Prediction of Sensory Texture Characteristics of Deli Meat Using Instrumental Analysis

by

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Abstract

The objective of Experiment 1 was to develop a method that has the ability to measure multiple readings on the same deli meat sample and have those readings be highly correlated with descriptive sensory data. Texture profile analysis was applied to 4 deli meat brands: classic oven roasted turkey (CORT), brand oven roasted turkey (ORT), natural oven roasted turkey (NORT), and bulk oven roasted turkey (BORT). Descriptive sensory analysis was conducted by a 10-member, highly trained panel employed by a corporate deli meat producer. The objective of Experiment 2 was to determine how number of slices affects texture using 3 different types of deli meats, including: hard salami, original roasted turkey breast, and turkey bologna. Increasing the number of slices of deli meat analyzed from 1 to 5 slices stacked at a time. For Experiment 1, 3 treatments, 25% strain, 30% strain, and a distance of 5-mm was applied to samples. A total of 15 samples per treatment were analyzed, with 3 readings per sample- totaling 45 readings per treatment. Texture analyzer settings were: the treatment being applied, a pre-test speed of 2-mm/s, test speed of 0.5-mm/s, post-test speed of 0.5-mm/s, and a trigger force of 5-g. For Experiment 2, texture analyzer settings were a distance of 5-mm, a pre-test speed of 2-mm/s, test speed of 0.5-mm/s, post-test speed of 0.5-mm/s, and a trigger force of 5-g. Experiment 1 showed treatment distance was a 'good' indicator (R^2 of 0.64 to 0.81) of mean hardness with sensory amount of striations

(r=0.85 and R^2=0.73) and showed a ‘good’ correlation between mean chewiness and amount of striations (r=0.72 and R^2=0.67). Mean cohesiveness was a ‘good’ indicator of sensory fibrousness between teeth at treatment level 30% strain (r=0.71 and R^2=0.70). For Experiment 2, increasing stack size proved to be an 'excellent' predictor (R^2 > 0.81) of sample mean hardness and chewiness for brands Hillshire Farms Hard Salami (HFHS) and Oscar Mayer Oven Roasted Turkey Breast (OMORT), and a 'good' predictor of mean hardness for Oscar Mayer Turkey Bologna (OMTB). Increasing the number of slices on brand OMTB showed this had an ‘excellent’ correlation between slice number and average springiness, while the other two brands (HFHS and OMORT) depicted ‘good’ correlations. Increasing the number of slices showed a 'good' correlation between brands OMORT and OMTB and mean cohesiveness and mean resilience. In conclusion, some sensory attributes were correlated with texture profile analysis readings in Experiment 1; additionally, in Experiment 2, increasing the number of stacked slices showed to increase correlation coefficient (R^2) values in most cases.

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Introduction

Little is known in regards to textural properties of deli meat (Luckett et al., 2014). Deli meats fall into the category of restructured meat products. The restructuring process is carried out by multiple pieces of meat being combined with chilled brine and formed in desired size and shape (Owens et al., 2010; Luckett et al., 2014). The texture of restructured meat products can vary greatly. This variation is due to many contributing factors: 1) wide array of processing equipment and manufacturing technology, 2) addition of non-meant ingredients, 3) degree of extension with added water, and 4) quality of raw materials (Luckett et al., 2014). Even with the known variation found with the texture of deli meats, little research has been conducted which is aimed at understanding the underlying causes of variation (Kardouche et al. 1978; Lyon et al. 1980; Luckett et al., 2014). Cost of deli meat is a contributor to the lack of research. Deli meat is much lower in price compared to whole muscle meat products. Research dollars are more likely to be directed to products that can make a greater financial impact.

Traditionally, deli meat texture has been quantified through the use of descriptive sensory analysis (Kardouche et al. 1978; Lyon et al., 1980, Luckett et al., 2014); however, maintaining trained descriptive panels is an economic burden for companies. To properly train a descriptive panel is an extremely time intensive process. Discovering a method of instrumental texture analysis that accurately quantifies texture attributes of deli meat the same as a descriptive sensory panel could prove to alleviate the time and financial burden experienced presently (Warner, 1952; Cavitt et al., 2004, 2005; Meullenet, et al., 2004; Lee et al., 2008; Luckett et al., 2014).

Because deli meats are so highly processed (multiple processing techniques, functional ingredients, types of proteins used, etc.) the final texture can vary from loaf to loaf and even from slice to slice. The potential for variation makes consistency a challenge. Currently, companies employee descriptive sensory panels to determine the consistency among texture attributes of deli meat within a single brand, and the differences across brands. These panels are made of highly trained individuals, specializing in deli meat texture.

Comparing analysis by descriptive panels versus analysis by instrumental means a few differences should be noted. Samples used in descriptive analysis are processed orally. Orally processing samples is much more sophisticated than instrumental measures, and encompasses parameters that instruments cannot mimic. Additionally, a larger portion of the sample is used in analysis by descriptive panelists compared to the area that is analyzed instrumentally. The larger area analyzed allows for a great understanding of the sample in its entirety, which is a glaring problem when considering the repeatability of results measured by instrumental means. Discovering an instrumental method that has the ability to produce data that is highly correlated to results obtained by descriptive panels would be a huge asset to the production of deli meats. This instrument could be utilized in a research and development pilot plant or production facility.

This study was divided into two experiments. The objective of Experiment 1 was to develop a method that has the ability to measure multiple readings on the same deli meat sample and have those readings be highly correlated with descriptive sensory data. While instruments cannot mimic an oral process, taking multiple data points from the same sample will allow for a more uniform understanding of the differences throughout the entire sample and allow for a better correlation between panelists' results and the results obtained by instrumental measures. The objective of Experiment 2 was to determine how number of slices affects texture using 3 different types of deli meats, including: hard salami, original roasted turkey breast, and turkey bologna. Increasing the number of slices of deli meat analyzed from 1 to 5 slices stacked at a time. Increasing number of slices could potentially offer more sample stability and simultaneously increase correlations between instrumental analysis and descriptive sensory data.

Review of Literature

Texture

Texture is a critical factor in an individual's eating experience. The role texture plays within food acceptability is complicated and encompasses a variety of parameters. Texture can be defined as, the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinesthetics (Szczesniak, 2002). Szczesniak stresses the importance of understanding 1) texture is a sensory property, 2) it is a multi-parameter attribute, 3) it derives from the structure of the food, and 4) it is detected by several senses, most important being touch and pressure. These four points provide insight into understanding the underlying fundamentals of texture.

The perception of texture can be derived from one sense, or a combination of senses (vision, hearing, touch, etc.), depending on the food product. Texture encompasses foodstuffs organoleptic, sensorial, mechanical, and geometric properties (Figura & Teixeira, 2007). Figura and Teixeira (2007) explain that the organoleptic and sensory properties of foods can be categorized into mechanical, acoustic, and visual parameters. This concept explains how consumers' analyze texture perception subconsciously. The mechanical aspect can be further broken down into two subcategories; tactile, what can be felt, and kinaesthetic, what is perceived during chewing and mastication (Figura & Teixeira, 2007). Consumers use their senses to assess quality attributes of food, and texture plays a major role in this. For example, an individual's expectation of texture begins prior to food consumption, visual texture can be utilized when determining freshness of products- i.e., wilted spinach and shriveled grapes are not pleasing to the eye (Szczesniak & Kahn, 1971). Visual appearance of food creates subconscious expectations of the eating experience (Lawless & Heymann, 2010). Visual texture assessment aids in expectation of tactile texture, for instance, from a tactile standpoint, there are perceivable differences between a head of broccoli and a carrot when touched, but these same differences can be seen with the eye. When the visual and tactile texture characteristics of a product are at variance the discrepancy causes a decrease in product acceptance (Lawless and Heymann, 2010).

Consumers have grown accustomed to certain food products having specific textures and deviating from these expected textures negatively impacts product quality in the consumers' mind. According to Civille (2011) consumers comment on texture in two instances: 1) when flavor is mild and the texture is pronounced or 2) when the texture is 'off' (stale or uncharacteristic). Schiffman (1977) showed the importance of texture in food recognition and consumer acceptance, findings indicated that only about 40% of products tested were identifiable by their flavor after homogenization in a blender. Bourne (2002) divides foods into three categories based on the importance of texture: critical, important, and minor. Texture is the major quality characteristic in the 'critical' category (meat and potato chips), in the 'important' category, texture is significant but not the main quality characteristic (cheese and bread), and texture makes only ‘minor’ contribution to those foods in the minor category (beverages and soups).

To the consumer, texture is one of the most important factors associated with food quality; however, a consumer’s opinion of texture can vary depending on social class. According to Lawless and Heymann (2010), individuals in higher socioeconomic classes were more aware of texture as a food attribute than those in lower socioeconomic classes. The texture of the food product itself plays major impact on price of the food. For example, beef cuts that are known to be tougher are marketed at lower prices or even ground and sold as ground beef or utilized in other processed meats. In contrast, those cuts known to be more tender in texture are sold for much higher premiums as either steaks or roasts (Bourne, 2002).

Age also plays a role in texture perception. Infants and small children may avoid certain textures due to tactile and oral defensiveness. Tactile defensives is defined as an overreaction to the experience of touch or an observable aversion or negative behavior in response to certain types of sensory stimuli that most people experience as inoffensive, while oral defensiveness is defined as, the avoidance of certain textures of food (Smith, Roux, & Venter, 2005). Children most often do not like foods that contrast in texture or possess textural variety, such as: certain candy bars, desserts, and main meals (Civille, 2011). Oppositely, Szczesniak (2002) states that the population of industrialized countries are aging at a rapid pace, and that the 85+ age group is the fastest growing in the United States. Their age has allowed them to become used to having their food texture a specific way and are not likely to be swayed in their acceptance of new texture; however, the upper end of this age demographic can also have difficulty chewing/swallowing their food- stemming from a multitude of reasons.

Oral Processing

Oral processes have a significant effect on the breakdown of the physicohemical structure of the food in the mouth and, thus, on the sensory perception (Wilkinson, Dijksterhuis, & Minekus, 2000). Stokes et al. (2013) describes oral processing as a dynamic process that encompasses a variety of sensory features that occur during eating and even handling of food prior to consumption. Researchers suggest that visual appraisal of food that occurs prior to consumption or during preparation is extremely important to sensory perception during oral processing (Guinard & Mazzucchelli, 1996). Oral processes are dependent upon two main factors: 1) individual people vary one from another and 2) the properties of the food being evaluated (Chen, 2009). An individual's stage of life (age), sex, nationality, health history, economic class, etc., work together with a food's rheological and textural properties to determine how food is orally processed and its sensory properties discerned (Chen, 2009).

Characteristics that are specific to a given food change constantly during mastication. Perceived texture from a sensory standpoint stems a great deal from the food's structure (Chen, 2009). The structure of food changes continuously once in the mouth, making it a time intensive process. For solid and semi-solid foods, continuous chewing during eating reduces particle size, saliva wets the surface particles, the saliva moistens the particles, and the moist particles clump together in what is called bolus formation—giving a much different texture than the initial solid/semi-solid ingested

(Chen & Stokes, 2012). Changing of sensory properties during mastication is a well-recognized fact and has been adopted by sensory scientists in Time Intensity (TI) analysis of food sensory properties, a technique which describes the intensity change as a function of oral processing time (Chen & Stokes, 2012). Full mastication of a food occurs in multiple stages, each stage provides a different sensory experience for the eater.

Guinard and Mazzucchelli (1996) originally described oral processing as a simple, three-stage operation: initial ingestion, incision and repetitive chewing, and swallowing; however, since that time it has become evident that it is a much more dynamic process, involving: grip and first bite, first stage transportation, chewing and mastication, second stage transportation, bolus formation, and swallowing (Chen, 2009). Sensory perception that is detected during oral processing occurs due to mechanorecptors that are found in the mouth and placed into 3 categories: 1) those in the superficial structures of the mouth such as the hard and soft palate, tongue, and gums, 2) those in the periodontal membrane surrounding the roots of the teeth, and 3) and those that are found in the muscles and tendons involved in mastication (Guinard & Mazzucchelli, 1996). Mechanical receptors work together with nerve endings found in the mouth to sense force responses; these responses will be sent to the brain, processed and the texture of the food will be interpreted (Chen & Stokes, 2012). Guinard and Mazzucchelli (1996) also state that the main differentiation between these 3 types of mechanorepeptors is the ability to deform the food.

Sensory Evaluation

Sensory analysis can be described as a science of measuring given attributes. Pfenninger (1979) explained that in order to accurately measure sensory attributes, four key parameters must be followed: 1) define the problem: clearly understand the what is to be measured, 2) proper test design: the design cannot be subjective and the sensory scientist must understand where bias can occur, 3) proper instrumentation: subjects tested must be selected and trained to produce accurate data; sensory scientist must understand their sensitivities, and 4) interpretation of results: clearly defining the null and alternative hypothesis and utilizing appropriate statistical analysis.

