**The Effect of Processing Parameters and Methylcellulose on Texture and Consumer
Acceptability of a Non-Melting Dairy Protein Gel**

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TITLE: The Effect of Processing Parameters and Methylcellulose on Texture and Consumer Acceptability of a Non-Melting Dairy Protein Gel

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ABSTRACT

THE EFFECT OF PROCESSING PARAMETERS AND METHYLCELLULOSE ON TEXTURE AND CONSUMER ACCEPTABILITY OF A NON-MELTING DAIRY PROTEIN GEL

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The overall goal was to understand the capabilities of a dairy based meat alternative. This was done in three phases: 1) the production of a dairy protein gel as a base for a dairy based meat alternative, 2) texturization of the dairy protein gel base to produce a nugget like texture, and 3) a consumer test to determine the acceptability of the dairy based nugget compared to meat and meat alternatives on the market.

For phase I, a dairy protein gel base was tested to understand the textural attributes. Milk to whey percentages and level of acidification were examined to determine their effects on instrumental textural attributes of the protein gel. The milk to whey percentages and level of acidification that were tested were 5/95, 10/90, and 15/85, and pH 5.70-5.60, 5.15-5.05, and 4.6-4.5; respectively. The texture was objectively measured using a texture analyzer. The results showed that there was an increase in the hardness, gumminess and chewiness which was associated with an increase of the milk to whey ratio. Also a firmer dairy protein gel was produced using a low pH. A milk to whey percentage of 15/85 and a pH of 4.6-4.5 produced the highest overall instrumental textural attributes, specifically .

For phase II, the dairy protein gel composed of a milk to whey ratio of 15/85 and pH of 4.6 was evaluated in the formulation of a dairy based nugget. The grinding of the dairy protein gel was used to determine if different size grinding plates and the presence of a

gum can influence the textural attributes of the dairy protein gel. The dairy protein gel base was evaluated by a trained sensory panel to compare to the results of the objective texture analyzer. The dairy protein gel was processed using a meat grinder with a grind size of 3 mm, 6 mm and a blend of 4 parts 6 mm grinded and 1 part 3 mm. The increase in the grind size produced an increased instrumental hardness, springiness, cohesiveness, chewiness and gumminess. The usage of gum in the dairy protein gel system produced a higher instrumental adhesiveness. The sensory results showed that an increase in the grind size increased the sensory attributes; hardness, cohesiveness, chewiness and adhesiveness. The use of gum in the system had no influence on the sensory textural attributes. Both the texture analyzer and trained sensory testing showed a similar trend for the texture attributes. No correlation between the texture analyzer and sensory was found. This was a surprise because literature indicates there are significant correlations between instrumental textural attributes and sensory texture attributes. The lack of correlation may be explained by the variability of the panelists ($P\text{-value} < 0.05$) for each sample.

For phase III, an acceptability test was performed on untrained consumers of chicken nuggets to determine if the dairy based meat alternative was acceptable compared to meat nuggets and meat alternatives on the market. Texture, flavor, and appearance were evaluated by a consumer panel. The consumers evaluated the dairy based meat alternative and concluded that the appearance, texture and flavor needed improvement.

From this research, it was concluded that a dairy based meat alternative can be created to imitate meat and meat alternative textures. By understanding the processing

conditions to produce the dairy protein gel base and grinding of the product, an acceptable meat alternative can be produced. Dairy based meat alternative texture attributes were produced from a milk to whey percentage of 15/85 and a pH of 4.6, and a large grind plate of 6 mm with the use of methylcellulose.

Keywords: non-melting, dairy protein gel, meat alternative, ricotta method, nugget.

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“Everyone needs to eat”

- Joshua Goldman

“Food is our common ground, a universal experience.”

- James Beard

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1.0 INTRODUCTION

The per capita consumption of cheese in the United States since 1982 has increased steadily from 19.9 pounds to 32.4 pounds in 2008 (Board, 2008). This number is expected to grow to 37.0 pounds by 2017 (Board, 2008). As this number increases, the dairy industry looks toward developing new products that will capture the consumer's palate, as well as increasing nutritional value at a competitive price. Since milk is an excellent source of nutrients and essential amino acids, many companies have developed dairy based nutritional drinks and bars to keep up with the health and fitness trends. Research and development of innovative dairy foods with health and value-added ingredients are the way of the future.

One area of product development that is growing is in the meat alternative market. This is due to the large demand in the food industry for meat alternatives that are lower in fat, higher protein, higher nutritional value as well as producing products to meet religious and ethnic dietary guidelines. The vegetarian and vegan communities represent the majority of the population that consumes meat alternatives. Due to the high demand of meat alternatives, the dairy industry should strive to develop a dairy based meat alternative.

Meat alternatives tend to come from protein sources that imitate the texture, flavor and appearance of a meat based product. There are basically three protein meat alternatives on the market: vegetable based, dairy based and fermented. This thesis research will be directed to a dairy based meat alternative.

One category of a protein based meatless alternative is a non-melting dairy protein gel. Many consumers prefer dairy protein gels that easily melt and provide a creamy smooth texture, which is the opposite of non-melting dairy protein gels. Non-melting dairy protein gels are not widely found in America, and have not gained popularity. The non-melting dairy protein gel niche market tends to be limited to mostly ethnic groups. In other countries such as Brazil, pieces of a non-melting cheese are placed on a stick and grilled over an open flame as a snack, which is called queijo coalho. Queijo coalho is a renneted dairy protein gel that is first boiled and then placed in a hot whey bath to assist with restricting the melt of the protein. In Greece, halloumi has been used as a grilling cheese due to its ability to not melt. Halloumi is also a renneted dairy protein gel that is boiled in whey which assist in the cross linking of the proteins to assist in melt restriction. In Italy, ricotta is used as a non-melting dairy protein gel in high temperature foods such as lasagna. Also in India, Paneer has been used as an alternate protein source and has non-melting capabilities. Paneer has been used in stews, sauces and main dishes and acts as a firm tofu like structure. The paneer is created by boiling milk and introducing acid into the system to drop the pH to around 4.6 to precipitate casein. The coagulum is then pressed and cut into cubes. Looking at these non-melting dairy protein gels shows that these products are widely used and are essential food items within the fast food and frozen industry. Restricting melt can help to make products more acceptable to consumers.

By using specific processing methods and ingredients, non-melting dairy protein gels can be achieved. Manufacturers have used gums and stabilizers to restrict flow in dairy protein gel products such as dairy protein gel analogues. These dairy protein gel analogues have gums and stabilizers which enhance the firmness of the gel while keeping

the shape while heated. But the movement towards a clean label has brought new challenges to manufacturers. Many companies have clean labels which have removed or hidden ingredients that seem “unnatural” and are looking for alternative methods that can even eliminate “unclean” ingredients. By looking at the previously stated ethnic group dairy protein gels, there are natural alternatives for non-melting dairy protein gels.

In this project, a non-melting dairy protein gel was produced by adapting the procedures from previous research (Yeung 1997; Shah 2007) to compete with meat alternative products. The dairy based meat alternative was compared to meat products in the fast food and frozen food industry.

