ABSTRACT

AN EVALUATION OF CHARACTERISTICS OF BABY FOOD IN CORRELATION TO AN INTERNATIONAL DIET STANDARDIZATION PROTOCOL

by Larson Ann Pax

Purpose: This study evaluated characteristics of baby food in order to increase clinical knowledge about pediatric dysphagia. Important characteristics included viscosity, flow rate, cohesion, adhesion, and temperature. Samples were selected from three popular organic and non-organic brands (Gerber, Beechnut, Earth's Best) and included four manufacturing stages and a variety of ingredients (fruits, vegetables, proteins, and blends). *Methods:* The International Dysphagia Diet Standardization Initiative (IDDSI) and a rheometer was used in order to identify characteristics of baby foods for evaluation. *Results:* A significant difference was found between the brands and between the non-organic and organic brands. No logical progression in manufacturing stages was observed; the highest manufacturing stage possessed the lowest IDDSI level. Reduced temperature of samples yielded an overall increase in IDDSI level and all samples demonstrated shear-thinning behaviors when increased force was applied. *Conclusions:* Findings from the results suggest clear clinical implications including the need for clinicians/caregivers to understand the characteristics of the food presented to the child and how changes in temperature and amount of agitation applied can affect the behavior of the food. Additionally, clinicians/caregivers should know how to implement IDDSI and evaluate foods.

AN EVALUATION OF CHARACTERISTICS OF BABY FOOD IN CORRELATION TO AN INTERNATIONAL DIET STANDARDIZATION PROTOCOL

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CHAPTER I
Introduction

Dysphagia is a broad term used to characterize difficulties with swallowing and is estimated to affect 4% of adults and 1% of children annually (Bhattacharyya, 2014, 2015). The intricate process of deglutition is comprised of a series of interconnected phases: oral, pharyngeal, and esophageal. Proper conjunction of the phases is integral to effective and safe swallowing. When the process is interrupted during the oral and pharyngeal phases, oropharyngeal dysphagia is consequent. Oropharyngeal dysphagia is characterized by issues related to anatomic defects, motor components such as the reduced ability to bite, masticate or clear the bolus, and sensory components as evidenced by a delay in the initiation of the swallow. In adults, oropharyngeal dysphagia may result from numerous etiologies secondary to damage to the central nervous system and/or cranial nerves including, but not limited to stroke, traumatic brain injury, and other neurodegenerative disorders. Diagnoses impacting the head and neck region may also result in dysphagia. In children, oropharyngeal dysphagia also results from a variety of etiologies including complex medical conditions, developmental disabilities, genetic syndromes, structural abnormalities, and neurodevelopmental disorders. Etiology aside, oropharyngeal dysphagia can result in major consequences including malnutrition, dehydration, pneumonia, compromised health, choking and disinterest in eating/drinking. To reduce the possible consequences of oropharyngeal dysphagia, speech-language pathologists (SLPs) commonly use rehabilitative and compensatory strategies such as diet and texture modifications.

Diet modifications have evolved into one of the most common compensatory interventions to treat oropharyngeal dysphagia (Steele et al, 2014; Garcia, Chambers, and Molander, 2005). The modifications aid in remediating the possible motor and sensory effects of dysphagia by altering the viscosity, texture, temperature, portion size, and/or taste of foods and liquids. Often when initially making or modifying diet recommendations, thickness of the foods and liquids is considered, especially in reference to liquids. Thin liquids (such as water and tea) move through the oropharynx more quickly than other bolus types frequently resulting in penetration and/or aspiration for patients with oropharyngeal dysphagia (Clave et al, 2006). The underlying premise which guides a clinician to increase the viscosity of a liquid is to reduce the

rate of flow of the liquid through the oropharynx. This rate reduction should allow the patient more time to organize motor movements to allow for increased airway protection while swallowing (Clave et al, 2006). While it is pertinent to consider thickness for patient safety while swallowing, the term "thick" is subjective and has poorly defined universal parameters and terminology. In the United States, diet modifications are based on the National Dysphagia Diet (NDD) or other unstandardized protocols. These protocols serve to guide therapeutic modification of diet recommendations of foods and/or liquids for speech language pathologists (SLP). However, these protocols only offer subjective and qualitative definitions of how liquids should visibly appear and behave. Without standardized terminology, little consistency between facilities, individual practitioners, and geographical regions can result. Inconsistencies can lead to miscommunication and ultimately poor patient care and safety.

To increase patient care and safety, examination of liquids must go beyond visible appearance and clinical judgement. Consideration of multiple factors such as viscosity, flow rate, adhesion, and cohesion are critical, as each of these impacts how the liquids will behave (See Figure 1 for details regarding rheological interaction, see Table 2 for rheological definitions and clinical relevance). Knowledge of this viscosity-flow rate relationship has strong clinical relevance as recommendations of types of liquids are heavily based on this principle. Additionally, thicker liquids may help to contribute to timelier laryngeal vestibule closure (Nagy et al, 2015). Adhesive and cohesive properties also have clinical relevance. Liquids with increased adhesion will be stickier in nature. The interaction between the bolus and the mucosa interface in substances with increased adhesion could potentially lead to increased oral and pharyngeal residue. Liquids with increased cohesion will possess increased clump-ability meaning the likelihood of the bolus remaining in one piece is increased. Higher amounts of cohesion can help lead to better bolus control in the oral cavity and pharynx. Materials which demonstrate reduced cohesion with increased agitation are characterized as shear-thinning materials (Coster & Schwarz, 1987). Shear-thinning characteristics can be determined from a regression analysis of experimental data to fit a power law model ($\sigma = k\gamma^n$ or $\eta = k\gamma^{(n-1)}$) where σ represents the shear stress, η represents the viscosity, γ represents the shear rate, k is the consistency constant and n is the power law index. Knowledge of fluid characteristics of fluids other than thickness allow for the prediction of possible flow behavior (Barnes, 2000). By

understanding how a fluid will behave, more accurate recommendations and ultimately more personalized patient care are enabled.

To attempt to offer standardization of food and liquid classifications across countries, ages, care settings, and cultures IDDSI was created by a multi-discipline group of volunteers in 2012 (Cichero et al, 2017). The group recognized a need for worldwide standardization and terminology to ensure patient safety across all geographic jurisdictions (Steele et al, 2015). The IDDSI Functional Diet Scales, represented by two inverted triangles, capture the range of foods and liquid consistencies available for all patient populations ranging from pediatric to geriatric (Steele et al, 2018). Additionally, IDDSI offers standardized protocols for determination of food and liquid classification in correlation to the each of the levels of the Functional Diet Scale. Initial validation studies indicate IDDSI has clear consensual (73% agreement) and criterion validity (Spearman correlation: $R=0.84$, $P<0.001$) (Steele et al., 2018). Validation studies also suggest clinicians can reliably use IDDSI to effectively describe diet texture restrictions (Steele et al, 2018). While IDDSI recommends using the Functional Diet Scales with patient populations ranging from pediatric to geriatric, minimal evidence is available for infants and toddlers transitioning to more advanced diets (Steele et al, 2015; Gosa, Carden, Jacks, Threadgill, and Sidlovsky, 2016).