Precision, accuracy, sensitivity, and avoiding false positives are major concerns in sensory evaluation (Meiselman, 1993). Sensory professionals are employed to ensure the aforementioned concerns are not seen. Erhardt (1978) explains sensory analysts, during the product development stage, prevents possible issues if the following 7 steps are carried out: 1) determine project objectives, 2) determine test objective, 3) screen the samples, 4) design the test, 5) conduct the test, 6) analyze the test, and 7) interpret the results.

Using human subjects as instrumentation methods has significant shortcomings. Individuals each possess a unique ability to taste. Humans as test subjects will vary from individual to individual and the same person may not reproduce the same result for the same sample twice. Subjects utilized as sensory panelists inherently differ in their sensitivity to food attributes by levels of 2-10, based on a 15-cm line scale where 0 means no perceived difference and 15 indicates a large perceivable difference (Civille, 1979), or greater (Meilgaard, Civille, & Carr, 2007; Meilgaard & Reid, 1979). Individuals can be categorized as supertasters, tasters and non-tasters. It has been established that an individual's ability to perceive bitterness intensity with the use of the compounds phenylthiocarbamide (PTC) and 6-*n*-propylthiouracil (PROP) places the individual into either the supertaster, taster, or non-taster category (Fox, 1932; Bartoshuk, Duffy, & Miller, 1994; Bartoshuk, Fast, Karrer, Marino, Price, & Reed, 1992). It is preferred that panelists fall within the taster category, due to the fact they do not over/under perceive sensory thresholds. Meilgaard et al. (2007) state that tasters exhibit quite a bit of variability over time, they vary amongst themselves, and are highly prone to bias. Meilgaard et al. (2007) suggests that a) the measurement should be repeated, b) there is a representative sample of subjects, and c) the sensory analysts respects the rules and pitfalls that govern panel attitudes, in order to overcome the potential bias.

Extreme consideration must be taken when assembling sensory panels. Civille and Szczesniak (1973) state that, a texture profile panel is a valuable tool for describing and quantifying textural characteristics of food products when the panel is carefully selected, trained and maintained. Before allowing individuals to participate on sensory panels, an intense screening process must be conducted. Panelists must have received prior extensive training on the term definitions as well as exposure to suggested reference food samples (Meullenet, Finney, & Gaud, 2002). Still, Meullenet et al. (2002) state that even well trained sensory panelists will perceive samples in different ways and that these differences will impact the panelist's perception of the texture attributes.

Descriptive Sensory Analysis

According to Lawless and Heymann (2010), descriptive sensory tests are among the most sophisticated tools available for use by sensory scientists. Descriptive analysis testing involves the detection and description of both qualitative and quantitative components of food products using a panel of trained individuals (Civille, 1991; Murray, Delahunty, & Baxter, 2001). Munoz and Civille (1998) explain that qualitative attributes of a product are those that are perceived, while quantitative attributes are the intensities of the perceived attributes. Aroma, flavor, appearance, taste, and sound all fall under qualitative properties of a food product. One or a combination of these properties are unique to specific products, and allow for foods to be distinguished from one another. It is then the job of the trained sensory panelists to quantify the qualitative results to provide an accurate description of what is perceived (Murray & Delahunty, 2000). Meilgaard and Civille (2007) explained panels comprised of 5-10 subjects are utilized for the average product found on the grocery store shelf; however, those products that are mass-produced (i.e. beer and soft drinks) require panels consisting of much higher subject numbers because the most minute differences can be extremely important. The sensory panel must also be able to distinguish the intensity of the perceived quantitative attribute and have the ability to rank it on a 15-cm line scale, where 0 means no perceived difference and 15 shows a large detectable difference (Civille, 1979). Two products might be the same from a qualitative standpoint, but be inherently different in regards to their quantitative attributes—giving them distinct sensory differences (Meilgaard, Civille & Carr, 2007).

There are numerous descriptive analysis methods used throughout the food industry. These include: Flavour Profile Method (Cairncross & Sjostrom, 1950), Texture Profile Method (Brandt et al., 1963), Quantitative Descriptive Analysis™ (Stone et al., 1974), Spectrum™ (Meilgaard et al., 1991), Quantitative Flavour Profiling (Stampanoni, 1993), Free-choice Profiling (Langron, 1983; Thompson & MacFie, 1983), and generic descriptive analysis. While each method employs its' own approach, the generic descriptive analysis method is the most applicable to a practical setting as it can be manipulated to fit specific project goals (Lawless & Heymann, 2010; Murray et al. 2001).

Descriptive analysis can be carried out in both research and development and manufacturing to, 1) define the sensory properties of a target product for new product development (Meilgaard et al., 2007; & Sczcesniak, Loew, & Skinner, 1975), 2) define the characteristics/specifications for a control or standard for QA/QC and R&D application (Meilgaard et al., 2007), 3) document product attributes before a consumer test to help in the selection of attributes to be included in the consumer questionnaire and to help tin an explanation of the results of the consumer test (Meilgaard et al., 2007), 4) track a product's sensory changes over time with respect to understanding shelf life, packaging, etc. (Meilgaard, et al., 2007), 5) map perceived product attributes for the purpose of relating them to instrumental, chemical, or physical properties (Bargman, Wu, & Powers, 1976; & Meilgaard *et al.*, 2007), and 6) measure short-term changes in the intensity of specific attributes over time (Meilgaard et al., 2007). Through thorough comprehension of descriptive terms on a technical and physiological level for flavor, texture, and appearance, proper training of panelists to ensure proper application of terms can be applied, and the ability to use those terms on a consistent basis is the key to valid and reliable descriptive tests (Meilgaard et al., 2007).

Lexicons have been developed to establish a method to consistently interpret descriptive terms across all technical levels. Lawless and Civille (2013) define lexicons as a method of standardization for a vocabulary that has the ability to describe the sensory properties of consumer products. The development of lexicons arose from a need to relate information across all levels of an industry (research and development, sensory, marketing, etc.), and if based on scientific principles lexicons can be utilized by differing panels to accurately describe the same products (Lawless & Civille, 2013).

The American Society for Testing Materials (ASTM) describes lexicon development using 5 steps: 1) establishing the ‘frame of reference’ from a wide array of products in the category, 2) developing and generating terms that describe the products, 3) using references that describe the terms to clarify the terms and definitions, 4) using examples so the panel fully understands the terms, and 5) developing the final list of descriptors for the lexicon (ASTM; ASTM Stock #DS72 2011; Lawless & Civille, 2013); however, the 5 aforementioned steps assume: 1) that panelists have been appropriately selected and meet the necessary criteria, 2) that product space has been screened for products that represent the entire sensory panel, and 3) the given method of measurement for each attribute is appropriate (2013).

Donnell et al. (2001) investigated a method in order to develop a vocabulary to accurately describe odors of select distilled beverages. The research was done over 12 panel hours and the performance of each panelist and the panel as whole was monitored during development. Three sessions were conducted where 8 samples were analyzed encompassing a wide range of odors. Initially, the panel developed 30 terms, which was eventually reduced to 20 terms. After statistical analysis, it was determined sufficient improvement was seen in each individual panelist to deem the entire panel proficient in the descriptive analysis of distilled beverages (Donnell et al., 2001).

Spectrum Sensory Analysis

Meilgaard et al. (2007) explain that the Spectrum descriptive analysis method is a ‘custom design’ approach to panel development, selection, training, and maintenance. The Spectrum method, designed by Civille, provides a method to gain reproducible descriptive sensory data that can be replicated. Munoz and Civille (1998) provide 3 steps toward the Spectrum sensory analysis method: 1) review of samples and preliminary terminology development; 2) review of references and development of common terminology; and 3) product evaluation, discussion of results, and validation of the lexicon. Through proper implementation of these steps, the Spectrum descriptive analysis method will produce accurate, repeatable data. Civille (2010) states the Spectrum method utilizes a panel of 10 to12 highly competent consumers to converse about sensory and product attributes; these consumers aid in the early stages of marketing and product development by providing insight into the product being evaluate. The overall intention for Spectrum sensory analysis is to decide the most practical procedure for: 1) the product in question, 2) the overall sensory program, 3) the specific project objective(s) in developing a panel, and 4) the desired level of statistical treatment of the data (Meilgaard et al., 2007).

Sensory and Texture Correlation

Descriptive analysis methods are used heavily in the food industry because of their ability to be correlated with instrumental analysis. Sensory tests are often conducted simultaneously alongside instrumental analysis to determine correlations between the two (Meullenet et al., 2002; Szczesniak, 1987). Ruiz de Huidobro et al. (2005) explain that physical characteristics of meat are generally assessed using instrumental methods; however, these characteristics are of no value if they cannot be connected by sensory evaluation. Murray and Delahunty (2000) state that, knowledge of desired composition allows for product optimisation and validated models between descriptive sensory and the relevant instrumental and/or preference measures are highly desirable and are being utilized increasingly in the food industry. It should not be assumed that a linear relationship is appropriate when evaluating the relationship between sensory and instrumental attributes (Meullenet et al., 2002), and not evaluating non-linear relationships could lead poor statistical correlations (Szczesniak, 1968; Szczniak, 1987). Suggestions have been made to utilize several instrumental methods in order to properly and accurately predict a single sensory attribute (Meullenet et al. 1997; 1998; 2002).

Luckett et al. (2014) compared how well three different instrumental methods (Texture Profile Analysis (TPA), Blunt-Meullenet-Owens Razor Shear (BMORS) test, and Allo-Kramer Shear Press test (AKS)) predicted sensory texture attributes of poultry deli meats from data collected from a descriptive sensory panel. Fifteen commercially available poultry deli meats were used in the study. After analysis using the 3 varying instrumental texture measurement methods it was found that the BMORS test was an excellent predictor of the sensory attributes of hardness (R^2=0.95) and fibrousness (R^2=0.93), where R^2, the coefficient of determination, is a statistical measure of how close data are fitted to a regression line. It was seen that TPA provided the most accurate prediction of springiness (R^2=0.97). Cohesiveness of mass and rubberiness were not as highly correlated in the study with R^2 values of 0.59 and 0.70, respectively. The conclusion of the research made evident that a single instrument does not have the ability to accurately predict every texture attribute and the apparent importance of utilizing the correct instrumental method for the appropriate sensory characteristic (Luckett et al., 2014).

Caine et al. (2003) investigated the relationship between TPA, Warner-Bratzler-Shear (WBS), and sensory characteristics of beef rib steaks. TPA parameters were evaluated by cyclical texture profile analysis, using a star-shaped probe with two cycles of 80% penetration. Beef loins (n=52) were used in the study. TPA attributes of hardness, cohesiveness, and chewiness were negatively correlated ($P<0.05$) with trained sensory panel data showing initial tenderness at r=-0.64, -0.41, and -0.62, respectively, amount of connective tissue at r=-0.57, -0.27, and -0.55, respectively, overall tenderness at r= r=-0.68, -0.39, and -0.64, respectively, and overall palatability values at r=-0.56, -0.37, and -0.53, respectively. The r value, or correlation coefficient, measures the strength and direction of a linear relationship between two variables on a scatterplot. These attributes also displayed a negative correlation ($P<0.05$) with WBS values at r=-0.61, -0.49, -0.60, and -0.56, respectively. A stepwise regression analysis was conducted to generate equations that included the TPA parameters of hardness and adhesiveness, these accounted for 47, 36, 51 and 38% of the variation in initial tenderness, amount of connective tissue, overall tenderness, and overall palatability, respectively. The same predicted equations using WBS accounted for 37, 24, 36, and 31% of variation in initial tenderness, amount of connective tissue, overall tenderness, and overall palatability, respectively. The study concluded that TPA better explained the variation in subjective sensory tenderness (Caine, et al., 2003).

Cavitt et al. (2005) conducted research comparing razor blade shearing method, Allo-Kramer, and Warner-Bratzler shear force method on their ability to be accurately correlated to descriptive sensory methods by predicting tenderness of broiler breast fillets. The relationship between instrumental analysis and descriptive sensory attributes exhibited coefficients of determination of $0.53 < R^2 < 0.73$ for initial hardness and chewdown hardness, while, the relationships between the instrumental analysis and the consumer sensory attributes of tenderness acceptability and intensity had coefficients of determination ranging between $0.71 < R^2 < 0.97$. It was determined that all shear tests utilized produced similar results for predicting broiler breast tenderness; it was noted that the razor blade shear held an advantage over the other methods due to lack of sample prep and lack of sample destruction compared to the other methods (Cavitt et al., 2005).

Instrumental Texture Analysis

Sensory evaluation is an expensive, time-consuming process that requires years to gain proper training, so instrumental approaches for texture analysis have been developed to offset some of these challenges (Bourne, 2002). The multi-parameter nature of texture, as reported by Szczesniak (2002), makes understanding texture challenging. This is especially true considering how individuals' tastes vary from person to person. Even individuals who have been extensively trained will perceive food texture in different ways from other individuals with the same training (Meullenet et al., 2002). Instrumental analysis can alleviate some of the variation.

It is known that human-beings are capable of perceiving, describing, and quantifying texture (Xiong et al. 2002); however, conducting sensory evaluations are labor intensive, time consuming, and expensive (Caine et al., 2003). The texture of products that are mass-produced must be confidently assessed, and the data collected must be statistically comparable to what would be gathered from sensory panels. The process of human mastication involves various structures such as lips, cheeks, tongue, an array of muscles and joints, and selection of teeth, which are used to manipulate foodstuffs (Meullenet et al., 2002). Instruments used to measure texture lack these structures, and cannot accurately mimic oral motion, bite force, or show the effects of temperature and saliva that occur during mastication (Jack et al., 1993; Meullenet, 2002).