2.0. LITERATURE REVIEW

2.1 MEAT ALTERNATIVES

A meat alternative is a high protein source that has comparable texture, flavor and appearance to real meat. There is a market for meat alternatives because the consumers want to include healthier alternatives of protein in their diet which is seen as environmentally friendly and is safer than meat products (McIlveen et al., 1999). Many consumers of vegetarian products are not complete vegetarians but a mixed consumer that consumes both meat, dairy and vegetable products (McIlveen et al., 1999). Also religious and ethnic dietary guidelines require different religious groups and cultures to consume only vegetarian foods. Many of the meat alternative products satisfy the dietary restrictions of different religious groups and cultures due to the products being vegetable or dairy based. The vegetarian sector of the Indian culture consumes milk, vegetables, and grains while several religious groups such as Buddhism and Judaism require vegetarian based foods to follow dietary laws. Meat alternatives can be an essential part of the cultural and religious markets.

These meat alternative options can be comparable in price with real meat. There are many brands of meat alternatives on the market. There are three distinct protein alternatives groups on the market which can be used as a meat alternative. The three types of meat alternatives are dairy based, vegetable based, and fungus based. The dairy based meat alternatives use milk's ability to produce casein and whey protein gels which are

texturized through processing and pressing of the gels (Section 2.1.1.). Vegetable based meat alternatives use soy's ability to form fibrous proteins that are mixed with an emulsifier and are formed into meat like textures (Section 2.1.3.). The fungus based proteins use the natural fibrous structure from fungus which are harvested and formed with an emulsifier to produce meat like textures (Section 2.1.2.).

2.1.1. Dairy Based Meat Alternatives

Dairy based meat alternatives are usually made with skim milk that has been coagulated or precipitated and formed into a shape with flavoring. Further research has been conducted to produce meat fibers using a dairy system. Valess, a brand from Friesland Campina is a Dutch based company that produces a dairy alternative product. The company produces meat like fiber dairy products which are pressed into shapes and flavored accordingly (Kweldam, 2005). The company sells their products in Germany, Netherlands and in other European countries. One of the formulas from the patent's author Adrian Kweldam (Kweldam, 2005) (Figure 2.1) explains that cheese curds from five week ripened Maasdam type cheese were grated and mixed with polyphosphate and water that was 55° C. Sodium alginate and more water were added to the cheese and mixed with a high speed mixer. The mass was then blended with CaCl₂ until fibers form. The fibers were removed and washed to remove excess calcium chloride. The fibers were then pressed into shapes that are packaged and pasteurized. The final product has a pH of 5.8 to 6.8. Other dairy sources can be used instead of cheese such as sodium caseinate, whey protein, and powdered milk.

Figure 2.1 Valess Flowchart (Kweldam, 2005)

Figure 2.2 Valess dairy based meat alternative (Pink, 2011)

2.1.1.1. Dairy Based Meat Alternative Advantages and Disadvantages

Dairy based meat alternatives are made up of a unique protein source that has the ability to supply all of the essential amino acids. Most protein sources do not have the ability to supply all of the amino acids and need other protein sources to supply the additional amino acids. The dairy protein gels used in the process of producing a meat alternative have the ability to be produced with low-fat or non-fat milk to produce a healthier product. Dairy also contains a large amount of calcium. Valess's Toscana meat alternative has approximately 75% of the daily value of calcium in 100 g of the product (Valess, 2011). Further nutritional data can be found in Table 2.1. Milk fat is also easy to flavor compared to other meat alternatives and can leave a milky aftertaste if desired. Milk proteins can be easily denatured without severe changes in pH and increase in temperature compared to soy products that needs a drastic change in the pH from 12 to 2.5 to process the soy proteins (Fennema, 2007). Specific types of dairy protein gels do flow when

heated. The use of processing techniques (Farkye and Lee, 1998) and emulsifiers help to restrict the flow of the dairy protein gels. Milk may be a more costly protein source than soy but dairy has more nutritional benefits. Soy and fungus based meat alternatives have the ability to form fibrous structures that mimic meat fibers. There has not been enough research in the formation of fibrous structures in the dairy industry. Research was conducted on globular dairy protein spinning to produce fibers but the microstructure did not result in the preferred texture by consumers (Purwanti et al., 2010). Further research needs to be conducted in fiber development with dairy proteins. Dairy proteins provide excellent nutrients while supplying a stable protein structure that enhances flavor and produces an acceptable texture.

2.1.2. Fungus Based Meat Alternatives

Fermentation based meat alternatives are made from vegetable proteins that have been fermented by micro-organisms and have flavor added to the product. Fungus ferments sugars to produce mycoprotein that are bound with egg to form a meat alternative patty. Mycoprotein is a high protein (48%) (Wiebe, 2002) byproduct from the fungus *Fusarium venenatum*. *Fusarium* is grown in a glucose broth in which mycoproteins develop as the microbes grow. The mycoproteins are drained from the fermenter and purified. The fungus comes from a genus known for its filamentous structure which is made up of many hyphae (Madigan et al., 2000). The hyphae have a similar animal muscle fiber structure as beef, chicken, and turkey (Solomons, 1985). The only company that

makes this product at this time is Quron which is a British based company. The fungus based product is made in chicken breast forms and in chicken nugget shapes.

2.1.2.1 Quron Meat Alternative Processing

The Quron process is started in 2 bioreactors (Ugalde and Castrillo, 2002) (Figure 2.2). The bioreactors are called external loop airlift fermentors (Chisti and Moo-Young, 1989). The continuous system is made up of a broth that includes glucose, nitrogen and oxygen (Ugalde and Castrillo, 2002). The oxygen is also used to mix and circulate the broth through the unit. The fungus produces carbon dioxide which is released at the top of the vessel and heat which is exchanged with a water based cooling system (Coutouly, 2006) to help the fungus grow at the optimal temperature of 30⁰ C. About 7925 gallons of fungus is processed per hour in each bioreactor (Ugalde and Castrillo, 2002). After leaving the bioreactor, the biomass is heated to around 64⁰ C for 20 to 30 minutes (Ugalde and Castrillo, 2002). The biomass is then heated to 90⁰ C and centrifuged immediately into a paste. The paste is then cooled to 4⁰ C. This paste is called mycoprotein. The mycoprotein's filaments are mechanically aligned and egg albumin is added to stabilize the alignment. Flavor and color are added to the mycoprotein and is heated and formed into the shapes for packaging (Ugalde and Castrillo, 2002).

Figure 2.3 External Loop Fermentor (Ugalde and Castrillo, 2002).

2.1.2.2. Fungus Based Meat Alternative Cooking Methods

Mycoprotein can be cooked with different methods. Mycoprotein can be steamed, deep fried, pan fried, baked, sautéed, wokked, smoked, boiled, broiled, stewed, simmered, grilled, and sous vided. Mycoprotein's texture can be manipulated for consumption by grating, pureeing, cubing, and slicing the product. Direct heating techniques causes the mycoprotein to produce a brown, dry and caramelized skin. Indirect heating techniques produce a moist texture on the inside and outside of the product.

2.1.2.3. Fungus Based Meat Alternative Advantages and Disadvantages

Fungus based meat alternatives have a very firm texture compared to soy products due to the fungus's hyphae that form fiber like structures. Quorn nuggets contain a high amount of protein compared to the dairy based meat alternative (Table 2.1). The mycoprotein used in the production of the nugget has very little fat and mostly comes from the egg added into the mycoprotein during processing. Previous research conducted on the mycoprotein showed that egg was the best emulsifier to produce a stable product (Miri et al., 2005). The use of egg in the product limits cultures that do not consume egg and also produces problems for people that have an egg allergen. The removal of egg from the process will produce a more beneficial product that will allow more people to consume the product. Also, the process of making the fungus meat alternative is very costly and requires specific equipment for large production. The fungus based meat alternative is a high protein product that produces a very firm texture but is limited by the ingredients that are used and the cost of production.