Infancy and childhood are characterized by dramatic physical growth and cognitive development. During this time complex sensorimotor coordination of skills needed for oral feeding is observed. As children mature and develop these complex oral motor skills, recommendations for appropriate foods and liquids are based on their current skill level. Infants and children require a separate set of guidelines from adults when discussing appropriate food and liquid recommendations, as skills needed to manage new consistencies and textures may not be mature (Glinsmann, Bartholmey, and Coletta, 1996). Development and maturation of oral motor and sensory abilities occur on a spectrum and are refined through childhood. In general, food and liquid advancements are introduced based on children's motor and sensory development. Infants in the United States are recommended to receive primary nutrition from breast milk or infant formula for the first 6 months of life. However, with the onset of volitional control, as demonstrated by increased head and trunk control, mastication abilities including subsequently tongue lateralization emerges (Scarborough, Brink, & Bailey-Van Kuren, 2017). At this time, more advanced textures can be introduced because the child possesses the necessary

skills to manage the more complicated foods and liquids (Scarborough, Brink, & Van-Kuren, 2017; Ruark, McCullough, Peters and Moore, 2001). At this time, transitional feeding or weaning can commence thus influencing the child's oral-motor swallowing skills again (Dodrill & Gosa, 2015).

Weaning refers to the time in which the child's intake of breastmilk or infant formula is progressively reduced and intake of more solid foods (baby foods, table foods, etc) are gradually increased (Brown, 2018). Recently, baby-led weaning (BLW) has gained popularity among parents and caregivers. Key tenets of BLW include: participation in family mealtimes on the part of the infant, and parents offering healthy, safe size foods but allowing the child to decide what, how much, and how quickly to eat (Rapley, 2008). Proponents of BLW argue this method provides an early and stable learning environment for the child to experience more complex feeding and eating thus giving children positive experiences while acquiring and mastering the complex sensorimotor skills needed for feeding and swallowing (Brown and Lee, 2015). While BLW may result in positive feeding experiences for children, children following BLW and children following more traditional methods of feeding both experience choking episodes (Fungupo et al, 2016). Children with oropharyngeal dysphagia may not be able to tolerate an increase in food complexity due to delayed or abnormal motor or sensory abilities. In a more traditional approach, children are introduced to solid foods via spoon-feeding of purees ranging from thin to thick depending on the child's age and subsequently their oral-motor skills. The traditional approach to increasing food complexity allows for more appropriate consideration of the child's oral-motor and sensory skills in the recommendations of appropriate foods to be presented to the child. Oral motor skills necessary for feeding and swallowing follow the same developmental progression as gross motor skills (Rudolph, 1994; Carruth, Zeigler, Gordan and Hendricks, 2004).

The purpose of this study is to examine and evaluate characteristics of baby foods using the IDDSI framework and testing methods and rheometer. Multiple study aims identify differences in viscosity, flow rate, adhesion, and cohesion within and between brands, packaging types, and temperatures between regionally available baby foods. Because the purpose of this study has multiple components, the researchers hypothesized the following statements:

1) There will be no significant difference in viscosity, flow rate, adhesion, and cohesion, as measured by IDDSI level, between the different brands and their current manufacturing classifications.

2) There will be a direct correlation between the manufacturer stages and the current IDDSI classifications.

3) Chilling or refrigerating samples will decrease flow rate and increase viscosity of purees therefore changing the IDDSI classification.

4) There will be no significant difference between viscosities between room temperature purees.

CHAPTER II
Methods

A total of 171 baby foods were identified as possible samples. Possible samples were selected from three national brands (Gerber, Beechnut, and Earth's Best Organics) and included a variety of fruits, veggies, proteins and blends at manufacturers' stages 1, 2, 3, and 4. Once possible samples were identified, researchers then randomly selected approximately 30% of the regionally available samples (n=66).

Utilizing research published by IDDSI (Cichero et al, 2017), the researchers interpreted prescribed IDDSI testing methods and created the detailed testing protocols used for this study. A decision-making chart (Figure 2), detailed descriptions of the IDDSI testing methods (Figures 3, 4, 5, and 6), and observation questions were all included in the protocols created. Testing protocols were used systematically to determine the best IDDSI level of the individual samples during the trials.

Four research assistants (three undergraduate students, one graduate student) were assigned to two research teams (Team A and Team B) to conduct the IDDSI tests on the selected samples. Teams were blinded to brand, manufacturer stage, packaging type, and ingredients.

The selected samples were randomized using a randomization function in Excel by a faculty member or graduate assistant, who were not blinded to the protocol, prior to commencement of trials and given a sample number. Each research team (Team A and Team B) had respective randomized lists of samples for testing. Randomized samples were prepared for each research team by the privy faculty member/graduate assistant and presented to each

research team. On testing days, each sample was removed from its original packaging, placed into clear glass jars with all identifying information removed, and presented to each individual research team. Using the decision-making chart (Figure 2), research team would systematically evaluate the samples using the IDDSI clinical tests. For detailed descriptions of the IDDSI clinical tests refer to Figures 3-6 and Table 2. At commencement of trials, research teams would visually inspect the samples for large particles or chunks in the sample. If the sample had visible chunks, the fork pressure test was conducted and the sample was determined to be IDDSI Level 5, 6, or 7. If the sample did not have visible chunks, the flow rate test was conducted. The amount of the sample which remained in the syringe after being allowed to flow for 10 seconds determined the IDDSI Level to be either Level 0, Level 1, Level 2, Level 3, or Level 4. If the sample was determined to be a Level 0- Level 2, the trial was complete and the final IDDSI level was recorded for the trial. If the sample was determined to be not a Level 0 – Level 2, the fork drip test was conducted. Based on how the sample behaved on the fork, the sample was determined to be either a Level 3 or Level 4. If the sample was a Level 3, the trial was complete. If the sample was determined to behave like a Level 4, the spoon tilt test was conducted. Based on the behavior of the sample when the test was conducted, the final IDDSI level was determined and recorded.

Room Temperature Process

During room temperature sample trials, the research teams consulted the Decision-Making Flow Chart (Figure 2) to guide implementing the IDDSI testing methods and determination of final IDDSI level. For each individual testing method, research teams consulted the Materials and Methods charts (Figure 3, 4, 5, 6). Each team used a stopwatch, 10 ml syringes, metal forks (15mm across all tines, 4mm between tines), and metal spoons (length 2 in, width 1 1/6 in) to conduct the tests. Based on the behavior of the sample during the IDDSI testing methods, teams used the observation questions to determine the final IDDSI level (IDDSI Level 0, Level 1, Level 2, Level 3, Level 4, Level 5, Level 6, or Level 7) of the selected sample. This process was repeated five (5) times per sample (total trials across research teams =10) per research team for all 66 samples at room temperature. All trials were recorded using a recording device and uploaded to a Google Shared Drive (separate drives for team A and team B) at the end of each testing session to allow for the trials to be re-watched for reliability purposes. Videos were coded according to team, sample number, and trial number.

Refrigerated Temperature Process:

Prior to refrigeration of samples, the selected refrigerator's temperature setting was placed between the cold and coldest setting on the interior of the refrigerator. Air temperature within the refrigerator was measured using a thermometer. Interior air temperature measurements fluctuated however remained below the temperature of ideal food safety, 40 degrees Fahrenheit.

During refrigerated temperature sample trials, research teams used the Refrigerated Manual Chart (Figure 7), the Decision-Making Flow Chart (Figure 2) and the Materials and Methods Charts (Figure 3, 4, 5, and 6) to determine final IDDSI level. The temperature of the samples was taken and recorded when the sample was initially removed from the refrigerator and prior to each trial to record the change in temperature across trials. All trials were recorded using a recording device and uploaded to a Google Shared Drive at the end of each testing session. Videos were coded according to team, sample number, and trial number.