The multi-dimensional aspect of texture in the field of sensory evaluation has long been understood (Szczesniak, 1963, 1987; Meullenet & Gross, 1999; Meullenet *et al*., 2002). Using instrumental methods requires a firm understanding of the vast texture vocabulary, as well as the realization that the same attribute for one food product might be perceived differently for another. Examples suggested by Lawless and Heymann (2010) are: is sensory hardness the same for cheese as it is for a cookie; is the perceived juiciness for a grape the same as for a cooked steak? Blindly assuming all foods have the same perceived sensory texture could lead to skewed results.

Szczesniak (1968; 1987) cautioned against assuming correlations between sensory and instrumental attributes. Aside from blind assumptions, if proper testing is done there may still be variability among samples. This can be caused by, a) the correlation coefficient is dependent on the range and number of samples used, b) the instrumental measurement should mimic as close as possible the condition used to evaluate the sensory attribute, c) since the sample is often destroyed during measurement, the same sample cannot evaluated by both methods, and d) natural variability among panelists in terms of chewing cycles, dentition, salivary flow rate, etc.—this will affect the quality of instrumental texture relationships (Lawless & Heymann, 2010; Szczesniak, 1968,1987).

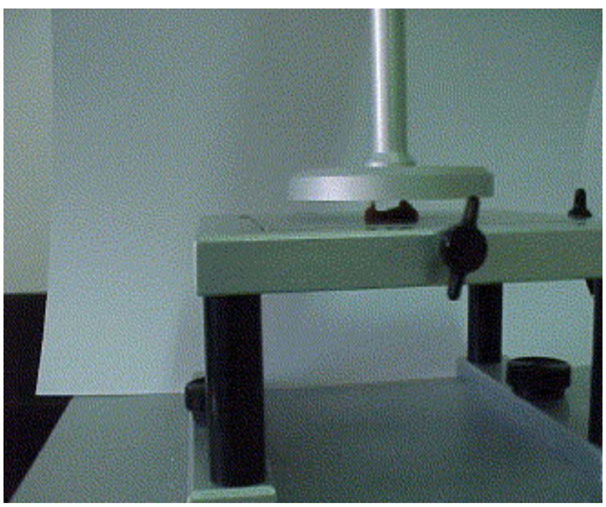
Texture Profile Analysis

Texture Profile Analysis (TPA) is an instrumental method used to determine texture of food products, in tandem with heavy use in other industries. TPA is a double compression test where samples are compressed twice in order to simulate chewing motion of the mouth (Illustrations 1 and 2). TPA is popular as an analytical texture measurement because it can, in some cases, quantify multiple textural food components in a single experiment; however, the TPA method chosen will not accurately assess each single texture parameter appropriately in a given study- extreme consideration must be taken by the researcher (Texture Technologies).

TPA measures 7 texture parameters: hardness, fracturability, cohesiveness, springiness, gumminess, chewiness, and resilience. Illustration 3 indicates a typical TPA curve, and delineates how each of the 7 parameters are calculated. Texture

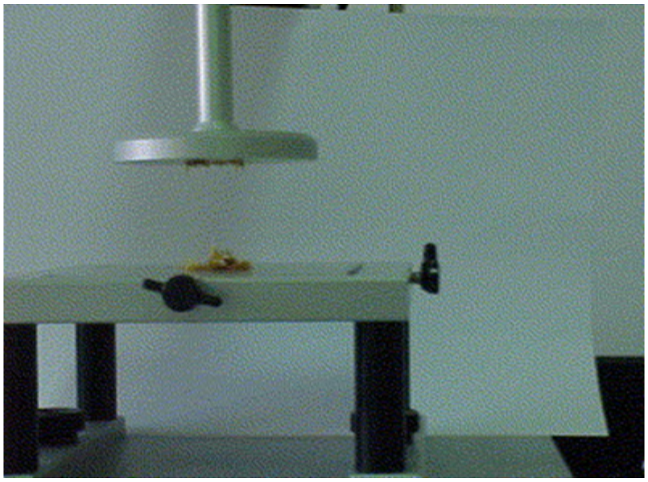
Technologies indicates that hardness is expressed as the maximum force of the first compression, fracturability is the force at the first peak, cohesiveness is the area of work during the second compression divided by the area of work during the first compression, springiness is expressed as a ratio or percentage of a product's original height and is most off measure by the distance of the detected height during g the second compression divided by the original compression distance, gumminess is found multiplying hardness by cohesiveness, chewiness is calculated as gumminess multiplied by springiness, and resilience is found by dividing area 4 by area 3.

Illustration 1. Initial TPA compression



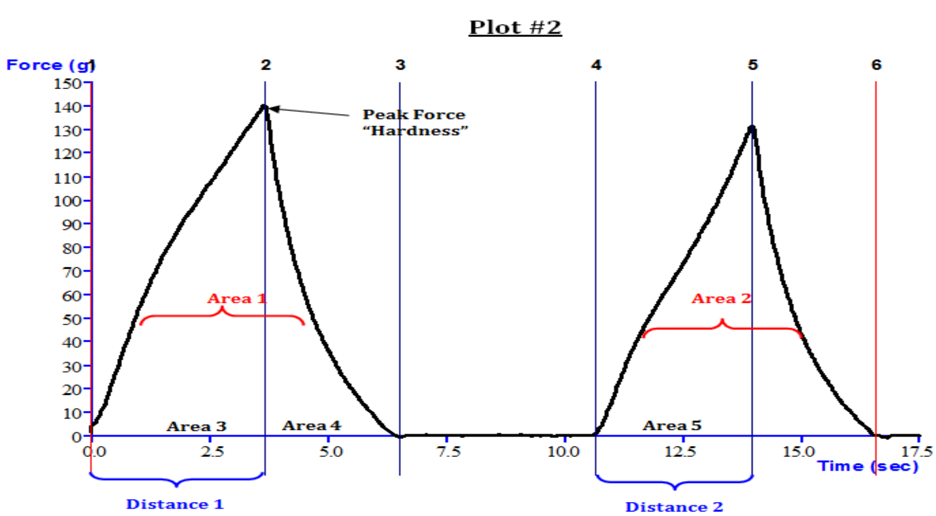
Adapted from Texture Technologies (http://texturetechnologies.com/texture-profile-analysis/texture-profile-analysis.php).

Illustration 2. Second cycle TPA compression



Adapted from Texture Technologies (http://texturetechnologies.com/texture-profile-analysis/texture-profile-analysis.php).

Illustration 3. Typical TPA curve with attribute calculation



Adapted from Texture Technologies (http://texturetechnologies.com/texture-profile-analysis/texture-profile-analysis.php).

Meullenet and Gross (1999) explain imitative instrumental methods are those that imitate conditions were sensory properties are perceived by humans. Texture Profile Analysis is a major example of an imitative test. Texture Profile Analysis was developed in the early 1960s by scientists at General Foods Corporation (Lawless & Heymann, 2010). Szczesniak (1963), one of the key contributors to TPA, realized the need of a method paralleling consumers' understanding of texture with that of industry professionals. Szczesniak (2002) describes TPA as an instrumental method that involves compressing the test substance at least twice and quantifying the mechanical parameters form the recorded force-deformation curves. TPA has the ability to be excellently correlated to sensory ratings, with good to excellent correlations for hardness (Szczesniak, 2002).

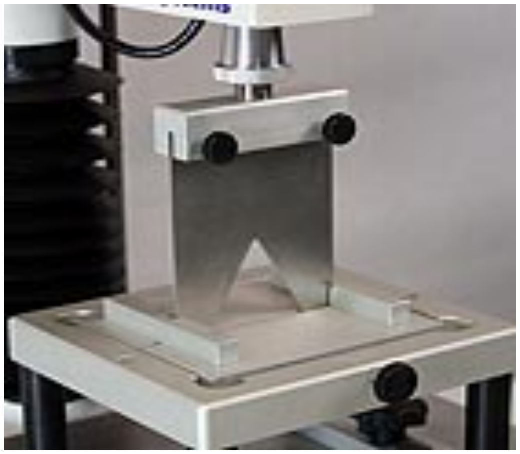
Yilmaz et al. (2012) used TPA as a method to analyze the effects of differing oil temperature levels on the viscoelastic behavior of oil-in-water (O/W) model system meat emulsions using creep and creep-recovery tests. The study showed increasing oil level increased hardness, chewiness, gumminess, resilience, and cohesiveness with R^2 values of 0.999, 0.988, 0.995, 0.979 and 0.878, respectively. The research concluded oil levels had a decreasing effect on adhesiveness and springiness with R^2 values of 0.939 and 0.938, respectively. Additionally, correlations between creep-recovery and TPA were found to be significant ($P < 0.05$) using Pearson's test. TPA results were significant for linear negative and positive correlation among all parameters evaluated, and displayed high determination coefficients falling between the range of 0.854 and 0.998.

Warner-Bratzler Shear

Warner-Bratzler shear force has been used extensively throughout the meat industry for many years. The Warner-Bratzler device is composed of a rectangular-shaped blade with a triangular- shaped area removed from the center, and can either be used on a WBS machine or with WBS blade that attaches to an automated testing machine (Illustration 4). The samples analyzed by the Warner-Bratzler Shear are generally a cylinder core for meat and a strip for poultry products. The sample is placed in the triangular hole of the blade, the blade is then lowered and the force required to penetrate the sample is measured.

The American Meat Science Association (2015) released Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat, and Warner-Bratzler shear force specifications are given. These specification include: 1) blade thickness of 1.1684 mm (0.046 inches); 2) V-notched (60º angle) cutting blade; 3)cutting edge beveled to a half-round; 4) corner of V rounded to a quarter-round of a 2.363 mm diameter circle; 5) spacers providing gap for cutting blade to slide through of 2.0828 mm thickness. Final cooked temperatures and weight of the samples should be taken post-cooking, and the samples should be chilled overnight at 2 to 5ºC before coring. Round cores should be a uniform 1.27 cm (0.5 inches) in diameter and removed parallel to the longitudinal orientation of the muscle fibers so that the shearing actions is perpendicular to the longitudinal orientation of the muscle fibers.

Illustration 4. Warner-Bratzler shear apparatus

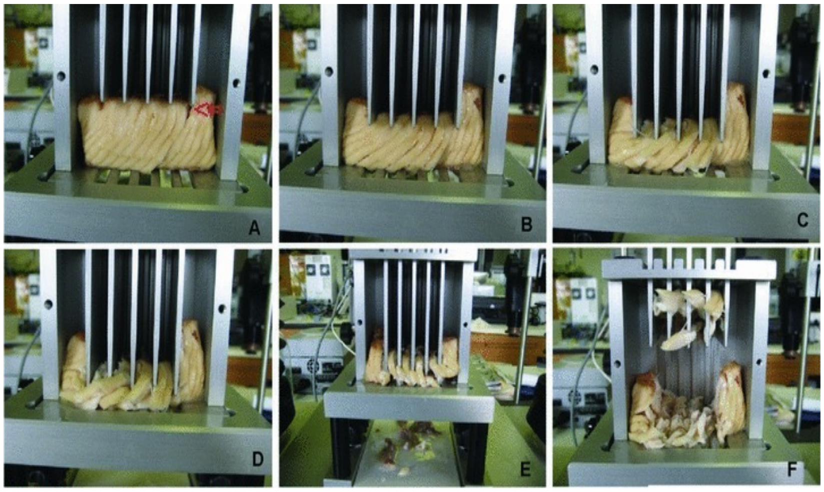


Adapted from Texture Technologies (http://texturetechnologies.com/texture-analysis/Probes-Fixtures.php).

Allo-Kramer Shear

The Allo-Kramer Shear cell is comprised of a metal box with slots where the sample is placed, the top portion of the Allo-Kramer Shear possesses metal blades (either 5 or 10) that correspond with the number of slots in the bottom portion of the device (Illustration 5). The top portion is attached to a texture analyzer that moves the blades downward, first compressing the sample, and then shearing the sample across the muscle fibers and through the sample. Compared to other texture analyzing methods the Allo-Kramer Shear is heavier and lacks portability; however, it is used extensively throughout the meat and poultry industries (Owens, Alvarado, & Sams, 2010).

Illustration 5. 5-blade Allo-Kramer shear



Adapted from Aussanasuwannakul et al., 2010.

Cavitt et al. (2005) conducted a study where Allo-Kramer Shear, among other texture analysis methods, was used to predict rigor development and meat quality of large and small broilers. Two trials were conducted, and each trial was comprised of 75 male and 75 female broilers of varying sizes. Breasts were deboned at 0.25, 1.5, 3, 6, and 24 hours postmortem. Allo-Kramer shear tests were performed on breast fillet strips measuring 40 x 20 x 7 mm. The Allo-Kramer shear test results showed differences at sampling times of < 1.5-h and > 6-h postmortem; nevertheless, Allo-Kramer shear results only showed a moderate correlation of r = 0.72 for differentiating breast meat of differing toughness.