2.1.3. Vegetable Based Meat Alternatives

Soy is a high protein (35-38%) legume that originated from East Asia. The functional properties of soy are emulsification and texturing. Soy can be used as a meat replacer due to its ability of texturing which can produce meat fibers and imitate a meat structure. The soy bean can be used to make soybean meal, soy vegetable oil, textured vegetable protein, soymilk, tofu, tempeh, shoyu, miso and natto (McGee, 2004). Some brands include Boca, Cluckpherg, Morning Star Farms, Gardein and Smart Tenders.

Tofu is a widely consumed food in the Asian community. Tofu is soy milk that has been curdled into a coagulated mass of proteins and oils with magnesium or calcium salts. The general process of making tofu begins with the soaking and grinding of whole soybeans. The proteins are extracted and a soybean slurry is formed. The slurry is heated to 100° C for three minutes and the paste is discarded. The liquid that emerges from the paste is the soy milk. The soy milk is heated to 75° C. Calcium chloride or magnesium salt is added to coagulate the soy milk to form curds and liquid (whey). The whey is separated and the curd is pressed for a certain amount of time depending on the textural characteristics. The curd is cut into blocks for packaging and is pasteurized (McGee, 2004; Fennema, 2007).

Tofu comes in many different textures depending on the region of the world. Chinese tofu was originally made with two types of coagulants which were gypsum and “nigari” (Tropp, 1996). Inland Chinese tofu producers used gypsum that was mined, which is a colorless mineral composed of hydrated calcium sulfate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) to produce a smokier characteristic in the tofu (Tropp, 1996). Coastal Chinese manufactures used

“nigari” which was extracted from sea water. “Nigari” is composed of magnesium chloride (MgCl_2) which produces a sweeter characteristic in the tofu. There are four common varieties of Chinese tofu: nèn dòufu (“soft tofu”), dòufu huā (“tofu brain”), lǎo dòufu (老豆腐 “old tofu”), and dòu gān (“dry tofu”). Nèn dòufu is a high moisture tofu that is very soft in texture and does not absorb flavors as easily. “Tofu brain” is a semi liquid tofu which is high in moisture and consumed with additional flavoring ingredients. “Old tofu” is a semi-high moisture tofu that has been pressed for a longer period of time and has a firm texture. “Dry tofu” is a low moisture tofu that has a very firm texture and has the consistency of meat.

Japanese and Korean tofu is commonly produced with “nigari” to produce a sweeter characteristic in the tofu. There are two types of Japanese tofu varieties which are Kinugoshi-dofu (silken tofu) and Momen-dofu (cotton tofu). The Korean soft tofu variety is called sundubu (pure tofu). The silken/soft tofu is a soft tofu that has a creamy and smooth texture. The cotton tofu is a firm tofu that is pressed and contains less moisture (Tropp, 1996).

In central Vietnam, a firm tofu (dau hu) and a soft tofu (dau hu-au) are produced. Vietnamese tofu is produced using two methods. The first method is to filter out the solids, boil the soy milk and pour into a salt solution made of magnesium chloride or gypsum for coagulation. The curds that form were squeezed and placed in a mold. The second method was to filter out the solids, place water in the soy milk and boil. Sour milk was added containing a low pH made from lemon, star fruit, sour leaves (from a tamarind plant), or vinegar and the soy milk was boiled again. The mixture was stirred until curds rose to the surface and were placed in a mold. The curds that are molded into a square are called đậu

khuôn (molded bean). Today, the second method of using a sour liquid to coagulate the liquid is widely used in Vietnam (Bois et al., 2008).

Tofu and soy based products are versatile products that can be cooked in different manners. Each cooking method produces different flavor profiles and textures. Tofu can be steamed, deep fried, pan fried, baked, sautéed, wokked, smoked, pickled, fermented, boiled, broiled, stewed, simmered, grilled, and sous vided. Tofu's texture can be manipulated for consumption by grating, pureeing, cubing, slicing, and pressing the product. Direct heating techniques causes the tofu to produce a crispy, brown, and caramelized skin. Indirect heating techniques cause tofu to produce a bland, white, and slight soggy outside.

The tofu's structure can be manipulated to produce a sponge like product for absorption of liquids. Bean curd can be frozen to produce a more concentrated protein structure and form pockets of ice crystals (McGee, 2004). When the tofu is defrosted and pressed, excess water will drain from the protein structure and allow a meatier texture to form (McGee, 2004) . The tofu will have a chewier texture which will give the consumer a better mouthfeel such as the texture in beef, pork or lamb. The defrosted tofu can easily absorb marinades and liquids which can add flavor and moisture back to the tofu.

Figure 2.4 Process flow chart for a typical commercial process for tofu manufacture (Fennema, 2007)

2.1.3.1. Vegetable Based Meat Alternative Advantages and Disadvantages

Soy based meat alternatives are a cheap protein source that provide ample protein. The soybean is widely grown crop throughout the US making the bean a cheap commodity. The soy alternative provides a very high amount of protein compared to the dairy based

meat alternative (Figure 2.1). In order to produce a texturized soy nugget, there is a lot of processing that needs to be conducted on the soy bean. To produce soy fibers, soy protein isolate is adjusted to a pH of 12-13 and extruded into fine strands where the strands are placed in a bath of phosphoric acid and salt at a pH of 2.5 (Fennema, 2007). The fibers are stretched and shaped into nuggets. The fibers produce a meat like structure that has the ability to mimic some meat and ground meat products. A big issue with soy is the flavor profile. The soy bean produces a bean flavor that is very aromatic and flavorful in products no matter how much the product is processed. The bean flavor needs to be masked or disguised using other processing techniques or flavors. The soy meat alternative is a cheap protein that is high in protein and has the ability to produce fibers through laboring processes and is limited by its bean flavor.

2.1.4. Meat Alternatives Summary

There is a wide variety of meat alternative products on the market. Each of the meat alternative products have specific advantages and disadvantages to the production, flavor and texture that make each product unique. The dairy based meat alternative has the ability to produce a meat like product that delivers the flavor and nutrients.

The formation of the dairy protein gel structure is important to understand the textural features of the gel and how the gels form. Further understanding of the mechanisms, rheology, and functional properties of dairy protein gels are discussed in Section 2.2.