Intra- and Inter-rater Reliability

Following completion of trials at room and chilled temperature, intra-rater and interrater reliability was determined by calculating the percent agreement of IDDSI levels within research teams and between research teams. Intra-rater reliability was determined by identifying the number of trials that had the same IDDSI level determination following the IDDSI clinical tests for each sample within a single research team. For example, for a single sample, if Research Team A determined a sample to be an IDDSI Level 3 for 3 trials and IDDSI Level 4 for 2 trials the intra-rater reliability would be 60% (3 trials out of 5 trials were similar). This process was repeated for each research team and all samples. Following the determination of intra-rater reliably, interrater reliability was determined. Interrater reliability was calculated by identifying the total number of trials that had the same IDDSI level determination following the IDDSI clinical tests for each sample between the two research teams. To calculate this measure, researchers combined the intra-reliability measures from each team. For example, if Research Team A's intra-rater reliability was 80% for a single sample and Research Team B's intra-rater reliability was 60% for the same sample, the combined interrater reliably would be 70%. Samples identified to have low intra-rater and/or interrater reliability (< 80%) were selected to have the videos taken during trials re-watched by independent raters (graduate assistants) for accuracy. Two graduate assistants were responsible for watching Research Team A's trial videos and two different graduate assistants were responsible for watching Research Team B's trial

videos. Prior to the graduate assistants watching the trial videos, they were trained using the decision-making flow chart (Figure 2), and the methods and materials sheets (Figures 3, 4, 5, and 6).

Description of IDDSI Tests

Flow Rate Test

To evaluate flow rate of the samples, the IDDSI Flow Test was utilized. Using a 10 ml syringe (Becton, Dickinson, and Company, 10 ml syringe) 10 ml of the sample was extracted from the clear glass jar. Syringe was tapped on table to release any air pockets. Tapping ceased when no air bubbles were observed by team members. One team member prepared the stopwatch while the other team member held a finger over the opening of the syringe, plugging the end. The syringe was unplugged and allowed to flow freely for 10 seconds and the remaining sample in the syringe was noted.

If sample was determined to have less than 7.9 ml remaining in the syringe after 10 seconds, the trial was ended and the correlating IDDSI score was recorded. If the sample was determined to have more than 7.9 ml remaining in the syringe after 10 seconds, the IDDSI Fork Drip Test was conducted.

Fork Drip Test

The Fork Drip Test was conducted by placing the sample on a standard metal fork (15 mm across, 4 mm between the tines) with the 10 mL syringe. The sample was observed to determine if it flowed through the tines of the fork. If the sample flowed through the tines, it was determined to be an IDDSI Level 3 and the trial was ended. If the sample did not flow through the tines, the IDDSI Spoon Tilt Test was conducted.

Spoon Tilt Test

The Spoon Tilt Test was conducted by placing the sample on a standard metal spoon (length 2 inches, width 1 1/6 inches). Spoon was held in dominant hand and turned one quarter turn of the wrist. Based on how the sample fell off of the spoon with one quarter turn, the sample's IDDSI level was determined.

Viscometer Methods

If a sample had high interrater reliability (100%) or low interrater reliability (50-70%), the sample was selected to be tested on the viscometer. Initially, fourteen samples were selected. Of the samples initially selected, five were Beechnut brand, eight were Gerber brand, and one

was Earth's Best. Manufacturer stages represented in the viscometer samples included Stages 1, 2, 3, and 4. However, upon visual inspection of the initial samples and understanding the capabilities of the viscometer (TA Instruments, New Castle, DE), eight samples were removed from the viscometer sample size. The samples were removed from the experiment because they contained large particles that would not be conducive for an accurate viscosity measure. Following the removal of the eight faulty samples, six appropriate samples remained. Of the remaining samples, four were Gerber brand and two were Beechnut brand and included manufacturer stages 2 and 4. All baby food samples were stored at ambient room temperature until testing and remained sealed until viscometer testing commenced. After trials were completed, the samples were discarded.

To determine the viscosity of the six samples selected, a TA Instruments Discovery HR-1 Rheometer (TA Instruments, New Castle, DE) was used. The rheometer was equipped with Trios software and a Peltier plate. A parallel plate geometry (20 mm in diameter), a small instrument attached to rheometer, which provided a top surface for the sample to be spun against for viscosity testing. Researchers began each test by conducting the appropriate setup and calibration steps in accordance to the rheometer manual. A flow sweep protocol was used to evaluate the viscosity of the samples. Experiments were conducted at 2.7 °C (refrigerated temperature) and 25 °C (ambient room temperature). Experiments were conducted by two researchers after a training session with a qualified chemical engineer.

At the beginning of each test, the researchers raised the geometry to the loading gap and loaded the sample onto the Peltier plate. The geometry was lowered to a constant trim gap of .9 mm. The sample was trimmed of excess around the edges of the geometry and the geometry was lowered to the test gap. Shear rates were varied in a logarithmic sweep from 0.1 to 100 s and the viscosity results were recorded at 5 points per logarithmic decade. See Figure 8 for sample data plot created from the data collected during rheometer tests. Data collected during each test at each temperature were transferred from the Trios software and uploaded to a Google Drive for analysis.

Chapter III
Results

IDDSI Results

Following data collection of room temperature and chilled temperature samples, approximately 20% of total trials were independently reviewed and yielded 100% agreement to initial IDDSI level determination. Descriptive statistical analysis was completed. A statistical change in means and distribution was observed as seen in Figure 9. Mean IDDSI level for room temperature (25 °C) trials was 3.3 ± 0.799 with a range of IDDSI levels from level 1 to level 6. Mean IDDSI level for chilled temperature (2.7 °C) trials was 3.5 ± 0.793 with a range of IDDSI levels from level 3 to level 6. For chilled temperature trials, the average difference in temperature from when the sample was removed from the refrigerator to the completion of all five trials for the sample was 4.86 °C. Trials ranged from in time from 2 minutes, 53 seconds to 15 minutes, 44 seconds depending on the sample characteristics. For example, samples with identified chunks did not take as long to finish testing as only one IDDSI clinical test was required. Whereas, samples which required three IDDSI clinical tests naturally took longer to complete.

Average IDDSI level for each manufacturer (Beechnut, Gerber, Earth's Best) stage (all trials combined) showed a significant difference between the four groups (Stage 1, Stage 2, Stage 3, and Stage 4) ($p = 0.000$). Mean differences were found as followed: Stage 1 ($M = 3.6$, $SD = 0.97$), Stage 2 ($M = 3.2$, $SD = 0.25$), Stage 3 ($M= 4.5$, $SD = 1.06$), and Stage 4 ($M= 3.2$, $SD = 0.25$).

A single factor, univariate analysis of variance (ANOVA) was used to determine the relationship of IDDSI level to manufacturer brand. A significant difference was found between IDDSI level and the three brands ($F = 15.53$, $p < 0.001$). However, upon further inspection, the Beechnut and Gerber brands appeared to have more similar IDDSI averages across trials (Beechnut ($M = 3.6$, $SD = 0.80$), Earth's Best ($M = 3.3$, $SD = 0.48$), Gerber ($M = 3.5$, $SD = 0.71$). To determine if Earth's Best was statistically different than the other two brands single factor ANOVA were completed. Results of the single factor ANOVA showed: between Beechnut and Earth's Best ($p = 0.000$), between Earth's Best and Gerber ($p = 0.000$), and between Beechnut and Gerber ($p = 0.12$).

Viscometer Results

All samples tested on the viscometer demonstrated shear thinning behavior when shear rate was increased (See Figure 10). To measure this behavior, a best fit power law model of the rheological data was calculated. See Table 3 for k- and n-values determined from the power law model. With known values, viscosity can be estimated at any corresponding shear rate. The power law indices, n, for the selected samples at all three temperatures ranged from 0.165 to 0.293. Chilled temperature n values ranged from 0.165 to 0.235. Room temperature n values ranged from 0.167 to 0.293. To evaluate changes in viscosity as a function of temperature, k- and n-values were charted (Figure 11).

