > Standard	30 Minutes > Standard	
	30 Minutes > 10 Minutes		

Table 5

Significant contrasts ($p < .05$) within each product at each time to thicken for honey-like beverages

	Time 1 (Standard)	**Time 2 (10 Minutes)**	**Time 3 (30 Minutes)**
Thick & Easy			
	Water > Milk	OJ > Water, Apple Juice, Coffee	OJ > Water, Apple Juice, Coffee, Milk
	OJ > Water, Apple Juice, Milk, Coffee	Milk > Water, Apple Juice, OJ	Milk > Water, Apple Juice, Coffee
	Milk > Water, Coffee	Coffee > Water, Apple Juice, Milk	Coffee > Water, Apple Juice
	Coffee > Water, Milk	Apple J> Water	
Thicken Up			
	Water > Milk	Water > Apple Juice	OJ > Apple Juice
	OJ > Water, Apple Juice, Milk, Coffee	OJ > Water, Apple Juice	Milk > Water, Apple Juice, OJ
	Coffee > Water, Apple Juice, Milk	Milk > Water, Apple Juice	Coffee > Water, Apple Juice, OJ
		Coffee > Water, Apple Juice, OJ	
Simply Thick			
	OJ > Water	--	--
	Milk > Water, Coffee		

Table 6

Product comparisons for honey-like beverages at each time to thicken (p < .05)

Beverage	***Time 1***	***Time 2***	***Time 3***
Water	Thick & Easy > Simply Thick Thick & Easy > Thicken Up	Thick & Easy > Simply Thick Thick & Easy > Thicken Up	Thick & Easy > Simply Thick Thick & Easy > Thicken Up
Apple Juice	Thick & Easy > Simply Thick Thick & Easy > Thicken Up	Thick & Easy > Simply Thick Thick & Easy > Thicken Up	Thick & Easy > Simply Thick Thick & Easy > Thicken Up
Orange Juice	Thick & Easy > Simply Thick Thick & Easy > Thicken Up	Thick & Easy > Simply Thick Thick & Easy > Thicken Up	Thick & Easy > Simply Thick Thick & Easy > Thicken Up
Milk	Simply Thick > Thick & Easy Simply Thick > Thicken Up	Thick & Easy > Simply Thick Thick & Easy > Thicken Up Thicken up > Simply Thick	Thick & Easy > Simply Thick Thick & Easy > Thicken Up Thicken Up > Simply Thick
Coffee	Thick & Easy > Simply Thick Thicken Up > Simply Thick	Thick & Easy > Simply Thick Thicken Up > Simply Thick Thick & Easy > Thicken Up	Thick & Easy > Simply Thick Thicken Up > Simply Thick Thick & Easy > Thicken Up