Table 2.1 Nutritional analysis of proteins

Serving Size (100 g)	Units	House Foods, Tofu, silken, soft ¹	House Foods, Tofu, silken, firm ¹	House Foods , Tofu, silken, extra firm ¹	Ricotta ²	Queso Blanco ⁴	Paneer ⁷
Moisture	%	86.0	83.6	82.1	68-73 ³	47-61 ⁵	50-54 ⁶
Calories	Kcal	58.8	70.6	94.1	174.0	321.0	60.0
Fat	g	2.9	3.5	4.7	13.0	21.0	5.0
Saturated Fat	g	0.0	0.0	0.6	8.0	14.0	3.0
Cholesterol	mg	0.0	0.0	0.0	51.0	71.0	17.0
Sodium	g	35.3	35.3	35.3	84.0	785.0	3.0
Carbohydrates	g	2.4	1.2	1.2	3.0	0.0	1.0
Dietary Fiber	g	1.2	1.2	1.2	0.0	0.0	0.0
Sugars	g	0.0	0.0	0.0	0.0	0.0	1.0
Protein	g	5.9	8.2	9.4	11.0	21.0	4.0

¹House Foods America, Garden Grove, CA

²(Le Révérend et al., 2010)

³(Di Luccia, 1994)

⁴Queso Blanco Nutrition: (LiveStrong, 2011)

⁵(Farkye et al., 1995)

⁶(Milkingredients, 2004)

⁷(Myfitnesspal, 2011)

Table 2.1 Continued nutritional analysis of proteins

Serving Size (100 g)	Units	Juustoleipa ¹	Halloumi ²	Mycoprotein (Quron) ³	Valess Toscana ⁴	Boca ⁵
Moisture	%	40.8	49.0	70.6	N/A	54.6
Calories	Kcal	393.0	340.0	116.0	201.0	206.9
Fat	g	32.0	28.0	3.6	9.5	8.0
Saturated Fat	g	21.0	15.0	1.0	1.5	0.6
Cholesterol	mg	107.0	70.0	7.0	N/A	0.0
Sodium	mg	607.0	1000.0	609.0	45.0	574.7
Carbohydrates	g	0.0	2.0	7.0	18.0	19.5
Dietary Fiber	g	0.0	0.0	3.0	4.5	3.4
Sugars	g	0.0	0.0	1.0	2.0	2.3
Protein	g	25.0	21.0	16.0	10.0	16.1

¹(Myfitnesspal, 2011)

²(Caloriecount, 2011)

³(Quorn, 2011)

⁴(Valess, 2011)

⁵(Boca, 2011)

2.2. MECHANISMS OF GELATION

2.2.1. Gelation Introduction

Gelation is an important process in the creation of a dairy protein gel. By understanding the gelation process, specific textures can be attained through different gelation procedures. These gelation procedures can produce different dairy protein gels which may have different melting capabilities when the gel is heated. In order to understand more about the gelation of dairy protein gels, the chemistry and configuration of the dairy protein gels were researched to understand the protein matrix within gels and texture that may be produced. Two specific food gels: polymer and particle gels (Fennema, 2007), will be presented.

2.2.2. Polymer Gels

The polymer gel has a long linear chain of molecules that are cross-linked at different points (Fennema, 2007). The chain of molecules can be cross-linked with covalent bonds or non-covalent cross-links such as salt bridges, entanglements and microcrystalline regions (Fennema, 2007). A polymer gel can be characterized as being flexible such as in gelatin gels to a rigid structure such as a polysaccharide gel (Fennema, 2007).

2.2.3. Particle Gels

Particle gels are particles that are dispersed throughout water. The particles can be hard particles such as triacyclglycerol particles in plastic fat and deformable particles such as casein micelles (Fennema, 2007). The junction of these particles can be bonded by van der Waals forces, electrostatic, hydrophobic, and hydrogen bonding. Also, the bonds can be cross linked with covalent bonds such as disulfide bonds.

2.2.4. Temperature and Colloidal Interaction Induced Gels

The gels can be induced through heating, cooling, and by changing specific molecular interactions. A heat -set gel denatures globular proteins and forms a gel if the protein concentration is above the critical value of c_0 (Fennema, 2007). c_0 depends on the rate of heating, physico-chemical properties, and the nature of the proteins in the system (Fennema, 2007). As these gels cool, they become firmer and mostly irreversible. When heated, both whey protein and egg albumin denature to produce an irreversible gel.

Cold-set gels are first formed through a heating process in which the particles in the materials disperse into smaller particles. During the cooling process, the gels are formed through cross-linking. While cooling, polymer gels form network-forming molecules through conformational transition (Fennema 2007). Gelatin is a common product when heated will disperse into smaller particles and while cooling will form a cold-set gel.

Gels can also be formed by changing the colloidal interactions such as using pH, salt concentration, enzyme, and different ionic strengths. For cheese production, rennet is used which cleaves k-Casein at Phe105-Met106 which produces the peptides para k-Casein (K CN (1-105)) and glyco macropeptide (K-CN(106-169)) (Fox, 1998). The casein micelles aggregate in the presence of ionic calcium to form a gel. Another example is at isoelectric point of casein at a pH of 4.6, an acid-gel will form due to the solubilization of colloidal calcium phosphate which precipitates out casein (Fox, 1998).

2.3. RHEOLOGICAL PROPERTIES OF DAIRY PROTEIN BASED GELS

2.3.1. Elastic Behavior in Gels

A gel mostly exhibits an elastic behavior and has a fairly small modulus ($<10^7$ Pa) compared to solids (Fennema, 2007). The modulus is the ratio between stress (σ /force/area) and relative deformation or strain (ϵ) (Fennema, 2007). An elastic behavior demonstrates that the object deforms instantaneously under stress while strain remains constant in time, but will return to its original state after stress is released. After stress is applied and released, some gels do not return to their original state. These types of gels are considered viscoelastic. Gelatin behaves in an elastic manner while acid-set and rennet gels behave with a viscoelastic manner.

2.3.2. Gels Under Stress

While gels are under stress, it may fracture or yield. Fracturing is the point at which the gel breaks at the maximum stress level (Bourne, 2002). Yielding is a gel which flows under stress and stays as a coherent mass such as butter under stress (Fennema, 2007). The fracturing of the cheese curds during the cheese cutting process assist in the release of whey from the curds.

Particle gels can form due to the aggregation of molecules through attraction by salt concentration, ionic strength or pH. The aggregation of the particles into large clusters is called cluster-cluster aggregation. The amount and radius of the aggregates that form have a relationship:

$$N_p = (R/r)^D$$

The N_p is the number of particles in an aggregate while R represents the radius. D is the fractal dimensionality which is a constant that is <3 (Fennema, 2007). The constant is less than three meaning that the larger aggregates are less dense and compressed than smaller aggregates. The aggregates rearrange themselves and form bonds with one or more aggregates to produce a gel. The modulus of the gel comes from the change in enthalpy during deformation (Fennema, 2007). The fractal structures are very similar, which suggests that the number of bonds between the aggregates is independent of the radius of each structure (Fennema, 2007). Particle gels are disorganized and can contain

different size aggregates but the strength of the bonds formed can help to increase gel strength.

2.4. FUNCTIONAL PROPERTIES OF DAIRY PROTEIN BASED GELS

2.4.1. Properties of Gels

Gels are created to obtain specific textures and consistencies that provide product stability. The properties of gels include consistency, motion of particles, local volume changes, motion of solvent and motion of solute. Consistency is measured during a certain time period or strain rate (Fennema, 2007). The motion of particles can be promoted and prevented through sedimentation and aggregation. Permeability follows Darcy's law which states the velocity of a liquid through pores:

$$v=Q/A=(B/\eta)x(\Delta p/x)$$

v = velocity

Q = volume flow rate (m^3s^{-1})

A = cross-sectional area

B = permeability (m^2)

η = viscosity

Δp = pressure difference

x = distance

Particle gels such as renneted cheeses which contains paracasein micelles has a higher permeability rate (10^{-12} m^2) compared to polymer gels (10^{-17} m^2) such as gelatin based gels (Fennema, 2007).