Chapter IV
Discussion

The purpose of this study was to evaluate selected characteristics of commercially available baby food and identify and analyze any differences between brands, stages, and packaging types, and temperatures. We were able to analyze 30% of the regionally available baby foods from three different popular brands, including an organic brand, at two separate temperatures: room temperature (25 °C) and chilled temperature (2.7 °C). At the beginning of this study, researchers hypothesized no significant difference between IDDSI level and brand. It was hypothesized manufacturer stages would correlate directly to the IDDSI classifications and decreased temperature would increase IDDSI level of samples.

One would expect when selecting two comparable baby foods by manufacturer standards, the food would behave similarly. Additionally, though no literature exists to support the claim, one would expect as a child ages, the viscosity of the food presented to them would increase as evidenced by the spectrum to consistencies represented on the IDDSI triangles. Such expectations were not upheld in the results, unexpectedly.

The identified difference between the distribution (kurtosis) of the room temperature trials and the chilled temperature trials is important to note. A decrease in temperature from 25 °C to 2.7 °C demonstrated an overall increase in IDDSI level during trials however, interestingly, not an even increase. As seen in Figure 9, for room temperature trials demonstrated a larger range of IDDSI levels found during clinical testing and chilled temperature trials demonstrated a reduced range of IDDSI levels. One would expect samples to demonstrate the same distribution or increase in an equal manner. Based on manufacturer descriptions of baby food staging and

assumptions of logical progression, one would also expect Stage 1 baby food would possess the lowest IDDSI level and Stage 4 would possess the highest IDDSI level. This logical progression was not observed during trials or in the results. Clinically, the unfulfilled expectations could result in unsafe or inappropriate presentation of foods to children. Children who have oropharyngeal dysphagia require calculated food consistency recommendations and inconsistent behavior of manufactured baby food compromises appropriate recommendations.

The results of this research indicate inconsistencies in manufacturers' baby food output. One would hope manufacturers would have a method of ensuring consistency of the baby foods produced. Manufacturer inconsistencies indicate there is no way to predict exactly how a sample is going behave based on the brand, stage, or packaging type. For this reason, each food or liquid recommended to be given to a child needs to be individually evaluated using the IDDSI protocols. Because of this, it is recommended speech-language pathologists, caregivers, and other health care providers become acquainted with the IDDSI testing protocols. By understanding the spectrum of foods and liquids available and being able to identify food and/or liquid characteristics, the child's safety while consuming these foods and liquids is held paramount.

Of the samples selected for viscosity testing, all exhibited shear thinning behaviors and thus impact clinical use of the baby foods. The samples' viscosity decreased as more strain was applied during testing and became thinner in nature which is directly related to cohesiveness. Clinically, this is significant in reference to strain applied via the musculature and movement of the oral and pharyngeal cavities during mastication and swallowing. Materials with decreased cohesiveness have reduced ability to remain together and could result in decreased control during deglutition.

A parallel study, testing Gerber and Beechnut brands at room temperature, was conducted at the University of Alabama (2019). The unpublished results of this study demonstrated no significant difference between the Beechnut and Gerber brands at room temperature-mirroring the results of this study. The Alabama study expressed interest in conducting further testing on organic brands of baby foods; this study included an organic brand. Based on finding Earth's Best was significantly different than Gerber and Beechnut, this suggests organic brands may have a different manufacturing or processing protocol.

Strengths and Limitations of the Study Design and Method

Research in the regards to the evaluation of foods in correlation to IDDSI or any diet modification program is limited. The evaluation of baby foods in reference to IDDSI is groundbreaking. Strengths of the study include systematic selection of samples and evaluation of the selected samples using the IDDSI protocols, blinding of all research assistants to brand, ingredient, and stage of the baby foods, testing a variety of available baby foods, and re-watching trial videos for accuracy.

Despite the strengths of this study, external limitations exist. The IDDSI protocol was designed to be used in the field for practitioners; IDDSI is not a wholly objective protocol and room for subjectivity exists. Because of the nature of the protocol, sensitivity is reduced, and error is inherent. For example, when conducting the spoon-tilt test, IDDSI does not offer clear criterion (as they do for the Flow Rate Test) for determining the IDDSI level the sample truly is. Instead, more subjective observations to make are offered. Despite how the IDDSI protocol was created, we believe our data is accurate representation of using IDDSI with baby food due the training the researchers underwent prior to conducting the tests on the samples, the systematic use of the IDDSI protocol, and re-watching testing videos for reliability purposes. Any variability in the results between brands, stages, temperatures, and packaging types are more likely due to manufacturer inconsistencies.

Future Directions

In the future, samples should be tested at a warmed temperature to capture the behavior of the samples across of the spectrum of possible temperatures of food presentation. Moreover, including additional popular brands of baby foods, including more organic brands, in the selected samples would help to add to the breadth of information, provide more information for clinicians and caregivers to use, and identify any significant differences between organic and non-organic brands. Furthermore, thermal behaviors of the food and container can be developed to predict thermal behavior of samples and eventually provide time based guidelines for clinicians.

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Tables

Table 1.

Rheological terms and their clinical relevance

Term	Definition	Clinical Relevance
Viscosity	Measure of a fluid's resistance to deformation, measured by internal friction (Barnes, 2000)	Speed of bolus, laryngeal preparedness and timely laryngeal closure (Nagy et al, 2015)
Flow Rate	Rate at which a fluid passes a given point	
Adhesion	Attractive force between unlike molecules (Barnes, 2000)	"Stickiness", potential residue in oral and pharyngeal cavity
Cohesion	Attractive force between like molecules (Barnes, 2000)	"Clump-ability", bolus control

Table 2.

IDDSI clinical tests

	Flow Rate Test	Fork Drip Test	Spoon Tilt Test	Fork Pressure Test
Ideal Foods	Liquids	Thick fluids and foods	Thick liquids and foods	Hard and solid foods
IDDSI Level	Level 0 – Level 4	Level 3 -Level 4	Level 3- Level 5	Level 5 -Level 7
Visual Representation				

Table 3.

k- and n-values from Power Law for samples tested on viscometer.

Brand	Ingredient (s)	Stage/Container	Temperature (°C)	k-value	n-value
Beechnut	Peaches	2 / Jar	2.7	17.8	0.174
			25	13.7	0.167
Beechnut	Apples	2 / Jar	2.7	23.9	0.185
			25	19.1	0.232
Gerber	Carrot Mango Pineapple	2 / Jar	2.7	13.7	0.165
			25	17	0.193
Gerber	Banana Blueberry	4 / Pouch	2.7	38.5	0.211
			25	26.5	0.233
			25	20.5	0.293
Gerber	Apple Avocado	2 / Jar	2.7	29.4	0.208
			25	20.6	0.233
Gerber	Banana Blueberry Blackberry Oatmeal	2 / Pouch	2.7	77.1	0.235
			25	47.1	0.273