Cavitt et al. (2004) performed a study to evaluate an alternative shearing method to determine poultry meat tenderness comparing Allo-Kramer (AK), razor blade (RB) shear, and laser sarcomere length determination. Breast fillets were deboned at varying postmortem times from 0.25 to 24-hours in attempts to differentiate a broader spectrum of tenderness. Commercial age broilers (n=270) divided evenly into 3 replications were harvested at 7 weeks of age. After processing, the birds were divided into 30 carcasses per treatment in 3 replicates and chilled using a two-stage chilling system involving 0.25 hour pre-chill at 13ºC followed by an agitated ice-slush chill at 1ºC for 0.75 hours. At deboning, both right and left pectoralis muscles were removed then aged on ice until 24 hours post mortem in plastic bags, then stored at -20ºC until evaluation. Sarcomere length is known to be an indirect measure of tenderness and was evaluated by examining the cranial region of the left fillets using laser diffraction method. The entire right pectoral and cranial region of the left fillet were used for sensory and instrumental analysis. The samples were baked individually, covered in an aluminum foil lined pan using raised racks under the same cooking variables (end point temperature of 76ºC). All samples were then wrapped in aluminum foil and stored overnight at 4ºC and analyzed the next day using the three aforementioned methods. Allo-Kramer shear values (AKSV), razor blade shear force (RBF), and razor blade energy (RBE) were used as the determinants of meat tenderness. It was found that for predicting initial hardness, RBF and RBE gave R^2 values of 0.75 and 0.84, respectively; while sarcomere length showed an R^2 value of 0.86- these were better indicators compared to AKSV with an R^2 value of 0.68. In addition, chewdown hardness was more accurately portrayed by RBF, RBE, and sacromere length- with R^2 values of 0.73, 0.84, and 0.86, respectively; compared to an AKSV R^2 value of 0.66. Evaluating root mean square error it was determined both RBE and sarcomere length were significantly better predictors than AKSV.

Meullenet-Owens Razor Shear

The Meullenet-Owens Razor Shear (MORS) is comparable to the methods used in Allo-Kramer and Warner-Bratzler methods; however, it has the capabilities to be used on intact muscle samples rather than cores or strips (Owens, Alvarado, & Sams, 2010). MORS is performed on cooked, whole breast fillets and analyzes the sample by shearing the sample perpendicularly to the longitudinal fiber orientation in four or more predetermined locations (Illustration 6) (Owens et al., 2010).

Illustration 6. Meullenet-Owens Razor Shear.

Adapted from Texture Technologies (http://texturetechnologies.com/texture-analysis/Probes-Fixtures.php).

Meullenet-Owens Razor Shear is most commonly performed on a texture analyzer (Texture Technologies Corporation, Scarsdale, NY); however, the University of Arkansas to conducted an experiment to determine if MORS can be successfully performed on an Instron InSpec 2200 tester (Lee, Owens, & Meullenet, 2008). In part of the study, the tenderness of 157 cooked broiler breast fillets was determined using a texture analyzer and an Instron InSpec 2200. A correlation coefficient of 0.95 for MORS energy was determined for both of the tests, showing that MORS tests can be performed on an Instron InSpec 2200 as accurately as tests ran on a texture analyzer (Lee, Owens, & Meullenet, 2008).

Materials and Methods

Preliminary Data

A single instrumental method does not have the capabilities to accurately assess each single texture parameter appropriately in a given study; therefore, multiple probes and fixtures were tested. A 5-blade Allo-Kramer shear (AKS) was used on test samples. Samples, were analyzed as a single slice folded over, were too thin for proper reading on the AKS. The 5 blades quickly penetrated samples and pulled portions of the sample through the corresponding slots in the base of the apparatus. Many studies have utilized the AKS successfully in whole muscle texture analysis, including: broiler breast fillets, poultry pectoralis muscles, Rainbow Trout fillets, and pork longissimus muscles (Lyon et al. 1990; Cavitt et al., 2004; Cavitt et al., 2005; Xiong et al., 2006; Aussanasuwannakul et al., 2010; Miller et al., 1989); however, Luckett et al. (2014) conducted a study using the AKS on poultry deli meat. The samples were not deli meat slices, but cores from deli loaves. The increased sample thickness allowed for a proper reading to be taken by the machine.

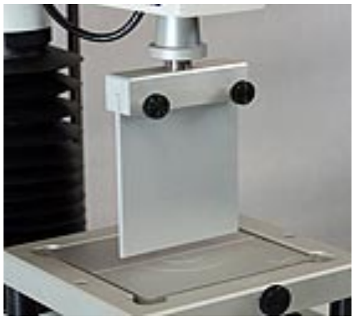
Combinations of different probes and fixtures were utilized using TPA on samples. The TA-108s (Illustration 7) fixture was tested using both a ½" and a ¾" diameter ball probes. Using both probe/fixture combinations resulted in usable data; however, the corporate headquarters are interested in a method that can be used efficiently and sanitarily in a plant or pilot plant setting. The sample was larger than the surface of the TA-108s fixture and a large amount of residue from the sample became engrossed in the bolts used to secure the sample into the fixture.

Illustration 7. TA-108s

Adapted from Texture Technologies (http://texturetechnologies.com/texture-analysis/Probes-Fixtures.php).

The TA-43R, 3-mm knife blade, (Illustration 8) was used. Similar to the AKS, the samples were pulled through the slot at the base of the fixture during the first compression, skewing the first reading and making the reading of the second compression unreadable.

Illustration 8. TA-43R



Adapted from Texture Technologies (http://texturetechnologies.com/texture-analysis/Probes-Fixtures.php).

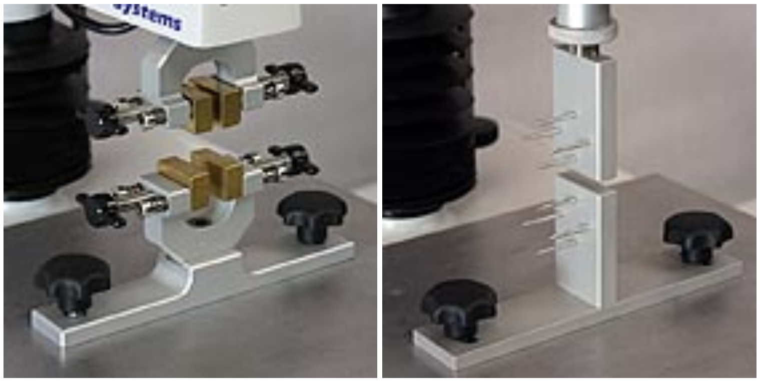
Two cylinder probes were utilized (TA-25 and TA-40). TA-25 (Illustration 9) has a 2” diameter and is 20-mm tall, during the first compression the probe destroyed the sample and after the first compression a large portion of the sample was stuck to the bottom of the probe or stuck around the outer perimeter of the probe preventing accuracy for the second compression. This was seen for the TA-40, a 4” diameter, 10-mm tall, (Illustration 10). Distances of 3-mm and 4-mm were also tested seeing the same problems.

Illustrations 9 TA-25, and **10**, TA-40, respectively.

Adapted from Texture Technologies (http://texturetechnologies.com/texture-analysis/Probes-Fixtures.php).

Samples' tensile properties were tested to differentiate the presence of muscle fibers among the samples. The TA-96B (Illustration 11) and the TA-226 (Illustration 12) were used. Of the two, the TA-96B was preferred. The TA-226 possesses very sharp needle points used to pull apart the samples; while the TA-96B has flat, adjustable clamps. Neither probe could accurately assess the quantity of textural attributes deemed necessary; however, both did well at analyzing the tensile properties.

Illustrations 11. TA-96B and **12**, **TA-226**, respectively.



Adapted from Texture Technologies (http://texturetechnologies.com/texture-analysis/Probes-Fixtures.php).

The TA-108s5i fixture (Illustration 13) with a ¼” rounded end (TA-8) was finally chosen as the testing official testing method. The fixture has the capabilities to take up to 5 readings from the same sample, aiding in analyzing the texture of the deli meat sample in its entirety. The fixture does have bolts to secure sample; however, residue does not contaminate the bolts. Running up to 5 readings per sample is timely, but it is believed to give the most accurate texture reading. Also, it meets the safety requirements set forth by the corporate office.

Illustration 13. TA-108s5i

Adapted from Texture Technologies (http://texturetechnologies.com/texture-analysis/Probes-Fixtures.php).

Descriptive Sensory Analysis

Descriptive sensory analysis was conducted by a group consisting of 10 highly trained panelists, employed by a deli meat production company for over 4 years. Their training focused on the lunchmeat category. Employed panelists met 15 hours weekly to profile products, review scales, and review references ensuring panel synchronization with one another. Panelists were trained in the Spectrum method (Sensory Spectrum Inc, Chatham, NJ) for flavor, texture, and appearance using a 15-point scale. Seventeen textural attributes were evaluated for this study. The 17 attributes evaluated were: surface roughness, surface moisture, firmness, denseness, cohesiveness, uniformity of bite, juiciness, cohesiveness of mass, roughness of mass (grainy, lumpy, and fibrousness), moistness of mass, fibrous between teeth, mouthcoat (type), loose particles, and appearance of striations. References were used throughout the descriptive panel; however, these are proprietary and not disclosed. Tables 1.1-1.4 were adapted from Civille, Meilgaard, & Carr (2010) as an illustration of a lexicon that could be used for training and testing.

Samples were removed from refrigerated storage (4 ± 2ºC) and distributed to panelists each given a single slice of deli meat, folded over. The 17 attributes were divided into 5 stages: surface, first bite/chew, chewdown, residual, and appearance. Analysis of the samples' attributes were analyzed according to these stages and ranked using a 15-point numerical scale.

Table 1.1 Lexicon for surface texture analysis

Term	Definition	Technique	Reference
		Surface	
Roughness	The overall amount of small and large particles in the surface	Hold sample in mouth; feel the surface to be evaluated with the lips and tongue	Gelatin: 0 Potato Chip: 8 Rye Wafer: 15
Moistness	The amount of wetness or oiliness on surface	Presence of oil of the surface	Unsalted Premium cracker: 0 Apples: 7.5 Water: 15

*Adapted from Civille, Meilgaard, & Carr, 2010, Chapter 11

Table 1.2 Lexicon for first bite/chew texture analysis

Term	Definition	Technique	Reference
		First bite/chew	
Firmness	The force required to bite completely through the sample	Place food between the molars and bite down evenly	Cream Cheese: 1 Frankfurter: 7 Hard Candy: 14.5
Denseness	Compactness of cross sections	Place sample between molars and compress	Cool whip: 0.5 Malted Milk Ball: 6 Fruit jellies: 13
Cohesiveness	Amount of sample that deforms rather than ruptures	Place sample between molars; compress fully	Corn muffin: 1 Dried fruit: 10 Chewing gum: 15

*Adapted from Civille, Meilgaard, & Carr, 2010, Chapter 11

Table 1.3 Lexicon for chewdown texture analysis

Term	Definition	Technique	Reference
		Chewdown	
Juiciness	The amount of juice/moisture perceived in the mouth	Chew sample with molar for up to 5 chews	Banana: 1 Cucumber: 8 Watermelon: 15
Cohesiveness of Mass	Degree to which samples holds together in a mass	Chew sample with molars for up to 15 chews	Licorice: 0 Frankfurter: 7.5 Dough: 15
Fibrous Between Teeth	The amount of short, smooth fibers in the sample	Place sample between molars and chew up to 6 times	Dried Apricots: 2.5 Hard Salami: 5 Celery: 9

*Adapted from Civille, Meilgaard, & Carr, 2010, Chapter 11

Table 1.4 Lexicon for residual texture analysis

Term	Definition	Technique	Reference
		Residual	
Mouthcoat (type)		Swallow sample and evaluate residue in mouth	Cooked Cornstarch: 3 Pureed potato: 8 Tooth Powder: 12
Oily	Amount of oil left on mouths surfaces		
Sticky	Stickiness/tackiness of coating when tapping tongue on roof of mouth		
Loose Particles	Amount of particles left in mouth	Swallow sample and evaluate residue in mouth	Corn Starch: 3 Sour cream and instant cream of wheat: 5 Mayonnaise and fine corn meal: 10

*Adapted from Civille, Meilgaard, & Carr, 2010, Chapter 11

The Spectrum Descriptive Analysis Method

When selecting panelists for descriptive analysis, the panel leader or panel trainer should determine each candidate's capabilities in three major areas: 1) for each of the sensory properties under investigation, the ability to detect differences in characteristics present and in their intensities; 2) the ability to describe those characteristics using (a) verbal descriptors for the characteristics and (b) scaling methods for the different levels of intensity, and 3) the capacity for abstract reasoning, as descriptive analysis depends heavily upon the use of references when the characteristics must by quickly recalled and applied to other products (Meilgaard, Civille, & Carr, 2010).

Panelists should be screened for their ability of descriptive language, and it is required of the panel leaders to prescreen candidates for the following personal criteria: 1) willingness in full participation and in the rigors of the training, practice, and ongoing work phases of a descriptive panel, 2) availability to participate in 80% or more of all phases of the panel's work; regardless of outside duties and commitment, and 3) general good health and no illnesses related to the sensory properties be measured (Meilgaard, Civille, & Carr, 2010).