2.4.2. Syneresis in Gels

Syneresis and swelling are important properties of gels. Syneresis is the expulsion of liquid from the gels. Swelling is the ability of a material to absorb and hold onto fluids. Syneresis can be caused in polymer gels by lowering the solvent level, the addition of salt, and/or increase in cross-links. Syneresis will occur slower in polymer gels but in particle gels, the liquid will be expelled faster due to permeability (B). Renneted milk gels needs syneresis to occur during pressing so excess whey can be removed to form a block of cheese.

2.5. GLOBULAR PROTEIN GELS

Soluble globular proteins form gels when heated if the protein concentration is above c_0 (Fennema, 2007). The gels form when some of the proteins completely denature and do not return to the protein's native state when cooled. One example is a gel made from whey protein isolate. The gels form by the proteins first denaturing, then aggregating together into different elongated shapes, and then the particles produce a network within a space (Fennema, 2007). These heat set gels form disulfide bond linkages and van der Waals, electrostatic, and hydrophobic interactions.

There are two types of strands that can form in a gel structure, fine-stranded and coarse-stranded. Fine stranded gels are transparent, have thin strands that can be branched to form the network in the gel, and are created by heating proteins that are far from the isoelectric point with low ionic strength (Fennema, 2007). Heat-treated whey protein gels adjusted to a pH of 7 and 3 produced fine stranded gels (Walkenström and Hermansson, 1996; Picone et al., 2011) . Coarse-stranded gels contain small sphere particles that make the gel turbid. The gel is created by heating proteins that are close to the isoelectric point with or without high ionic strength. Soy proteins gels adjusted to a pH of 3.8 produced coarse-stranded gels that are white in appearance (Renkema et al., 2000). Coarse gels tend to more rigid than fine stranded gels. Also globular proteins can be denatured at a specific pH while heating and can be brought to the isoelectric point during a process to form a gel while cooling (Davies et al., 1988). This type of method is used during the extruding of nonfat dried milk and whey protein concentrate.

2.6. CASEINATE GELS

Some gels are built on casein micelles which can form flexible bonds between each micelle. During gelation, the protein unfolds and can bind more water. The interaction of the proteins around the water molecules forms a network which entraps the water and forms a gel (Mangino, 1984). The strength of the gel depends on pH, ionic strength, protein concentration, and composition (Veith and Reynolds, 2004). Milk gels can be formed either through precipitation at the isoelectric point (acidic pH) or using a proteolytic enzyme (chymosin). Rennet based gels have a tendency to flow under the gels own weight and

undergo syneresis. Also, by applying a pressure over 10 Pa to the rennet-induced gel, the gel will flow and fracture after a period of time (Fennema, 2007). Rennet-induced gels above 20⁰ C show an increase in syneresis (Fennema, 2007). Both types of milk gels can increase the firmness of the final product due to time of aggregation of micelles (Lucey et al., 2003), temperature, increasing calcium, casein content and by reducing the pH (Walstra, 1984). Calcium in the system can have a major effect on the formation of gels because of the cross-linking properties of calcium (Barbut and Foegeding, 1993). High heat denaturing proteins such as whey proteins can increase firmness and lead to a higher modulus for acid-induced gels (Fennema, 2007). The use of whey proteins in acid milk gels will help to create a firmer curd structure (Lucey et al., 1999). Also, the use of higher concentrations of whey proteins such as WPC can increase the cohesiveness in Ricotta cheese curd (Jayaprakasha, 1999). Fat globules can interrupt the casein gels and weaken the structure but when homogenized, the gel can increase in firmness depending on homogenization factors. Also yield stress can be lowered through homogenization in rennet-induced gels (Fox, 1998).

2.7. MILK PROTEIN CHEMISTRY

Bovine milk contains approximately 3.5% protein. There are two groups of milk proteins which are caseins and whey proteins. Caseins are stable at high temperatures but precipitate at the isoelectric point of a pH of 4.6. Whey proteins denature at high temperatures around 90⁰C for 10 minutes while being stable at a higher pH (Fox, 1998). The milk proteins are discussed further by the type of milk protein.

Bovine casein is made up of five types of proteins: α s1, α s2, β - CN, κ - CN, and γ - CN. α s1 and β - CN make up 34% and 25% of the caseins, respectively. Each casein type has an important role for the stability of the micelle. β - CN dissociates at low temperatures and precipitates at calcium concentrations above 6 mM (Fox, 1998). α s1 and α s2 precipitates at calcium concentrations above 6mM. κ - CN is not sensitive to calcium so the protein is able to prevent precipitation by coating the outside of the micelle. During the cheese making process, chymosin hydrolyzes the micellar κ - CN at the Phe105-Met106 bond which is released into the whey solution (Fox, 1998). The proteins then aggregate and form a gel known as the coagulum.

Whey proteins are composed of α -lactalbumin and β -lactoglobulin. β -lactoglobulin is the major whey protein that represents 50% of all whey proteins. The protein contains sulfur amino acids and has 2 moles of cystine and 1 mole of cysteine per 18kDa (Fox, 1998). Cysteine is important in the binding process of the disulfide bonds between κ -casein and β -lactoglobulin. In the quarternary structure, β -lactoglobulin is a dimer at a pH range of 7.5 to 5.5.

When processing whey mixed with skim milk, the heating of the mixture to 85⁰ C will cause an irreversible denaturation of the β -lactoglobulin. The protein will aggregate and form intermolecular disulfide bonds, and then form hydrophobic and electrostatic bonding. The heating of β -lactoglobulin will expose sulfhydryl and disulfide residues which produce disulfide linkages between β -lactoglobulin, κ - CN and fat molecules or caseins. After heating the mixture for a length of time, acid is added to reduce the pH. The reduction of the pH helps to promote coagulation of the casein in the milk and to increase

syneresis in the curds to remove extra whey. The curds aggregate and entrap air which causes the curds to flocculate to the top of the heating vessel.

2.8. NON-MELTING DAIRY PROTEIN GELS

A variety of non-melting dairy protein gels were examined to produce a versatile product for different food systems. Dairy protein gels have different compositions and produce different textures. There is a large range of dairy protein gels, specifically products that are non-melting. There has been some previous research conducted on the non-melting dairy protein gels queso blanco, ricotta and halloumi. Analysis of queso blanco, ricotta, and halloumi were conducted by Farkye and Prasad (1995), Yeung (1997), and Shah (2007); respectively. The previous research conducted on the queso blanco was to evaluate the sensory preference and instrumental attributes of the dairy protein gel. The previous research on halloumi and ricotta were to determine if a tofu-like texture could be attained under different processing conditions. Each dairy protein has unique characteristics and textural attributes. In the following sections, five non-melting dairy protein gels will be discussed. These non-melting protein gels are ricotta, halloumi, juustoleipa, queso blanco, and paneer. The texture of the non-melting dairy protein gels are discussed in section 2.9.

2.8.1. Ricotta

Ricotta is an Italian cheese that is produced from the remaining whey of Mozzarella. Acid is added to whey to bring down the pH and the whey is brought up to 85°C until the proteins flocculate. The high heat causes denaturing of proteins and disulfide bonding of beta lactoglobulins and κ -CN in whey (Fox, 1998). Ricotta is produced by adding milk to the whey before raising the temperature of the mixture. The curds float to the top due to the entrapped air. Ricotta and ricotone are soft curds that crumble and can be used in dishes such as lasagna.