Figures

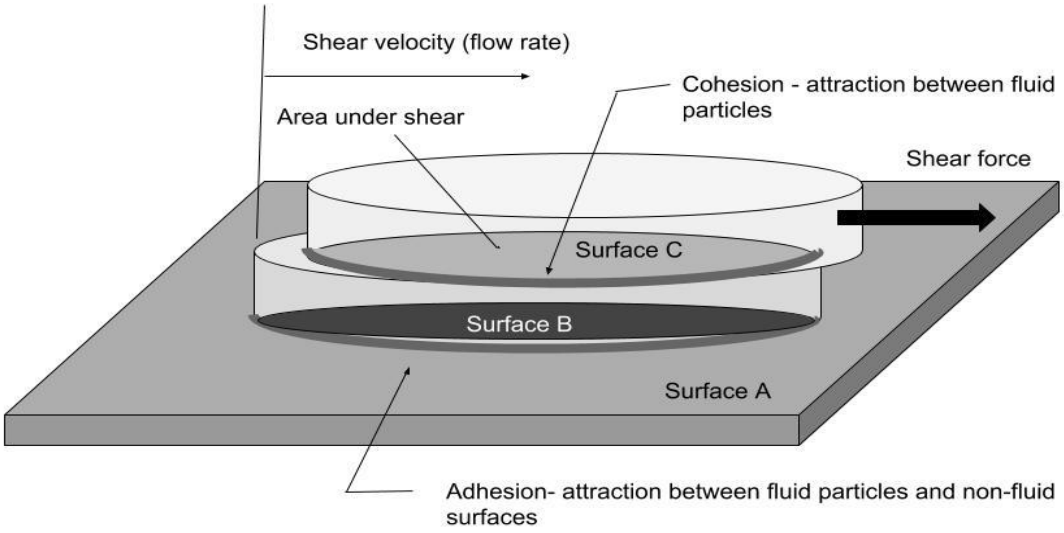


Figure 1: Rheological Interactions. Viscosity, flow rate, adhesion, and cohesion impact fluid behavior. Shearing forces are unaligned forces pushing one part of a body of a fluid in one specific direction, and another part of the body of a fluid in the opposite resulting in shear. Viscosity is a measure of a fluid's resistance to flow or deformation as measured by internal friction or intermolecular forces of attraction (Barnes, 2000). In fluids, internal friction exists between molecules. Greater internal friction yields greater resistance to flow resulting in higher viscosity; less internal friction yields less resistance to flow resulting in lower viscosity. Closely related to viscosity is flow rate or shear velocity. Flow rate is the rate at which a fluid passes a given point. Viscosity and flow rate are inversely proportional. Cohesion is defined as the tendency of fluids to resist separation (Barnes, 2000). This attractive force exists between molecules of the same substance. Adhesion refers to the attractive forces between unlike molecules in different substances or materials.

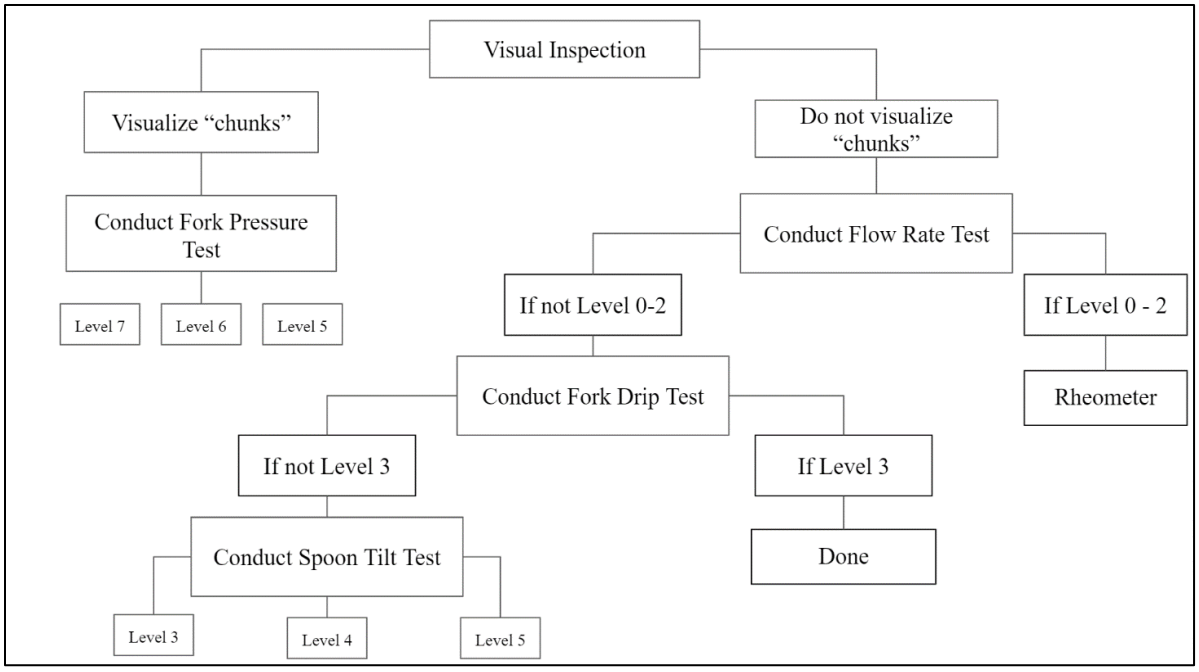


Figure 2: Decision-Making Flow Chart. Upon initial visual inspection of selected sample, research teams would determine what IDDSI test needed to be completed to most accurately categorize the sample into an IDDSI level. If the team visualized chunks in the sample, the fork pressure test was completed. If the team did not visualize chunks, the flow rate test was completed. Based on the behavior of the sample during the test, either an IDDSI level could be determined or the next IDDSI test would be completed.

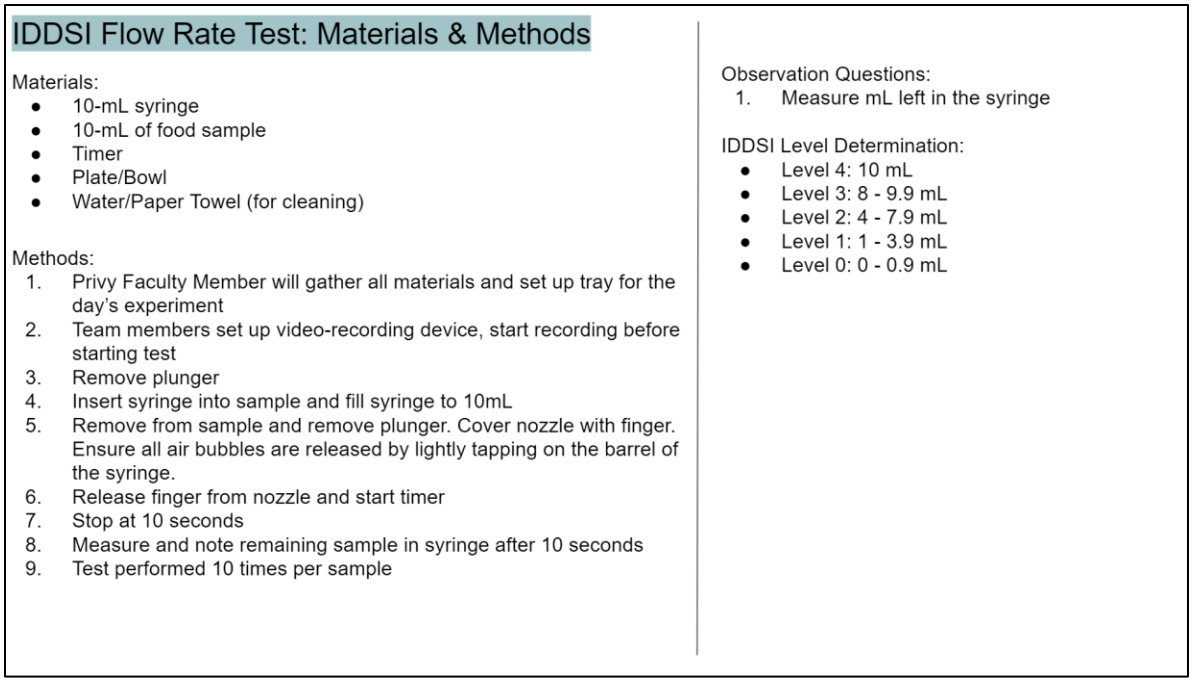


Figure 3: IDDSI Flow Rate Test Methods and Materials. If the Flow Rate Test was determined to be appropriate, research teams conducted the test according to the methods described above and used the observation questions to determine the IDDSI level.