Figure Legends

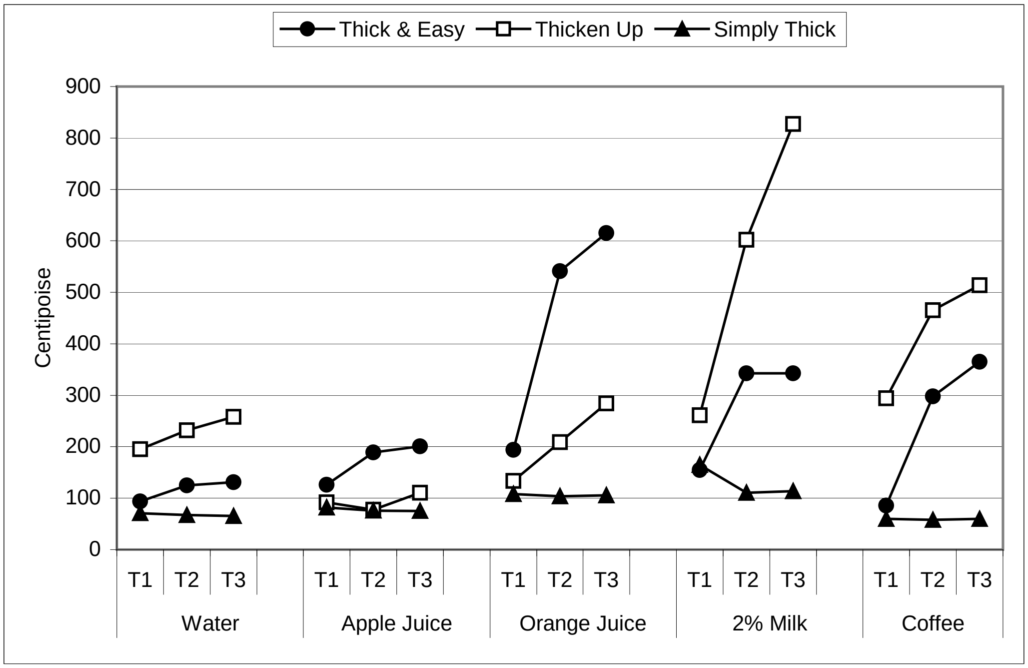
Figure 1. Viscosity measurements in centipoise (cP) for each product and liquid combination at the standard time (T1), 10 minutes (T2), and 30 minutes (T3) to thicken for nectar-and honey-like consistencies

Figure 2. Viscosity measurements in centipoise (cP) for serving and room temperature[5] nectar-like samples at each thickening time

Figure 3. Viscosity measurements in centipoise (cP) for serving and room temperature[5] honey-like samples at each thickening time