Ricotta contains a high amount of moisture from 68-73% (Table 2.1). This dairy protein gel has one of the highest moisture levels out of all the dairy protein gels. The dairy protein gel can produce approximately 11% protein (Table 2.1) which is lower compared to the other dairy gels due to the higher moisture content. The higher moisture content creates a softer product that can be formed into shapes but needs to have excess whey drained from the coagulum to support a final shape (Yeung, 1997). The gel produces a granulated texture like soft tofu and has the ability to not flow.

Previous research conducted by Yeung (1997) investigated the milk to whey ratios and pH level of acidification to determine the dairy protein gel composition and instrumental textural attributes (Section 2.9).

When properly pressed and drained, the dairy protein gel can be steamed, deep fried, pan fried, baked, sautéed, wokked, smoked, boiled, broiled, stewed, simmered, grilled, and sous vided. The dairy protein gel's texture can be manipulated for consumption by pureeing, cubing, and slicing the product. Direct heating techniques causes the ricotta to

produce a brown or even black skin due to the lactose that may be found in the dairy protein gel. Indirect heating techniques produce a moist texture on the inside and outside of the product.

2.8.2. Halloumi

Halloumi is an eastern Mediterranean cheese that comes from goat's or sheep's milk. The dairy protein gel has a higher pH around 5.7 to 5.9 range compared to other non-melting dairy protein gels which can have a lower pH. After the pH is reduced, the rennet is added to the milk and the whey is drained. The dairy protein gel is pressed and boiled in whey until the curd floats. When the dairy protein gel is boiled in whey, the kappa casein and beta lactoglobulins cross-link and form strong disulfide bonds. These bonds limit dairy protein gel flow. Many cultures grill or fry this dairy protein gel due to the dairy protein gel's inability to flow.

Halloumi contains a medium amount of moisture approximately 49% (Table 2.1). The dairy protein gel has a higher protein content around 21% protein (Table 2.1). The lower moisture content creates a firm product that can be sliced and manipulated to produce a chicken like structure (Shah, 2007). The gel produces a smooth texture that mimics firm tofu and has the ability to not melt. There is also more calcium in halloumi due to the addition of CaCl_2 and higher pH level of 5.8 which restricts the melt of the product (Farkye and Lee, 1998) and may increase the firmness of the product.

Previous work conducted by Shah (2007) investigated the impact of the processing parameters on the flow and instrumental textural attributes of the dairy protein gel;

specifically looking at the effect of pasteurization temperatures, pH of acidification and homogenization conditions on the flow and instrumental textural attributes of the dairy protein gel when heated.

The dairy protein gel can undergo different heating methods and conditions. The halloumi can be steamed, deep fried, pan fried, baked, sautéed, wokked, smoked, boiled, broiled, stewed, simmered, grilled, and sous vided. The dairy protein gel's texture can be manipulated for consumption by grating, pureeing, cubing, and slicing the product. Direct heating techniques causes the halloumi to produce uneven browning due to the lactose found in the dairy protein gel. Indirect heating techniques produce a moist texture on the inside and outside of the product.

2.8.3. Queso Blanco

Queso blanco is a Mexican cheese which cow's milk is traditionally used. Acid is added to the boiling milk, the curds are stirred, whey drained, and the dairy protein gel is sometimes pressed (Tunick et al., 2008). The milk proteins are precipitated due to heat and acid. The proteins form a particle gel which the κ -CN and beta lactoglobulin crosslink. Heating of the milk denature some of the milk and whey proteins. The addition of acid decreases the pH near the isoelectric point which causes the proteins to precipitate. The queso blanco produces a soft crumbly texture that can be used to garnish dishes and to accompany classical Mexican dishes. Research conducted by Farkye and Prasad (1995) showed that by using specific acid types such as acetic acid, lactic acid, and citric acid,

different textures in queso blanco can be produced. Also, as the dairy protein gel aged, the use of acetic and citric acid was preferred by a consumer panel.

Queso blanco has a large moisture range approximately from 47-61% (Table 2.1). The dairy protein gel has a higher protein content at 21% protein (Table 2.1). The moisture content can create a firm or soft product that can be crumbled. The gel does not melt due to the precipitated proteins.

The dairy protein gel can be steamed, deep fried, pan fried, baked, sautéed, wokked, smoked, boiled, broiled, stewed, simmered, grilled, and sous vided. The dairy protein gel's texture can be manipulated for consumption by pureeing, cubing, and slicing the product. Direct heating techniques causes the queso blanco to produce uneven browning and blackening due to the lactose found in the dairy protein gel. Indirect heating techniques produce a moist texture on the inside and outside of the product.

Figure 2.5 Queso Blanco (Alden, 2005)

2.8.4. Juustoleipa

Juustoleipa or “bread cheese” is a Finnish cheese made from cow or reindeer milk. Rennet is added to the milk and the curds are pressed into blocks. The high heating of the dairy protein gel deforms the dairy protein gel and reforms into a final shape. The polymer gel melts very slightly and retains its shape during further heating steps. The dairy protein gel is sliced and baked or broiled until a dark brown outside appears. It is served with jam or used as a biscotti (Cheese, 2011).

Juustoleipa contains a lower amount of moisture approximately 40% (Table 2.1). The dairy protein gel has a high protein content around 25% (Table 2.1) compared to the other non-melting dairy protein gels. The lower moisture content creates a firm protein gel that can be sliced. The gel produces a smooth texture that mimics firm tofu and also has the ability to not melt.

The dairy protein gel can be steamed, deep fried, pan fried, baked, sautéed, wokked, smoked, boiled, broiled, stewed, simmered, grilled, and sous vided. The dairy protein gel's texture can be manipulated for consumption by grating, pureeing, cubing, and slicing the product. Direct heating techniques causes the juustoleipa to produce a small amount of uneven browning due the small amount of lactose that is left after the initial direct heating process. Indirect heating techniques produce a moist texture on the inside and outside of the product.

Figure 2.6 Juustoleipa (Systems, 2010)

2.8.5. Paneer

Paneer is a firm tofu-like product that does not flow when heated. Cow's milk is used to produce this product. The dairy protein gel originates from India. Acid is added to hot milk, the curds are stirred, whey drained, and the dairy protein gel is pressed to remove excess whey (Gunasekaran and Ak, 2003). The milk proteins are precipitated due to heat and acid. The proteins form a particle gel which the κ -CN and beta lactoglobulin crosslink. The heating of the milk denature some of the milk and whey proteins. The addition of acid decreases the pH near the isoelectric point which causes the proteins to precipitate. The paneer produces a firm texture that can be used in stews and stir-fried dishes mostly found in Indian cuisine.

Paneer has a moisture range approximately from 50-54% (Table 2.1). The dairy protein gel has a lower protein content at 9% protein (Table 2.1). The low moisture content can create a firm product when pressed. The gel does not melt due to the precipitated proteins.

The dairy protein gel can be steamed, deep fried, pan fried, baked, sautéed, wokked, smoked, boiled, broiled, stewed, simmered, grilled, and sous vided. The dairy

protein gel's texture can be manipulated for consumption by pureeing, cubing, and slicing the product. Direct heating techniques causes the paneer to produce uneven browning and blackening due to the lactose found in the dairy protein gel. Indirect heating techniques produce a moist texture on the inside and outside of the product.