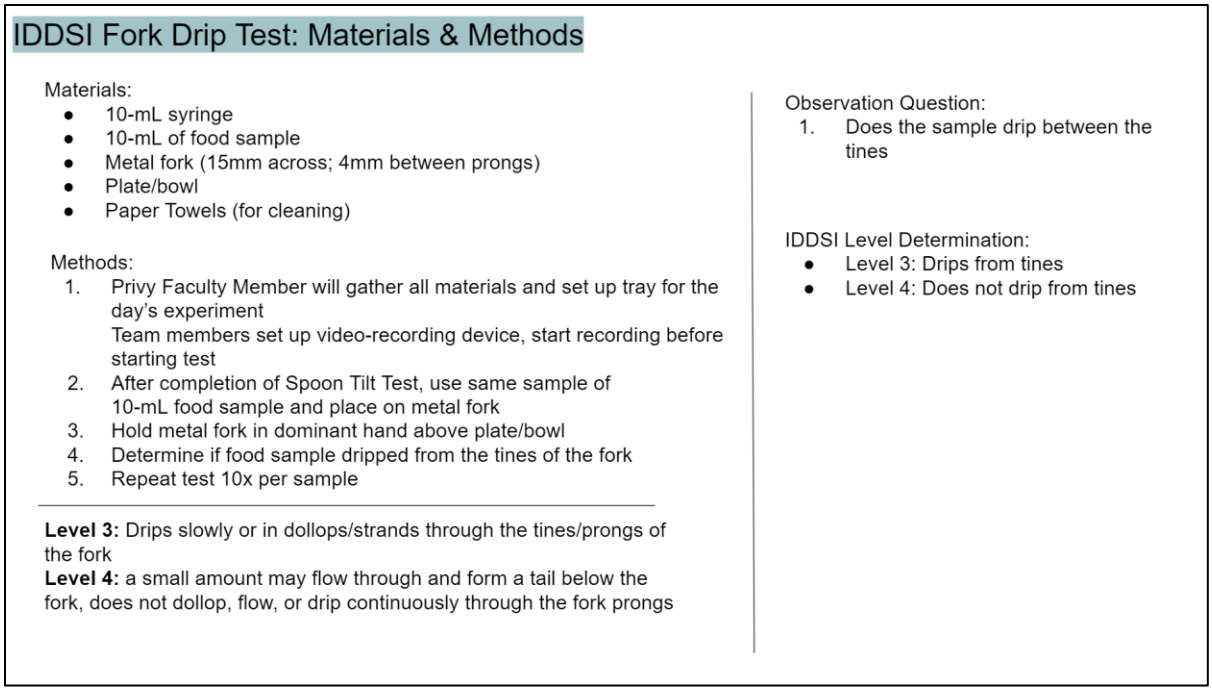


Figure 4: IDDSI Fork Drip Test Methods and Materials. If the Fork Drip Test was determined to be appropriate, research teams conducted the test according to the methods described above and used the observation questions to determine the IDDSI level.

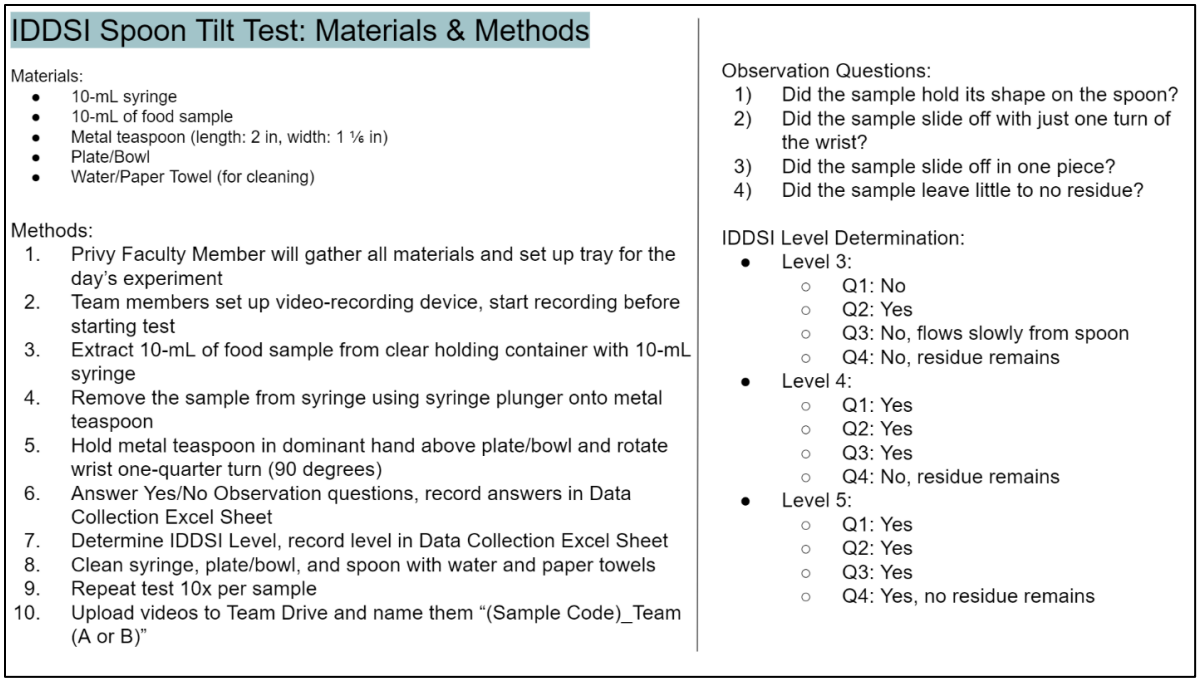


Figure 5: IDDSI Spoon Tilt Test Methods and Materials. If the Spoon Tilt Test was determined to be appropriate, research teams conducted the test according to the methods described above and used the observation questions to determine the IDDSI level.

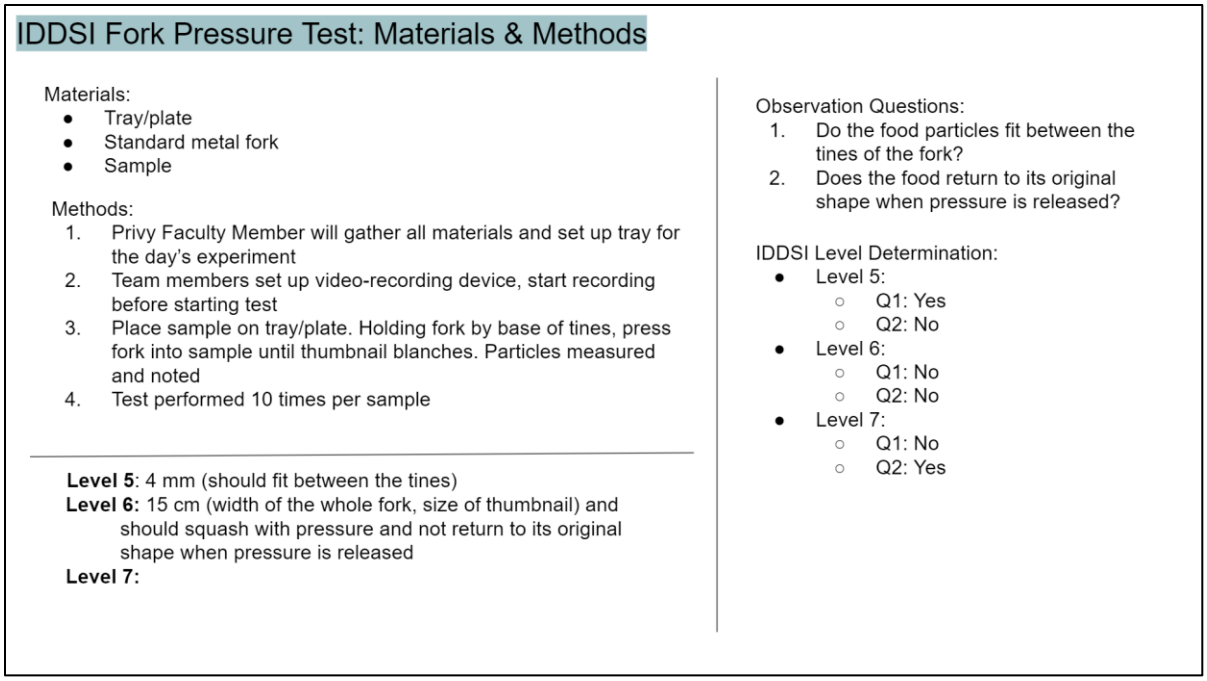
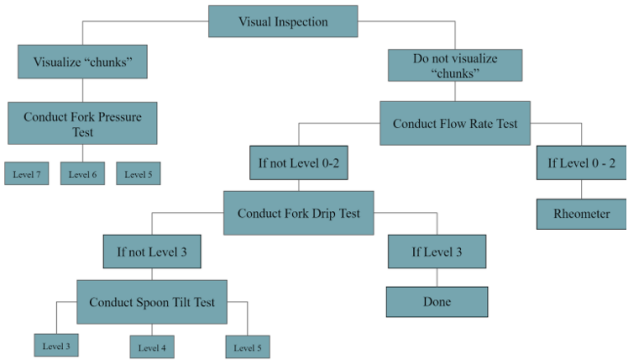