Panelists' ability to detect and describe differences and their ability to apply abstract concepts can all be determined through a series of tests that include: 1) a set of prescreening questionnaires, 2) a set of acuity tests, 3) a set of ranking/rating tests, and 4) a personal interview (Meilgaard, Civille, & Carr, 2010).

Experiment 1 Sample Preparation

Four different turkey deli meats were used to carry out this experiment. All were produced in commercial processing plants, where 3 were packaged in plant and shipped, and one was hand sliced at the corporate headquarters, placed in modified atmosphere packaging, and shipped. The products chosen for the experiment were from the company's deli meat line: Natural Oven Roasted Turkey (NORT), Bulk Oven Roasted Turkey (BORT), Brand Oven Roasted Turkey (ORT), and Classic Oven Roasted Turkey (CORT). Samples were received at Auburn University in an insulated shipping container and stored at refrigerated temperatures (4 ± 2º C) for 1 week. 24 h prior to instrumental texture analysis, samples were prepared (each treatment out of refrigeration ≤ 1-hr), and placed back into refrigerated storage (4 ± 2º C). Samples were prepared by dividing 15 slices per brand, per treatment (distance, 25% strain, 30% strain), with 3 data points being collected per sample, totaling 45 slices per brand. The 3 data points per sample were averaged for each TPA parameter.

Experiment 1 Texture Profile Analysis

Experiment 1 samples were folded over once and analyzed using TPA developed by Szczesniak (1963). A Texture Analyzer (TA-XT2i, Texture Technologies, Scarsdale New York) with a 30-kg load cell was used. A two-cycle compression was used with texture analyzer settings of: either a target distance of 5-mm, a strain of 25%, or a strain of 30%, a pre-test speed of 2-mm/s, test-speed of 0.5-mm/s, post-test speed of 0.5-mm/s, and trigger force of 5-g. The samples were analyzed for 5 TPA parameters: hardness, springiness, cohesiveness, chewiness, and resilience. Fifteen replications were done for each treatment (distance, 25% strain, 30% strain) with 3 data points from each replication- totaling 45 readings per treatment.

The fixture used for this study was the TA—108s-5i. This fixture was selected due to its ability to allow for up to 5 data points to be collected per sample. For this study specifically, 3 data points were obtained per sample due to sample size. Data points were acquired using Exponent Lite Express (Stable Micro Systems Ltd, Godalming, Surrey, U.K.), then averaged for each category.

Experiment 1 Statistical Analysis

The PROC CORR and PROC GLM procedures of SAS (SAS Institute Inc., Cary, NC) were used to analyze data collected in Experiment 1. PROC GLM was used to determine if instrumentation depicted similar differences to those seen in the descriptive sensory analysis results. Treatment (brand) was analyzed against descriptive sensory data, and treatment (distance, 25%, 30%) was analyzed against TPA parameters. PROC CORR was used to establish correlation coefficients between TPA parameters and descriptive sensory data. To verify correlations, Pearson's least squares regressions were made using Microsoft Excel (version 2010) where R^2 values were retrieved to check the fit to the regression line.

Experiment 2 Sample Preparation

The effects of stacking deli meat slices on texture was investigated. Three deli meat brands were analyzed: Hillshire Farms Hard Salami (HFHS), Oscar Mayer Turkey Bologna (OMTB), and Oscar Mayer Oven Roast Turkey Breast (OMORT). Samples were purchased from a local retail market, and produced in commercial processing plants from their respective companies. Samples were chosen to encompass a wide range of potential deli meat textures. Samples were all held under refrigerated temperatures (4 ± 2º C) for 24-hr. Samples were prepared by stacking 1 slice, 2 slices, 3 slices, 4 slices, and 5 slices of each brand, then divided into respective replicates, and placed on an 8 3/4'' x 6 1/4" Styrofoam tray (GenPak, LLC. Glens Falls, NY), wrapped in Saranwrap™, and placed back into refrigerated storage (4 ± 2ºC) overnight.

Experiment 2 Texture Profile Analysis

A Texture Analyzer (TA-XT2i, Texture Technologies, Scarsdale New York) with a 30-kg load cell was used. A two-cycle compression was used with texture analyzer settings of: target distance of 5-mm, pre-test speed of 2-mm/s, test-speed of 0.5-mm/s, post-test speed of 0.5-mm/s, and trigger force of 5-g. The samples were again analyzed for the same 5 TPA parameters. Five replications were done for each treatment, with 3 data points collected for each sample- totaling 15 reading per treatment. The 3 data points obtained for each sample were averaged for each corresponding category.

Experiment 2 Statistical Analysis

For Experiment 2, Pearson's least squares regression models were created in Excel (version 2010) to correlate how the number of stacked slices influences TPA parameters.

Results and Discussion

Texture plays a key role in most meat products; however, little research has been conducted on the texture of deli meat. Causative factors are: 1) deli meat encompasses proteins from multiple species and some products use a combination of different proteins, 2) depending on the value of the product, deli meat can be highly or minimally processed, and 3) even those ‘higher’ valued products are a fraction of the cost of deli meat’s whole muscle contemporaries. Research dollars are more likely going to be directed to whole muscle type products (i.e. steak) because they will have a greater financial impact on the industry; nevertheless, having the ability to accurately quantify deli meat texture is important.

Due to the extensive processing methods and techniques, wide array of non-meat ingredients, and varying quality of raw meat ingredients used, the uniformity of deli meat varies greatly. The inconsistency of deli meat is not only a problem from deli loaf to deli loaf of same products, but it is an issue seen from slice to slice of the same loaf. The ability to accurately quantify deli meat texture is challenging, and the aforementioned inconsistencies are to blame.

Spectrum Sensory Analysis

For Experiment 1 data gained through Spectrum sensory analysis at a corporate office is shown Table 9. The data represents mean values for each attribute from a 10-member, highly trained descriptive panel. Deli meat’s complex nature makes the

Spectrum method an appropriate descriptive method to use. Murray et al. (2001) explain this method focuses on the entire ‘spectrum’ of a product’s attributes. The main principal for Spectrum analysis is the use of reference scales, specialized panel training and scaling procedures (Murray et al., 2001 & Meilgaard et al., 1991). For Spectrum analysis in Experiment 1, 17 attributes were analyzed. Attributes were divided into 5 stages: product surface, first bite/chew, chewdown, residual, and appearance.

Bolded results seen in Table 2 represent the highest value for each attribute. Sample NORT ranked highest in 7 attributes, samples CORT and BORT ranked highest in 5 attributes each, and sample ORT ranked highest in 1 attribute. It is important to understand how each brand compares to the others in a descriptive sensory panel, to understand if the same comparisons are seen in instrumental analysis. Making connections between sensory attributes and TPA parameters is important to this portion of the experiment. TPA hardness was expected to correlate well with sensory denseness and firmness. TPA cohesiveness was expected to correlate well with sensory cohesiveness and sensory cohesiveness of mass, and TPA chewiness was expected to be correlated with sensory uniformity of bite.

Some differences perceived in the sensory panel are likely a result of the processing techniques and procedures used to manufacture these products. For instance, treatment NORT is a natural product, with minimal added ingredients and minimally processed. The process used to manufacture NORT is quite different than the processes used in the other 3 conventionally processed brands; therefore, this definite difference could explain why NORT treatment was consistently ranked higher. Oppositely, treatment CORT is marketed as a ‘value’ type product, where the raw materials (meat and non-meat) are assumed to be of lower quality to obtain the lower price point when marketed. This could also be attributed to the reason the sensory descriptive ratings for the product was consistently bottom tier.

Table 2. Mean descriptive sensory attributes

	CORT	ORT	NORT	BORT
SURFACE				
Roughness	0.0	0.0	1.0	3.0
Moisture	**7.0**	2.5	**7.0**	6.0
FIRSTBITE/CHEW				
Firmness	5.0	5.0	**5.5**	4.5
Denseness	**9.5**	**9.5**	**9.5**	9.0
Cohesiveness	3.0	3.5	**4.0**	**4.0**
U of bite	10.0	11.0	**11.5**	11.0
CHEWDOWN				
Juiciness	1.0	1.0	**3.0**	2.0
COM	4.5	5.5	7.0	**7.5**
ROM	**6.5**	6.0	6.0	5.5
Grainy	0.0	0.0	**1.0**	0.5
Lumpy	**5.0**	2.0	0.0	0.0
Fibrous	1.5	4.0	**5.0**	**5.0**
MOM	**7.5**	6.0	6.5	6.0
Fibrous b/w Teeth	2.0	3.0	3.5	**4.0**
RESIDUAL				
Mouthcoat (type)	**2.0**	1.0	1.5	1.5
Loose Particles	3.0	3.0	3.5	**4.0**
APPEARANCE				
Amount of Striations	1.0	1.0	3.5	**12.0**

Experiment 1

Experiment 1 applied TPA to deli meat samples from 4 different brands, with 3 treatments applied to each brand. The method of analysis stemmed from preliminary data, using multiple methods of instrumental analysis- including numerous TPA probes and fixtures. The TA-108s5i, with a ¼” rounded end probe was chosen as to conduct analysis. The TA-108s5i provided the ability to obtain 5 readings at different locations on the same deli slice. Multiple readings on the same sample will result in a more accurate analysis of the deli meat texture. Due to sample size, only 3 readings were taken per sample. Ideally, samples would have been large enough to take 5 readings, but size was predetermined by the processor.

To determine if differences between brands observed in corporate descriptive sensory analysis were the same as differences seen instrumentally, descriptive sensory data (seen in Table 2) were analyzed using PROC GLM function of SAS 9.4. Differences in treatment versus descriptive sensory data for the surface of the deli meat are shown in Table 3. For sensory roughness, NORT and BORT were different ($P < 0.0001$) among all treatments. There was no perceived roughness for CORT and ORT. For sensory moistness, CORT and NORT were not different from each other ($P > 1.00$), but were different ($P < 0.0001$) from treatments ORT and BORT- both different among all brands.

Table 3. Mean surface descriptive sensory data of 4 brands of turkey deli meat

Trt	Roughness	Moistness
CORT	0.00[c]	7.00[a]
ORT	0.00[c]	2.50[c]
NORT	1.00[b]	7.00[a]
BORT	3.00[a]	6.00[b]

[a-d]Means with no common superscript differ significantly ($P < 0.05$).

Treatment versus descriptive sensory first bite/chew data shown in Table 4. For sensory firmness, NORT and BORT were different among all treatments ($P < 0.0001$), and CORT and ORT were not different ($P > 1.0$). Sensory denseness data shows BORT was different ($P < 0.0001$) against all treatments, with no differences ($P > 1.00$) observed in the other 3 treatments. Treatments CORT and ORT were different ($P < 0.0001$) for sensory cohesiveness compared to all treatments. Treatments CORT and

NORT were different among all treatments ($P < 0.0001$) for uniformity of bite, while ORT and BORT were different ($P < 0.0001$) from CORT and NORT, but not different from each other ($P > 1.00$).

Table 4. Mean first bite/chew descriptive sensory data of 4 brands of turkey deli meat

Trt	Firmness	Denseness	Cohesiveness	Uniformity of Bite
CORT	5.00^{b}	9.50^{a}	3.00^{c}	10.00^{c}
ORT	5.00^{b}	9.50^{a}	3.50^{b}	11.00^{b}
NORT	5.50^{a}	9.50^{a}	4.00^{a}	11.50^{a}
BORT	4.50^{c}	9.00^{b}	4.00^{a}	11.00^{b}

$^{a\text{-}d}$Means with no common superscript differ significantly ($P < 0.05$).

Table 5 shows treatment versus sensory descriptive chewdown data. Sensory cohesiveness of mass and fibrous between teeth were different ($P < 0.0001$) among all treatments. For sensory juiciness, NORT and BORT were different ($P < 0.0001$) from all treatments, while CORT and ORT were different ($P < 0.0001$) from BORT and NORT, but not each other. Treatments CORT and BORT were different ($P < 0.0001$) from all treatments for sensory roughness of mass, while ORT and NORT were different ($P < 0.0001$) from CORT and BORT, but not different ($P > 1.00$) against each other. Sensory lumpiness was different ($P < 0.0001$) for all treatments. For graininess, CORT and ORT were not different from one another (P > 1.00); however, they were different against the other two treatments ($P < 0.0001$), and NORT and BORT were different ($P < 0.0001$) from all treatments. CORT and ORT were observed to be different ($P < 0.0001$) among all treatments, while NORT and BORT were not different ($P > 1.00$), but were different ($P < 0.0001$) from other treatments. Treatments ORT and BORT were not different ($P >$

1.00) for sensory moistness of mass, but were different (*P* < 0.0001) from all other treatments; CORT and NORT were different (*P* < 0.0001) against all treatments.