2.9 TEXTURE AND SENSORY ANALYSIS ON NON-MELTING DAIRY PROTEIN GELS

As discussed in the previous sections, the production of a dairy protein gel can produce different textures. A range of textures can be produced from a firm dairy protein gel like halloumi to a soft granular dairy protein gel like ricotta. In this thesis, a mechanical device and human subjects were used to measure texture attributes.

A texture analyzer (Section 4.1.1.2.) was used to objectively measure texture attributes with texture profile analysis. Texture profile analysis is a compression test which bite sized pieces of food are compressed two times to imitate the movement and action of the jaw (Bourne, 2002). From the compression of the food product, different texture attributes can be extrapolated from the data. The texture measurements that are produced are hardness, springiness, cohesiveness, chewiness, gumminess, and adhesiveness (Bourne, 1978). In Figure 4.1, A refers to the force that represents the measurement hardness. Springiness was extrapolated from subtracting the distance of D from B. Cohesiveness was produced by dividing C from E. F refers to the negative area which represents the texture measurement adhesiveness. Gumminess is the hardness multiplied by the cohesiveness. Chewiness was extrapolated by multiplying gumminess by

springiness. Multiple types of tests can be run on the textural analyzer to evaluate the texture of the product. In the meat industry, the Warner-Bratzler Shear test is conducted to determine the shear and firmness of meat products such as sausage (Bourne, 2002). There has been research demonstrating that instrumental texture attributes significantly correlate with sensory attributes for different food types (Szczesniak et al., 1963; Szczesniak and Torgeson, 1965). This shows that the texture analyzer is good predictor of the sensory texture attributes for a specific food product depending on the texture method.

Sensory evaluation is another method to determine the texture attributes of a product. Sensory evaluation is the use of human subjects to measure, analyze and interpret the reaction of the characteristics of food products with the use of the five senses touch, sight, smell, hearing and taste (Stone and Sidel, 2004). Human subjects are used to act as the detector of the specified characteristic of a food product. Sensory can be conducted on the characteristics of products such as flavor, moistness and texture to understand the characteristics of the food type. Human subjects can be trained or untrained depending on the research that is being conducted. Trained panelists are used to determine specific differences in one or more attributes of a product. The responses can be used to determine qualitative properties of the product. Untrained panelists tend to be used in consumer acceptability panels which no experience is needed. The consumer acceptability panel's responses judge the products acceptability. To measure the panel's evaluation of products, a series of scales and measurement techniques can be used to evaluate the five senses and specific food qualities and characteristics. Scales such as interval and ratio scales can be used to measure characteristics of a product from the weakest to strongest (Stone and Sidel, 2004).

In this thesis, hedonic scales and just about right scales will be used to evaluate dairy protein gels and commercial nuggets. Hedonic scales were produced by Jones et al., (1955) and Peryam and Pilgrim (1957) to evaluate military food. The scale can consist of five to nine points which describe the attribute of the product being tested. The scale consists of the points “like extremely” to “neither like or dislike” to “dislike extremely”. The hedonic scale has been proven to be reliable and valid (Meiselman et al., 1974) and has been used throughout the industry. While just about right scales are used to evaluate a larger scale of consumers (Stone and Sidel, 2004). This is a bipolar scale with three or five attributes to describe the product (Stone and Sidel, 2004). The scale consists of the points “much to strong” to “just about right” to “much too weak”. This type of scale is not recommended for sensory evaluation because of the reliability of the scales. The scales confound attribute intensities and preferences into a single response. Also interpretative errors due to the use of the product attribute name may cause problems in the scale reliability (Stone and Sidel, 2004). The just about right scale is not a reliable scale for evaluating descriptive sensory data. This scale should only be used for consumer acceptability tests but with caution due to the reliability of the scale. The hedonic scale with trained panelists was used in this thesis on dairy protein gels to determine textural differences in the product. The just about right scale with untrained panelists was used on dairy protein gels to determine consumer acceptability of the product.

2.9.1. Previous Research on Instrumental Textural Attributes of Non-Melting Dairy Protein Gels

Analysis of instrumental textural attributes was conducted on queso blanco, ricotta, and halloumi by Farkye and Prasad (1995), Yeung (1997), and Shah (2007); respectively. Texture attributes and terminology definitions can be found in Section 5.6.

The experiments conducted on queso blanco showed that there was an increase in the hardness, fracturability, chewiness and gumminess due to the use of acetic acid. Lactic acid produced the lowest hardness, fracturability, chewiness and gumminess. Springiness and cohesiveness were not dependent on the acid type used. As the age of the queso blanco increased, all of the textural attributes increased excluding cohesiveness.

The experiments conducted on ricotta showed that there was an increase in hardness as the acidification level increased. As the casein to whey ratio decreased from 30/70 to 20/80, a firmer product was produced. A firmer ricotta was reached as the level of acidification increased and the casein to whey ratio was decreased.

The experiments conducted on halloumi determined that the texture property hardness was affected by the pasteurization temperature and the pH of acidification. Milk that was coagulated at a high pasteurization temperature (88.3°C/ 16 sec) produced the highest hardness attribute. At a pH of 5.8, the halloumi hardness attribute was highest. Also as the coagulation time increased, there was a decrease in hardness.

There has not been any further research done on texture attributes, development, and acceptability of a dairy based meat alternatives in the dairy industry. Further research needs to be completed on the texturization of a dairy protein gel to produce a dairy base

meat alternative. Also, research needs to be conducted on the acceptability of a dairy base meat alternative comparing the dairy product to other meat alternatives on the market.

2.9.2. Previous Research on Sensory Textural Attributes of Non-Melting Dairy Protein Gels

Analysis of sensory textural attributes was conducted on queso blanco, and halloumi by Farkye and Prasad (1995), and Piggott et al. (1998), respectively. Texture attributes and terminology definitions can be found in Table 7.2.

Farkye and Prasad (1995) conducted an experiment on the effects of the type of acid and age on queso blanco sensory and instrumental texture. An acceptability test was used to determine the sensory attributes flavor, body, texture and overall acceptability. A nine-point hedonic scale was used (9= like extremely to 1 = dislike extremely). The sensory panel showed that acetic acid produced the best body and texture. Also the older queso blanco product at 7 weeks was preferred depending on the acid type used.

Piggott (1998) conducted experiments on the sensory characterization of halloumi and its relationship with headspace composition. A trained panel was used to use descriptive sensory analysis to profile the texture and flavor of halloumi. The panel was able to show that texture attributes were affected due to cooking such as coarse, rubbery, tough and squeaky. The sensory hardness decreased with the cooking of the halloumi.

There has not been any research done on the sensory texture attributes of ricotta. Further research needs to be conducted to understand the basic textural measurements of non-melting dairy protein gels using a sensory panel.