Figure 6: IDDSI Fork Pressure Test Methods and Materials. If the Fork Pressure Test was determined to be appropriate, research teams conducted the test according to the methods described above and used the observation questions to determine the IDDSI level.

1. Prepare materials (syringes, spoons, forks, plates, timer, etc)
2. Get the 1 (one) selected baby food sample from the fridge (leave the rest of the samples in the refrigerator until you are ready to test another sample)
3. Start **Total Trial Timer**
4. Take initial temperature of sample in jar using thermometer (tip must be in sample)
5. Record initial temperature of the sample on respective team's cooling data collection sheet
6. Fill syringes (5)
7. Start trial video
8. Before each trial, take and record Pre-T# Temperature and record in respective team's cooling data collection sheet
9. Proceed with IDDSI Protocol using Decision Making Flowchart for that trial



10. Stop trial video
11. Record IDDSI level in respective team's cooling data collection sheet under column corresponding trial #
12. Repeat steps 7-11 for remaining syringes
13. Stop **Total Trial Timer** and record total time in respective team's cooling data collection sheet
14. When all trials are completed, clean up materials
15. Upload videos to respective team's chilled sample video folder

Figure 7: Chilled Process Manual. Research teams utilized this manual and the Decision-Making Flow Chart to accurately identify the IDDSI level of the refrigerated samples.

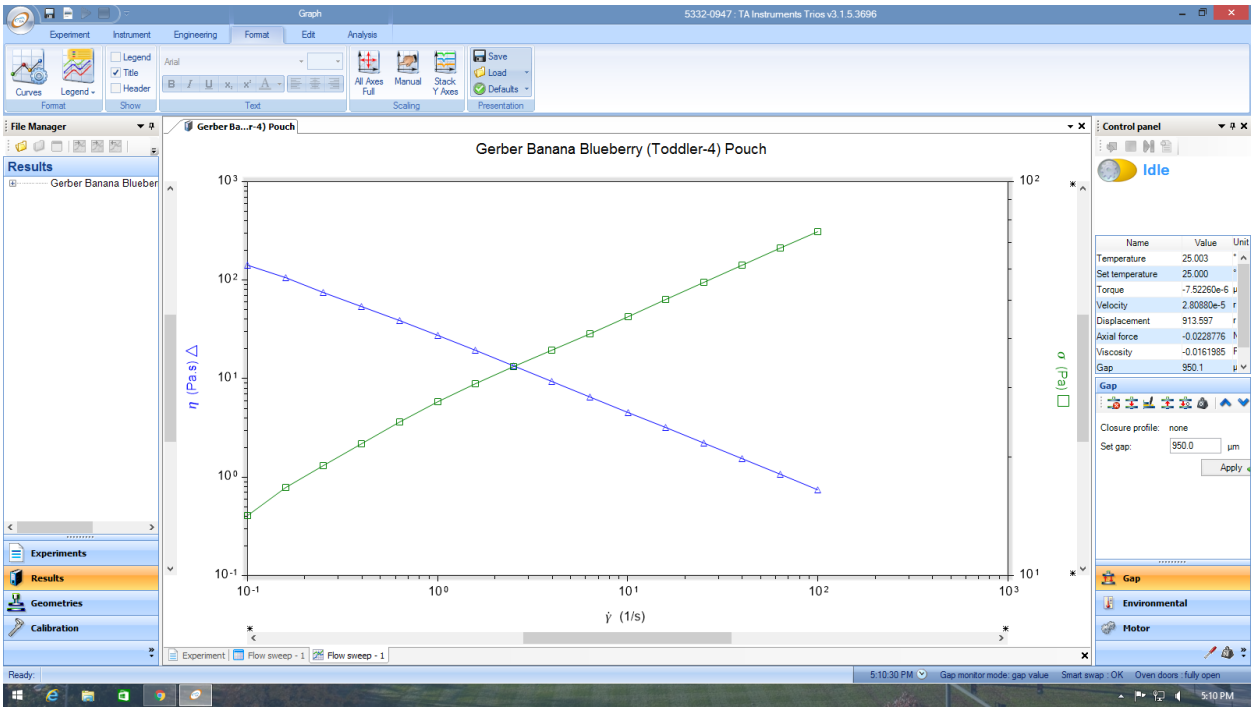


Figure 8: Sample Rheometer Data Plot from Trios Software. This selected sample was conducted at room temperature (25 °C) on a Stage 4 baby food. The X-axis is shear rate. The Y-axis on the left side of the plot in blue is viscosity. The Y-axis on the right side in green is stress. While conducting the test, researchers observed this plot being made in real-time. Observations about the plot that can be made include the crossing of the viscosity and stress lines and the relative straightness of the two lines. The specific data points from the plots created during all the trials were combined and analyzed outside of the Trios Software.