Table 5. Mean chewdown descriptive sensory data of 4 brands of turkey deli meat

Trt	Juicy	COM	ROM	Lumpy	Fibrousness	MOM	FBT
CORT	1.00^{c}	4.50^{d}	6.50^{a}	5.00^{a}	1.50^{c}	7.50^{a}	2.00^{d}
ORT	1.00^{c}	5.50^{c}	6.00^{b}	2.00^{b}	4.00^{b}	6.00^{c}	3.00^{c}
NORT	3.00^{a}	7.00^{b}	6.00^{b}	0.00^{c}	5.00^{a}	6.50^{b}	3.50^{b}
BORT	2.00^{b}	7.50^{a}	5.50^{c}	0.00^{d}	5.00^{a}	6.00^{c}	4.00^{a}

$^{a\text{-}d}$Means with no common superscript differ significantly (*P* < 0.05).

Table 6 provides results of the differences among treatment versus descriptive sensory residual data. CORT and ORT were different (*P* < 0.0001) for sensory mouthcoat against all treatments, NORT and BORT were not different from each other (*P* > 1.00), but were different compared to CORT and ORT (*P* < 0.0001). Comparing sensory loose particle data against the treatments CORT and ORT showed no differences (*P* > 1.00) from one another, but were different (*P* < 0.0001) from the other two treatments, while NORT and BORT were different (*P* < 0.0001) from all treatments.

Table 6. Mean residual descriptive sensory data of 4 turkey deli meat

Trt	Mouthcoat	Loose Particles
CORT	2.00 ± 0.00^{a}	3.00^{c}
ORT	1.00 ± 0.00^{c}	3.00^{c}
NORT	1.50 ± 0.00^{b}	3.50^{b}
BORT	1.50 ± 0.00^{b}	4.00^{a}

$^{a\text{-}d}$Means with no common superscript differ significantly (*P* < 0.05).

Differences between treatment and descriptive sensory appearance are shown in Table 7. For sensory amount of striations, NORT and BORT were different among all treatments (*P* < 0.0001), while CORT and ORT displayed no differences from one another (P > 1.00), but were different (P < 0.0001) compared to the other two treatments.

Table 7. Mean appearance descriptive sensory data of 4 brands of turkey deli meat

Trt	AOS
CORT	1.00^{c}
ORT	1.00^{c}
NORT	3.50^{b}
BORT	12.00^{a}

$^{a\text{-}d}$Means with no common superscript differ significantly (P < 0.05).

Instrumental hardness, springiness, cohesiveness, chewiness, and resilience of 4 different deli meat brands were assessed using TPA. Data obtained from the texture analyzer were then correlated to descriptive sensory data gained by a corporate office. The relationship between TPA parameters and the 4 deli meat treatments (brands) is shown in Table 8. All 4 treatments were different for instrumental hardness (P < 0.0001), cohesiveness (P < 0.0001), and chewiness (P < 0.0001). It was determined ORT and NORT treatments were different (P < 0.0001) for instrumental springiness, with no differences (P > 1.00) between CORT, ORT, and BORT treatments. CORT treatment was different (P < 0.0001) for resilience compared to the other 3 treatments, but no differences (P > 1.00) were seen among ORT, NORT, or BORT.

Table 8. Mean (± standard error) of TPA characteristics of 4 brands of turkey deli meat

Trt	Average Hardness	Average Springiness	Average Cohesiveness	Average Chewiness	Average Resilience
CORT	158.76±5.13^{c}	0.84±0.02^{ab}	0.27±0.01^{c}	35.67±2.25^{c}	0.09±0.00^{a}
ORT	129.41±5.13^{d}	0.81±0.02^{b}	0.24±0.01^{d}	25.57±2.25^{d}	0.07±0.00^{dc}
NORT	196.61±5.19^{b}	0.86±0.02^{a}	0.32±0.01^{b}	51.77±2.28^{b}	0.07±0.00^{cc}
BORT	281.47±5.13^{a}	0.84±0.02^{ab}	0.35±0.01^{a}	78.95±2.25^{a}	0.08±0.00^{bc}

$^{a-d}$Means with no common superscript differ significantly (P < 0.05).

As previously mentioned, instrumental hardness was expected to correlate well with sensory firmness and denseness, instrumental cohesiveness was expected to correlate well with sensory cohesiveness and cohesiveness of mass, and instrumental chewiness was expected to be correlated with uniformity of bite. Comparing results from Table 8 with findings shown in Tables 4 and 5, it was seen that descriptive data indicated BORT was the least firm and least dense brand; however, instrumentally, BORT was seen to be the hardest brand analyzed. Brands CORT and ORT possessed the same descriptive sensory ratings and were the second most firm brand and were both tied with brand NORT as the densest brand; instrumentally, there were differences observed among all treatments for TPA hardness and ORT was ranked as the least hard brand. For sensory cohesiveness, brands NORT and BORT were perceived as the most, this closely followed TPA data which showed BORT was the most cohesive and brand NORT was the second most cohesive. BORT was perceived as having the greatest cohesiveness of mass, and was also seen to have the highest value for TPA cohesiveness. Brand NORT had the highest ranking in uniformity of bite and BORT had the second highest ranking, this was seen inversely for TPA chewiness. It should be noted, brand ORT consistently ranked last in the 3 TPA parameters of interest (hardness, cohesiveness, and chewiness). Initial slice thickness is likely the cause of this difference. Brand BORT is marketed as a bulk product in retail stores and was sliced by hand at the manufacturers, rather than sliced as a production step seen as is done with the other 3 brands. BORT samples had an average slice thickness of 2.8-mm, while samples CORT, ORT, and NORT had slice thickness averages of 1.1, 0.9, and 1.2-mm, respectively. The added thickness creates a more stable sample and enhances instrumental readings, indicated by results found in Experiment 2 of this study.

Differences between treatments (distance, 25% strain, and 30% strain) versus TPA parameters are found in Table 9. For hardness, all treatments were different from one another ($P < 0.001$); however, for springiness, cohesiveness, chewiness, and resilience- treatment distance was different from all other treatments ($P < 0.0001$), while 25% and 30% were different from distance treatments ($P < 0.0001$) but not different against each other ($P > 0.58$, 0.65, 0.32, and 0.52, respectively). For springiness, only treatment distance provides an accurate measurement. The 25% and 30% strain treatments were much more destructive, preventing the samples from ‘springing’ back appropriately. Texture technologies explains that in instances where spring back is a critical factor being evaluated, distances that compress samples less are recommended so the product has the ability to retain enough of its geometric properties to show a difference.

Table 9. Mean (± standard error) TPA characteristics of 3 treatments of turkey deli meat

Trt	Mean Hardness	Mean Springiness	Mean Cohesiveness	Mean Chewiness	Mean Resilience
Distance	-0.48±10.7[a]	0.73±0.01[b]	0.51±0.01[a]	72.34±1.97[a]	0.22±0.00[a]
25%	-229.47±10.59[b]	0.90±0.01[a]	0.19±0.01[b]	37.20±1.95[b]	0.01±0.00[b]
30%	-288.55±10.59[c]	0.89±0.01[a]	0.18±0.01[b]	34.42±1.95[b]	0.00±0.00[b]

[a-c]Means with no common superscript differ significantly (*P* < 0.05).

Relationship between Instrumental and Descriptive Sensory Data

Correlation coefficients for the sensory and instrumental results can be found in Tables 10-12. For treatment distance (Table 10), hardness was highly correlated to sensory roughness (r=0.85), loose particles (r=0.83), and amount of striations (r=0.85). Chewiness was highly correlated to sensory roughness (r=0.72), sensory loose particles (r=0.70), and sensory amount of striations (r=0.72). Treatment distance also showed high correlations between resilience and sensory fibrousness between teeth (r=0.83), sensory loose particles (r=0.99), and sensory amount of striations (r=0.99).

Table 10 Correlation coefficients between TPA parameters and descriptive sensory data for treatment distance

	Mean Hardness	Mean Springiness	Mean Cohesiveness	Mean Chewiness	Mean Resilience
Roughness	**0.85**	-0.61	0.38	**0.72**	-0.18
Moistness	0.34	-0.14	0.39	0.37	0.31
Firmness	-0.53	0.53	-0.45	-0.48	-0.14
Denseness	-0.81	0.64	-0.45	-0.70	0.07
Cohesiveness	0.55	-0.31	-0.06	0.41	-0.54
Uniformity of Bite	0.21	-0.04	-0.34	0.08	-0.64
Juiciness	0.40	-0.12	-0.05	0.31	-0.36
Cohesiveness of Mass	0.68	-0.41	0.08	0.53	-0.46
Roughness of Mass	-0.67	-0.49	-0.10	-0.51	0.45
Moistness of Mass	-0.31	0.24	0.21	-0.16	0.59
Fibrousness Between Teeth	0.63	-0.41	0.00	0.47	-0.51
Mouthcoat	0.14	-0.07	0.47	0.22	0.57
Loose Particles	**0.83**	-0.56	0.33	**0.70**	**0.99**
Amount of Striations	**0.85**	-0.62	0.41	**0.72**	**0.99**

For treatment 25% strain (Table 11), correlation coefficients were also determined. Hardness was highly correlated to sensory roughness (r=0.87), sensory cohesiveness of mass (0.75), sensory loose particles (0.87), and sensory amount of striations (r=85). The TPA parameter cohesiveness was highly correlated with sensory cohesiveness of mass (r=0.72) and sensory loose particles (r=0.71). Chewiness showed a high correlation with sensory roughness (r=0.87), sensory cohesiveness of mass (r=0.77), sensory fibrousness between teeth (r=0.71), sensory loose particles (r=0.88), and sensory amount of striations (r=0.86).

Table 11. Correlation coefficients between TPA parameters and descriptive sensory data for treatment 25% strain

	Mean Hardness	Mean Springiness	Mean Cohesiveness	Mean Chewiness	Mean Resilience
Roughness	**0.87**	0.14	0.65	**0.87**	0.18
Moistness	0.40	0.23	0.42	0.39	0.01
Firmness	-0.41	-0.22	-0.02	-0.41	0.10
Denseness	-0.78	-0.19	-0.47	-0.78	-0.09
Cohesiveness	0.63	-0.11	0.67	0.66	0.33
Uniformity of Bite	0.31	-0.25	0.48	0.33	0.34
Juiciness	0.52	-0.08	0.52	0.53	0.30
Cohesiveness of Mass	**0.75**	-0.04	**0.72**	**0.77**	0.30
Roughness of Mass	-0.68	0.02	-0.52	-0.70	-0.24
Moistness of Mass	-0.32	0.18	-0.26	-0.34	-0.23
Fibrousness Between Teeth	0.68	-0.07	0.63	**0.71**	0.30
Mouthcoat	0.14	0.29	-0.07	0.11	-0.17
Loose Particles	**0.87**	0.11	**0.71**	**0.88**	0.22
Amount of Striations	**0.85**	0.16	0.59	**0.86**	0.15

Treatment 30% strain (Table 12) showed a high correlation between hardness and sensory roughness (r=0.82), sensory loose particles (r=0.81), and sensory amount of striations (r=0.81). Cohesiveness showed a strong correlation between sensory cohesiveness (r=0.71), sensory cohesiveness of mass (r=0.74), and sensory loose particles (r=0.71). For chewiness, a high correlation is seen between roughness (r=0.81), sensory cohesiveness (r=0.70), sensory cohesiveness of mass (r=0.78), sensory fibrousness between teeth (r=0.71), sensory loose particles (r=0.84), and sensory amount of striations (r=0.77).

Table 12. Correlation coefficients between TPA parameters and descriptive sensory data for treatment 30% strain

	Mean Hardness	**Mean Springiness**	**Mean Cohesiveness**	**Mean Chewiness**	**Mean Resilience**
Roughness	**0.82**	0.31	0.64	**0.81**	0.63
Moistness	0.43	0.28	0.33	0.39	0.10
Firmness	-0.43	0.12	-0.3	-0.26	-0.50
Denseness	-0.76	-0.18	-0.47	-0.68	-0.65
Cohesiveness	0.55	0.41	**0.71**	**0.70**	0.38
Uniformity of Bite	0.21	0.35	0.54	0.43	0.13
Juiciness	0.45	0.48	0.68	0.62	0.16
Cohesiveness of Mass	0.67	0.42	**0.74**	**0.78**	0.47
Roughness of Mass	-0.61	-0.26	-0.57	-0.67	-0.54
Moistness of Mass	-0.23	-0.13	-0.35	-0.34	0.16
Fibrousness Between Teeth	0.60	0.36	0.67	**0.71**	-0.36
Mouthcoat	0.20	0.03	-0.03	0.67	0.33
Loose Particles	**0.82**	0.38	**0.71**	**0.84**	-0.31
Amount of Striations	**0.81**	0.28	0.59	**0.78**	0.47

Correlations showing a high correlation coefficient (r-value >0.70), were then tested to determine how well each correlation fit to a partial least squares regression line. Coefficients of determination (R^2) values were determined to evaluate goodness of fit of each regression line. It has been explained that an R^2 value of >0.81 is 'excellent' and an R^2 value = to 0.64 to 0.81 is 'good' (Luckett et al. 2014 & Kramer 1951).