Figure 1

Part A. Nectar



Part B. Honey

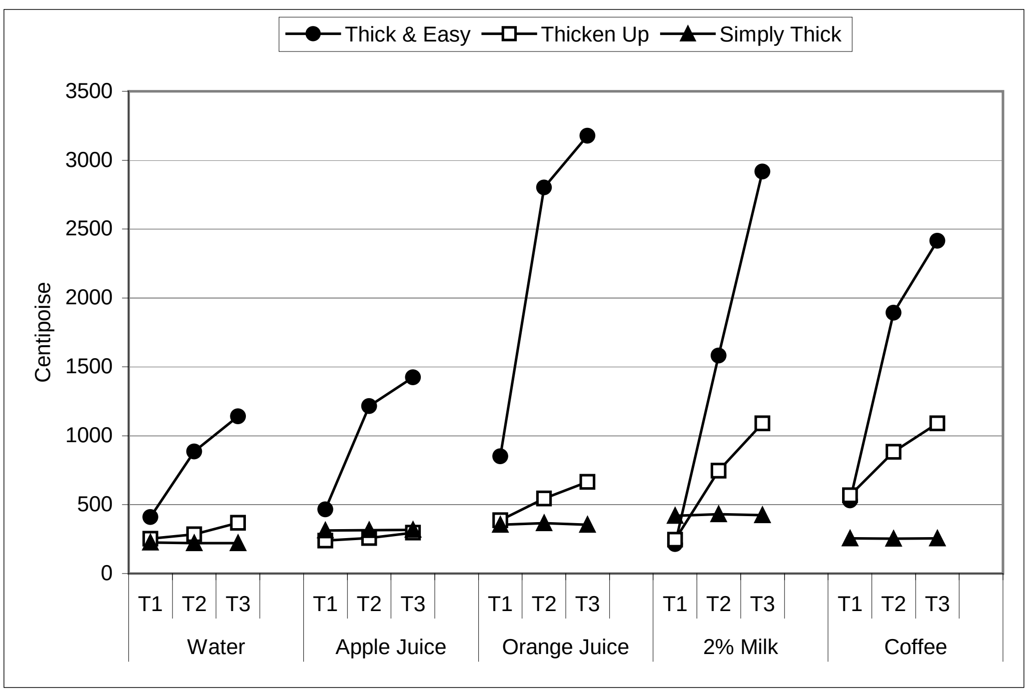


Figure 2—Nectar room/serving

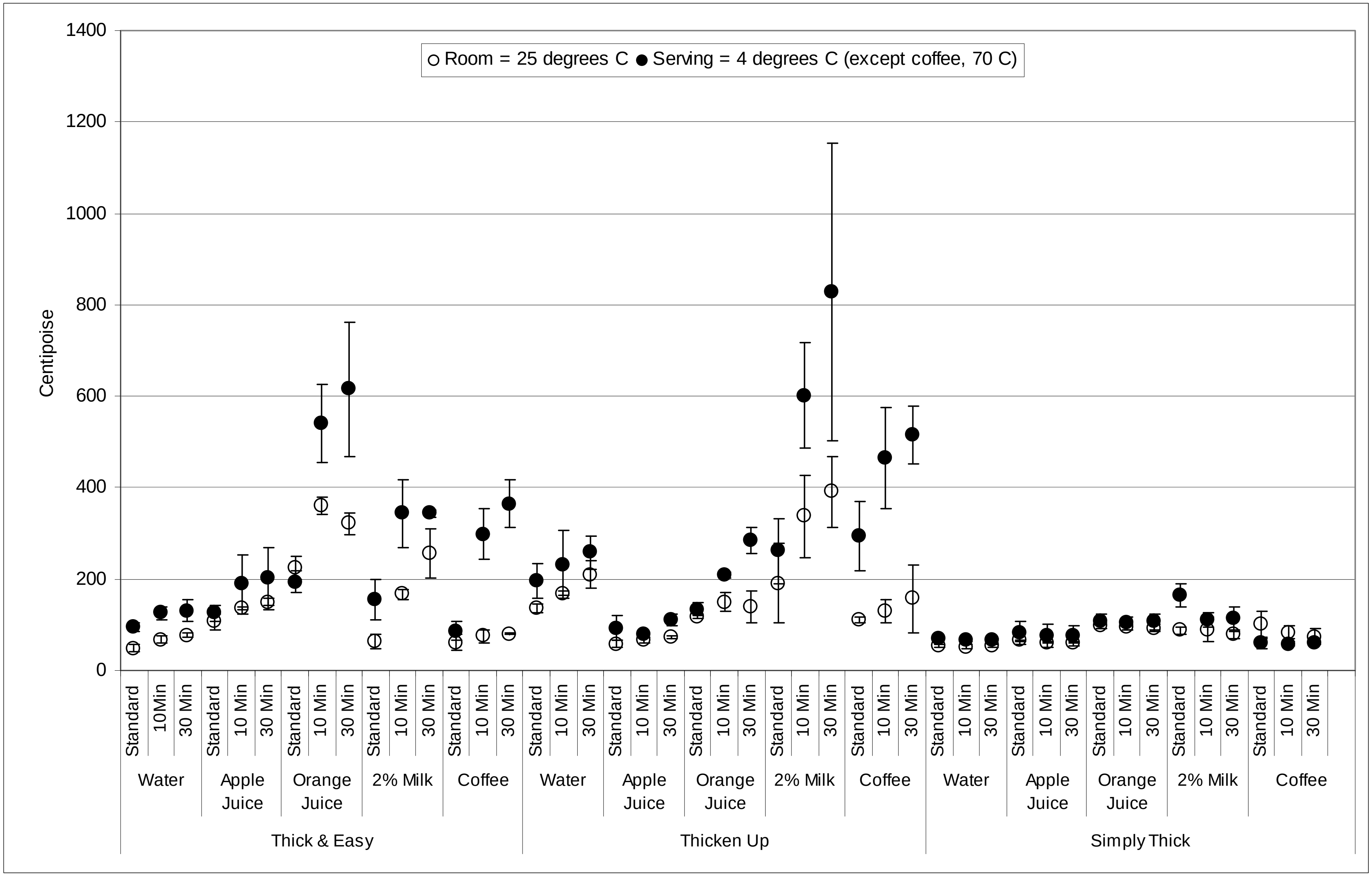


Figure 3—Honey room/serving