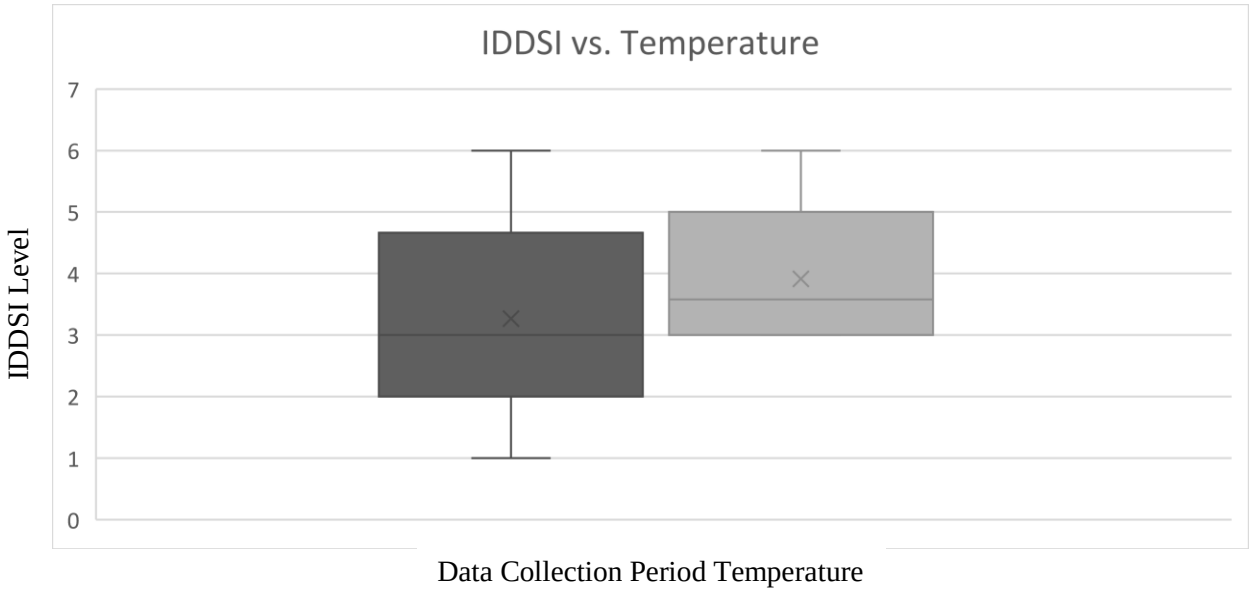


Figure 9. *Mean and Distribution of Room Temperature and Chilled Temperature Trials.* The dark grey boxplot represents the mean IDDSI level and distribution of levels for room temperature trials. The light grey boxplot represents the mean IDDSI level and distribution of levels for chilled temperature trials. Mean IDDSI level for room temperature trials was 3.3 ± 0.031 and kurtosis was 2.11 (SE = 0.031). Mean IDDSI level for chilled temperature trials was 3.5 ± 0.031 and kurtosis was 0.418 (SE = 0.031).

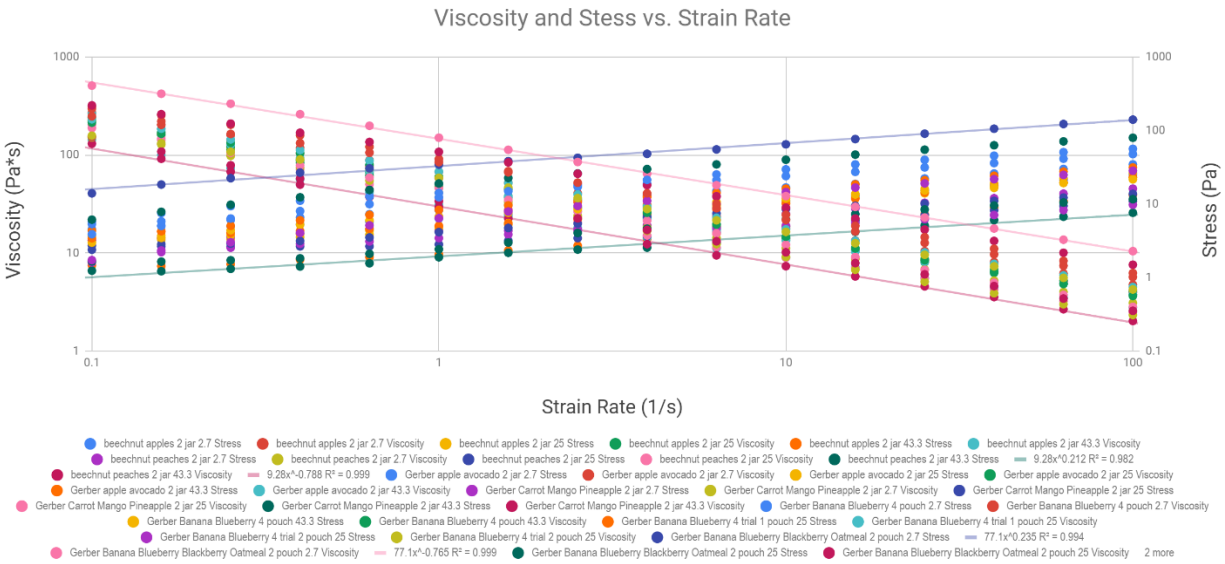


Figure 10. *Viscosity and Stress versus Strain Rate of Viscometer Samples*. X-axis refers to the strain rate, a measure of how the material changes in dimension over time. The left Y-axis refers to the viscosity of the material. The right Y-axis refers to the stress during testing. Axes are log-log scaled. Lines running from top left to bottom right indicate viscosity and lines running from the bottom left to the top right indicate stress applied during testing. The negative slope of the viscosity lines indicates all samples selected for viscosity testing demonstrate shear-thinning behaviors.

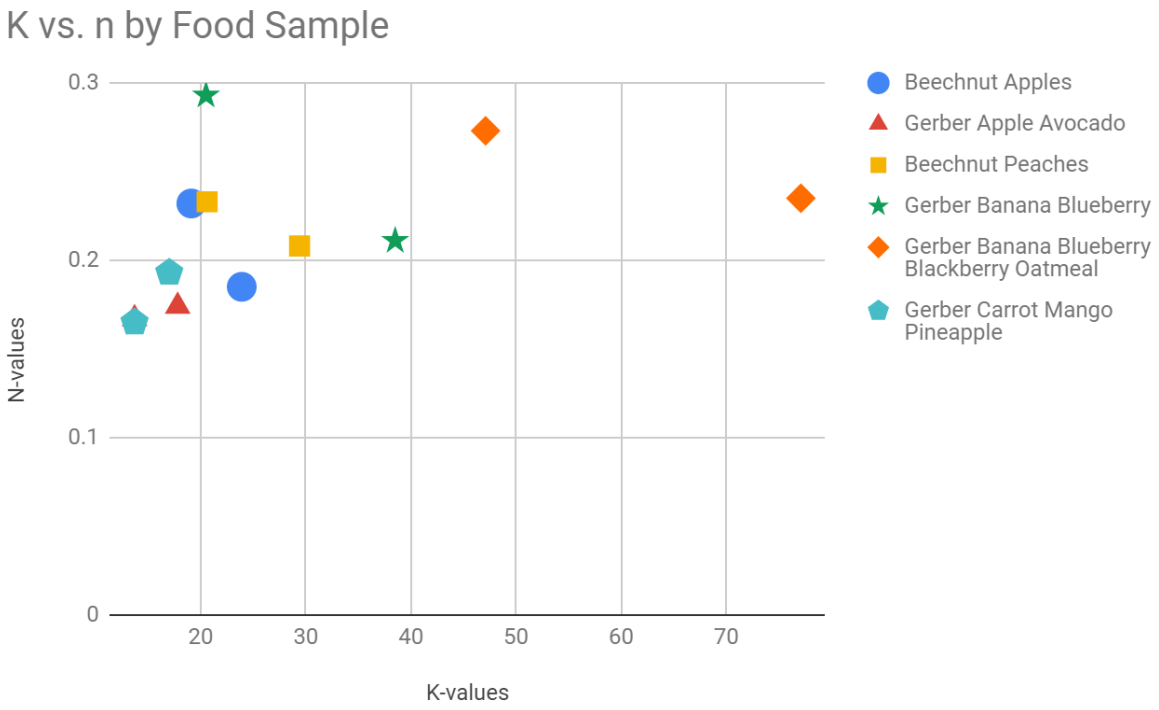


Figure 11. *K-values Versus N-values by Sample and Temperature*. The value k represents the consistency constant and n represents the power law index. An increased k-value represents a fluid with a higher viscosity. The range of the power law index (n) varies from 0 to 1 with 0 representing very shear thinning materials. Symbols located on the bottom left side of chart represent samples with lower viscosities. Symbols located on the top right side of chart represent samples with higher viscosities.