Table 13 shows R^2 values for TPA hardness versus descriptive sensory attributes deemed highly correlated. It was determined that distance was the best predictor of sensory roughness with an R^2 value of 0.63. Treatment 25% strain did the next best with an R^2 value of 0.51, followed by 30% strain with an R^2 value of 0.50. Mean hardness was plotted against sensory loose particle data; treatment distance showed an R^2 value of 0.47, 25% strain and 30% strain had R^2 values of 0.36 and 0.33, respectively. Hardness was also plotted against sensory amount of striations, treatments distance, 25% strain, and 30% strain had R^2 values of 0.73, 0.61, and 0.60, respectively. Treatment distance was seen to be a 'good' indictor of sensory amount of striations. Hardness was plotted against sensory cohesiveness of mass with R^2 values of 0.24, 0.19, and 0.15, respectively.

Table 13. Regression coefficients for mean hardness versus descriptive sensory data

	Roughness	**Loose Particles**	**Cohesiveness of Mass**	**Amount of Striations**
Distance	0.63	0.47	0.23	**0.73**
25% Strain	0.51	0.35	0.19	0.61
30% Strain	0.49	0.33	0.15	0.60

Table 14 shows regression coefficient values for TPA cohesiveness plotted against descriptive sensory data. Mean cohesiveness was plotted against sensory cohesiveness of mass data giving R^2 values of 0.00, 0.07, and 0.13 for treatments distance, 25% strain, and 30% strain, respectively. Cohesiveness was also plotted against loose particle data; treatments distance, 25% and 30% strains had R^2 values of 0.12, 0.08, and 0.12, respectively. Mean cohesiveness plotted against sensory cohesiveness data had R^2 values of 0.06 for treatment distance, 0.05 for treatment 25% strain, and 0.12 for treatment 30% strain.

Table 14. Regression coefficients for mean cohesiveness versus descriptive sensory data

	Cohesiveness of Mass	Loose Particles	Cohesiveness
Distance	0.00	0.12	0.06
25% Strain	0.07	0.08	0.05
30% Strain	0.13	0.12	0.12

Regression coefficients for instrumental chewiness versus descriptive sensory data are seen in Table 15. TPA chewiness plotted against sensory roughness data gave R^2 values of 0.56, 0.52, and 0.39 for treatments distance, 25% strain, 30% strain, respectively. TPA chewiness was plotted against sensory loose particle data; treatments distance, 25% strain, and 30% strain had R^2 values of 0.38, 0.36, and 0.26, respectively. TPA chewiness was plotted against sensory amount of striation data and treatments distance, 25% strain, and 30% strain gave R^2 values of 0.66, 0.61, and 0.48, respectively. It was determined treatment distance was a 'good' predictor of this correlation. TPA chewiness versus sensory cohesiveness of mass data had R^2 values of 0.14, 0.21, and 0.18 for treatments distance, 25% strain, and 30% strain, respectively. TPA chewiness plotted against sensory fibrousness between teeth data had R^2 values of 0.38, 0.63, and 0.70 for treatments distance, 25% strain and 30% strain, respectively. Note 30% strain was a 'good' predictor of this correlation. TPA chewiness was plotted against sensory cohesiveness, with treatments distance, 25% strain and 30% strain showing R^2 values of 0.05, 0.13, and 0.12, respectively.

Table 15. Regression coefficients for mean chewiness versus descriptive sensory data

	Roughness	Loose Particles	Amount of Striations	Cohesiveness of Mass	Fibrousness Between Teeth	Cohesiveness
Distance	0.56	0.38	**0.67**	0.14	0.38	0.05
25% Strain	0.52	0.36	0.61	0.20	0.63	0.13
30% Strain	0.39	0.26	0.48	0.18	**0.70**	0.12

Applying TPA settings from Experiment 1, it was seen that TPA hardness was able to be correlated with sensory amount of striations (r: 0.85; R2: 0.73) when treatment distance was applied. TPA chewiness was able to correlate sensory amount of striations when treatment distance was applied, r value of 0.72 and an R^2 value of 0.67. TPA chewiness was seen to be correlated with sensory fibrousness between teeth (r: 0.71; R2: 0.70) when treatment 30% strain was applied.

It was unexpected that with multiple correlation coefficients showing strong correlations between instrumental and descriptive sensory analysis that only 3 of were observed well correlated based on regression coefficients. At least one outlier was observed on each regression line. Similar to the discrepancies mentioned between perceived sensory attributes from descriptive sensory panel and what was perceived instrumentally, differences in sample thickness were thought to be the underlying problem. From findings in Experiment 2, increasing sample thickness enhances sample stability and increases correlations.

Experiment 2

Few studies have been conducted on deli meat texture; however, Luckett et al. (2014) explored different instrumental texture analyses of poultry deli meat to determine which method best correlated to descriptive sensory analysis. Researchers analyzed cores of deli loaves on 3 different instrumental texture analyzers: TPA, AKS, and BMORS. From preliminary data for Experiment 1, AKS and methods similar to BMORS were not appropriate methods of analysis for. The thicker core was more appropriate for AKS and BMORS analysis, where Experiment 1 samples were much thinner and pulled through the bottom of the analyzer. These findings lead to questioning the role sample thickness plays on texture, instrumentally. A second portion of this study, Experiment 2, was conducted to investigate how texture changed with the addition of deli meat slices (i.e. how does texture change from 1 slice vs. 2 slices).

Deli meat is consumed as slices, and examining cores from deli loaves is not thought to accurately depict the texture when consumed- but rarely is a single slice consumed alone. One or more slices will be stacked, so to test the changes in texture, 1 to 5 slices were stacked and data was acquired with the TPA setting on the Texture Analyzer using the TA-108s5i.

Differing classifications of deli meat were selected as treatments to encompass a wide variety of texture: hard salami (HFHS), original roasted turkey breast (OMORT), and turkey bologna (OMTB). Variation provides an understanding of textural differences across luncheon meat types.

Partial least squares regressions were used for data analysis. Number of slices was plotted against hardness (Figure 1); R^2 values of 0.98, 0.90, and 0.65 were obtained for the treatments HFHS, OMORT, and OMTB, respectively. It was seen that as number of slices increases for each treatment, there is an 'excellent' correlation between hardness and number of slices for treatments HFHS and OMORT, and a 'good' correlation for treatment OMTB.

Number of slices plotted against average springiness (Figure 2), treatments HFHS, OMORT, and OMTB had R^2 values of 0.69, 0.69, and 0.83, respectively. Indicating treatment OMTB was an 'excellent' predictor of springiness as slice number increases, while treatments HFHS and OMORT were 'good' predictors of springiness.

Number of slices per treatment versus TPA cohesiveness (Figure 3) had R^2 values of 0.02, 0.64, and 0.74 for treatments HFHS, OMORT, and OMTB, respectively. Treatments OMORT and OMTB were 'good' indicators of cohesiveness. N

Number of slices per treatment plotted against mean chewiness (Figure 4), had R^2 values are 0.98, 0.90, and 0.01 for treatments HFHS, OMORT, and OMTB, respectively. Treatments HFHS and OMORT were 'excellent' predictors of mean chewiness.

Number of slices per treatment versus TPA resilience (Figure 5), gave R^2 values of 0.32, 0.70, and 0.67 for treatments, HFHS, OMORT and OMTB, respectively. Treatments OMORT and OMTB were 'good' predictors of resilience.

Figure 1. Number of slices vs. mean hardness for 3 deli meat brands

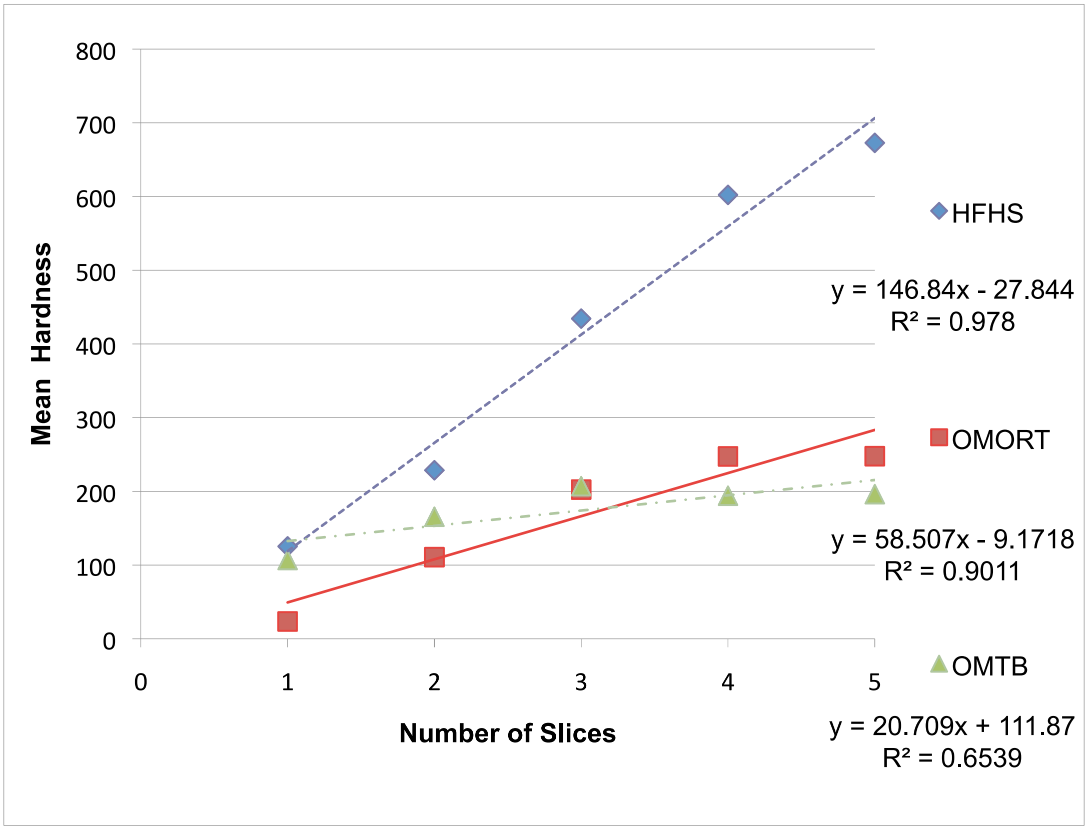


Figure 2. Number of slices vs. mean springiness for 3 deli meat brands

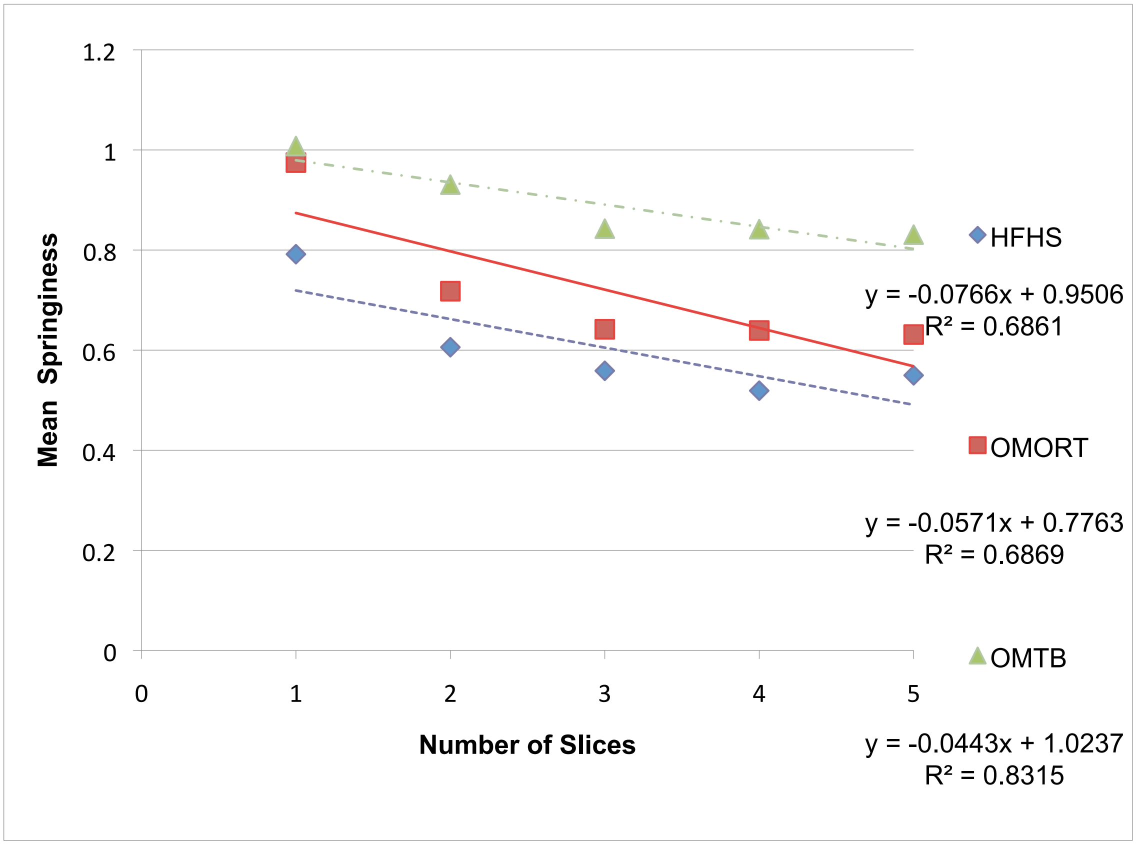


Figure 3. Number of slices vs. mean cohesiveness for 3 deli meat brands

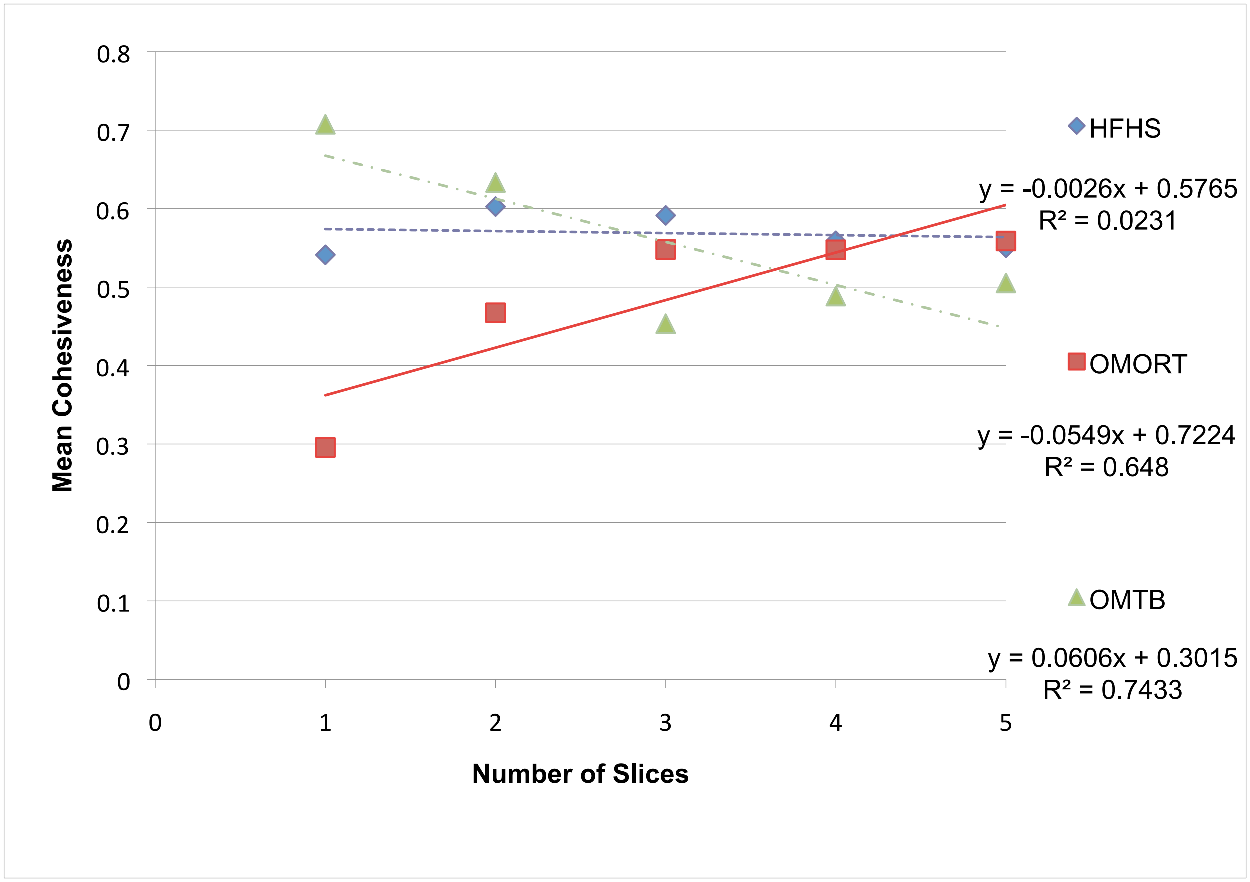


Figure 4. Number of slices vs. mean chewiness for 3 deli meat brands

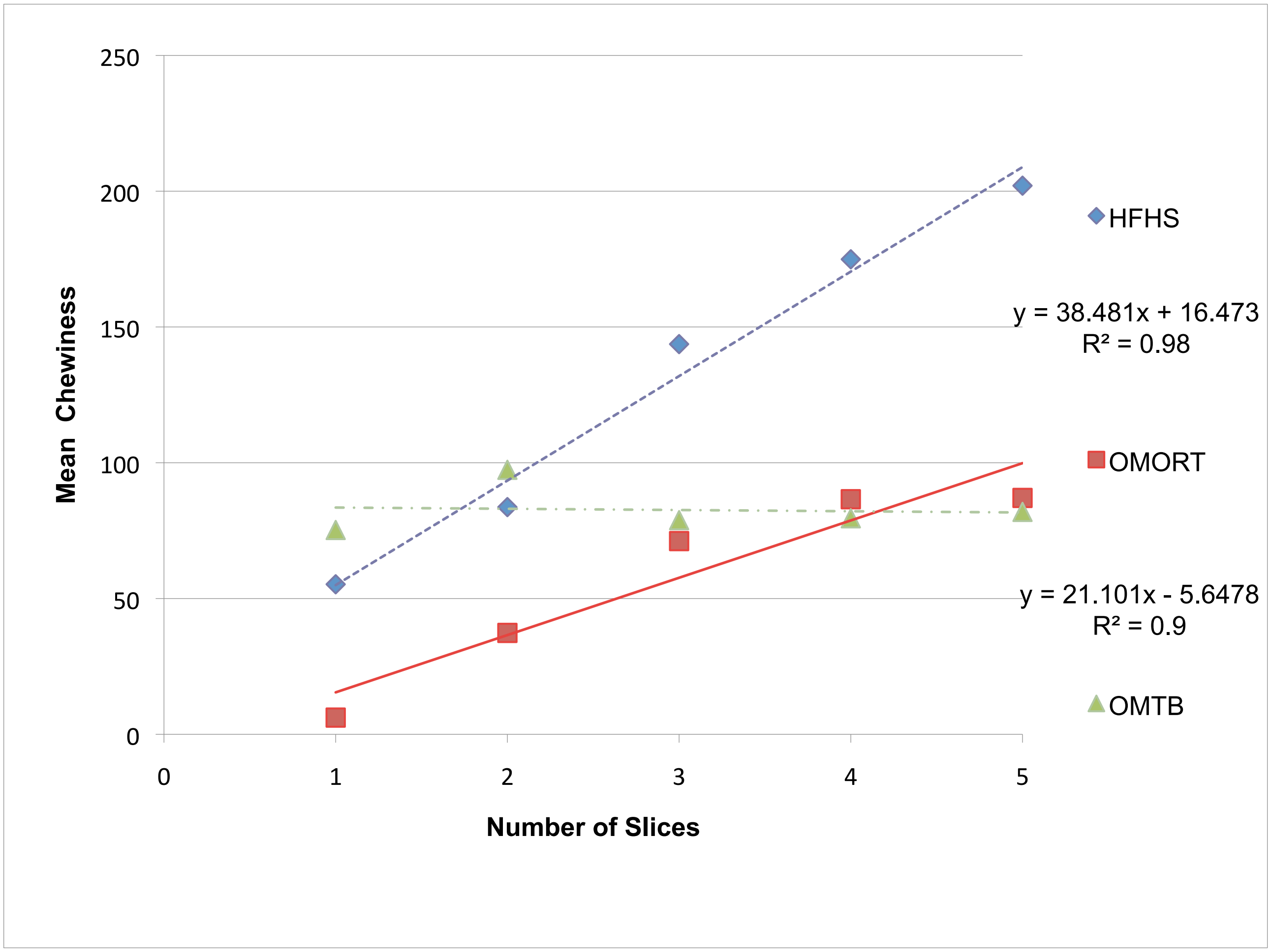
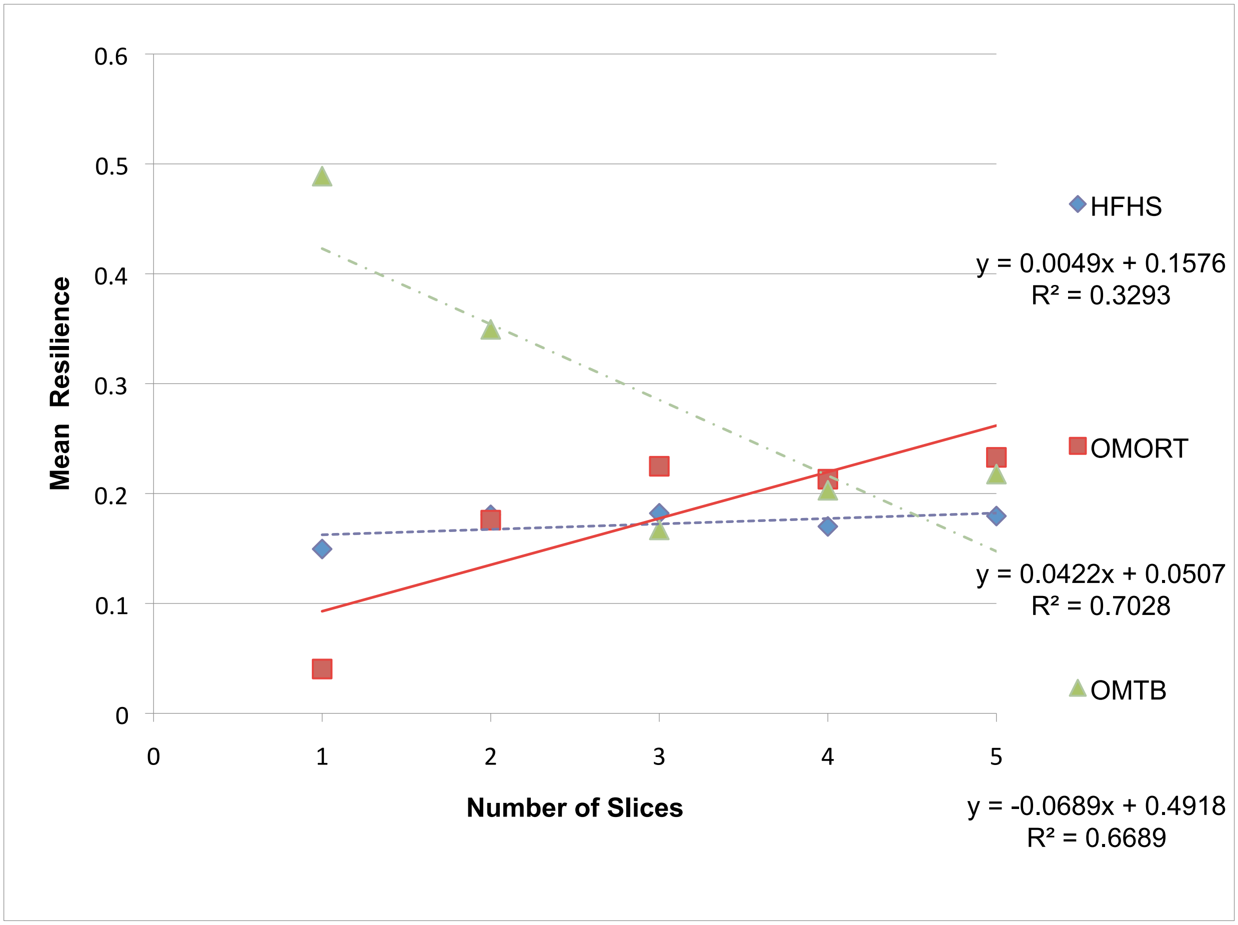


Figure 5. Number of slices vs. mean resilience for 3 deli meat brands



In most instances increasing the number of slices increased regression coefficient values. Increases stack size increases sample thickness, giving samples more stability during instrumental analysis. The increase in stability will allow for more instruments to analyze deli meats as a slice rather than a core, while being consistent with how individuals consume deli meat. Understanding how texture parameters change with the addition of stacked slices could prove valuable in future research looking at different instrumental methods.

Conclusion

Results from Experiment 1 showed mean hardness proved was a ‘good’ indicator of sensory amount of striations when treatment distance is applied (r=0.85 and R^2=0.73) using the TA-108s5i with Texture Analyzer settings of: target distance of 5-mm, pre-test speed of 2-mm/s, test-speed of 0.5-mm/s, post-test speed of 0.5-mm/s, and trigger force of 5-g. Mean chewiness was a ‘good’ predictor of sensory amount of striations when treatment distance is applied (r=0.72 and R^2=0.67) with the aforementioned probe and settings. Mean chewiness was seen to be a ‘good’ indicator of sensory fibrousness between teeth using treatment 30% strain (r=0.71 and R^2=0.70).

For Experiment 2, increasing the number of slices of deli meat analyzed was an ‘excellent’ predictor of sample mean hardness and chewiness for brands HFHS and OMORT, and a ‘good’ predictor of mean hardness for OMTB. Increasing the number of slices on brand OMTB had an ‘excellent’ correlation between slice number and average springiness, other brands (HFHS and OMORT) showed ‘good’ correlations. Increasing the number of slices had ‘good’ correlation between brands OMORT and OMTB and mean cohesiveness with mean resilience. Ultimately, increasing number of slices increased sample thickness and increased sample stability; therefore, positively affecting correlations between instrumental analyses.

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