2.10. GENERAL CONCLUSION

There is a wide range of meat alternative products on the market that vary in texture, flavor and type of protein source. There has been limited research conducted on the use of a dairy protein gel in the production of a meat alternative. Due to the manipulation of processing parameters, different dairy protein gels could be produced that have the ability to not flow. There are many textural differences between each dairy protein gel. By understanding the formation and texture attributes of dairy protein gels, a dairy protein gel can be selected to produce a meat-like texture. From the literature review, dairy has many beneficial attributes that can make it a superior product compared to other protein sources. Due to the limited research in dairy based meat alternatives, the production of a dairy based nugget needs be assessed to understand 1) texturization of a dairy protein gel to mimic a chicken texture, 2) emulsification of flavor and gum into the dairy system to produce a chicken like flavor profile, and 3) acceptability of dairy based nugget compared to commercial chicken and meat alternative products. Further investigation into the development of dairy based meat alternative will be discussed in the next sections.

3.0 HYPOTHESIS AND OBJECTIVES

The hypotheses of this study were:

- 1) The decrease in pH and increase in the milk to whey ratio in an acid and heat induced milk protein gel will increase the overall texture properties.
- 2) The increase in the grind size and use of the milk based protein gel will increase the overall texture properties.
- 3) The dairy based meat alternative will produce similar sensory attributes as other meat alternative products.

The overall objectives were completed in three phases.

Phase I

To determine the texture of an acid- heat induced milk protein gel by the effect of the pH level of acidification and milk to whey ratio on the dairy protein system.

Phase 2

To investigate if different size grinding plates and the presence of methylcellulose influence the texture of a dairy protein gel.

Phase 3

To determine if a dairy based meat alternative was considered an acceptable product by a consumer panelist.

4.0 PRELIMINARY STUDIES

Preliminary studies were conducted on the development of a dairy based meat alternative nugget. There has been very little research conducted on the production of a dairy based meat alternative. Due to the lack of research, experiments were performed to produce a non-melting dairy protein gel that can produce a meat-like texture and incorporate flavorings and emulsifiers/stabilizers into the dairy system. In this section, the process and formulation of a dairy based nugget will be discussed. A pictorial overview of the dairy based nugget development is depicted in Figure 4.1.

Figure 4.1. Pictorial overview of the dairy based nugget development

4.1 TEXTURE PROFILE ANALYSIS ON MEAT, MEAT ALTERNATIVES AND NON-MELTING DAIRY PROTEIN GELS

Before a dairy protein gel was selected to be used as a meat alternative base, the textural properties of meat, meat alternatives and dairy protein gels were investigated. An objective way to investigate the textural properties of meat, meat alternatives and dairy protein gels was to use the textural analyzer. Each category of nuggets was examined with the texture analyzer to understand the textural profile of each type of meat, meat alternative and dairy protein gel. The goal of understanding the textural profile of each category of nuggets was to determine reference points to compare to the final dairy based nugget. A meat nugget and soy-based nugget were chosen as the reference points for the meat and meat alternative nugget categories. The nuggets that were selected were the meat nugget McDonald's and the soy-based nugget Boca. Both of these products are highly consumed in the marketplace. Dairy protein gels, meat and meat alternatives were objectively measured by the texture analyzer and compared to each product in the following sections.

4.1.1. Methods and Materials

4.1.1.1. Texture Profile Analysis

Texture profile analysis was performed on the dairy protein gels using TA-XT2 (Texture Technology Corporation, Scarsdale, NY). The software used for the texture analyzer was Expert Version 1.22 software (Stable Micro Systems, Scarsdale, NY). Each

dairy protein gel was cut using a knife (20 mm width by 20 mm length by 15 mm height) and placed in the refrigerator at 4°C for 2 hours. The samples were cut in these dimensions due to the chicken nugget commercial samples that did not have a height above 15 mm. Before the samples were analyzed, the samples were removed from the refrigerator and held at room temperature (25°C) for 30 minutes. Each sample was tested in triplicates. The 75 mm compression plate probe and 50% compression was used for the texture analyzer. The test was performed on a P75-75 mm compression plate. The parameters of the texture analyzer and testing can be found in Table 4.1.

Table 4.1 Texture profile analysis parameters.

Parameter	Programmed Parameter
Text Mode	s TPA
Pre-test	1.2 mm/sec
Compression	50%
Time	5.00 seconds
Trigger Type	Auto
Force	5 g
Stop Plot	Trigger Return
Probe Type	P75- 75 mm compression plate

The texture measurements that were extrapolated from the data were hardness, springiness, cohesiveness, chewiness, gumminess, and adhesiveness (Bourne, 1978). In Figure 4.1, A refers to the force that represents the measurement hardness. Springiness was extrapolated from subtracting the distance of D from B. Cohesiveness was produced by dividing C from E. F refers to the negative area which represents the texture

measurement adhesiveness. Gumminess is the hardness multiplied by the cohesiveness. Chewiness was extrapolated by multiplying gumminess by springiness.

4.1.2. Texture Profile Analysis on Non-Melting Dairy Protein Gels

Texture profile analysis was conducted to analyze the texture properties of the non-melting dairy protein gels halloumi, juustoleipa, queso fresco and ricotta. The texture measurements that were measured were hardness, springiness, cohesiveness, chewiness, and gumminess.

Figure 4.2 TPA for hardness of non-melting dairy protein gels
n=12 Error bars represent the standard deviation for each sample

Figure 4.3 TPA for springiness of non-melting dairy protein gels
 n=12 Error bars represent the standard deviation for each sample

Figure 4.4 TPA for cohesiveness of non-melting dairy protein gels
 n=12 Error bars represent the standard deviation for each sample

Figure 4.5 TPA for gumminess of non-melting dairy protein gels
n=12 Error bars represent the standard deviation for each sample

Figure 4.6 TPA for chewiness of non-melting dairy protein gels
n=12 Error bars represent the standard deviation for each sample

From the figures above, halloumi was at least two times harder, gummier, and chewier compared to the other non-melting dairy protein gels. Queso blanco was the springiest of all the cheeses. Ricotta produced the least textural attributes due to the moisture content in the cheese (Figure 4.21). The increase in moisture content decreases hardness and springiness (Gunasekaran and Ak, 2003) which can reduce other textural properties of the dairy protein gels. Halloumi and juustoleipa had very similar cohesive properties.

Halloumi had very high textural attributes compared to all the cheeses. Even though queso blanco had a larger springiness, halloumi was very close in springiness. The textural attributes of non-melting dairy protein gels provides a base understanding of the starting point of the dairy protein gel products before the textural attributes are processed into a dairy based meat alternative.

4.1.3. Texture Profile Analysis on Commercial Meat Products

Texture Profile Analysis was used to analyze the texture properties of commercial chicken nuggets. The brands tested were Tyson chicken breast tenders, Tyson chicken nuggets, McDonald's chicken nuggets, Burger King nuggets, Carl's Jr. star nuggets. Frozen and fast food nuggets were compared to determine if there was a difference between the two types of nuggets. Frozen chicken nuggets from Tyson and fast food nuggets from McDonald's, Burger King and Carl's Jr. were analyzed.

Figure 4.7 TPA for hardness on commercial chicken nuggets
n=18 Error bars represent the standard deviation for each sample

Figure 4.8 TPA for springiness on commercial chicken nuggets
n=18 Error bars represent the standard deviation for each sample

Figure 4.9 TPA for cohesiveness on commercial chicken nuggets
 n=18 Error bars represent the standard deviation for each sample

Figure 4.10 TPA for gumminess on commercial chicken nuggets
 n=18 Error bars represent the standard deviation for each sample

Figure 4.11 TPA for chewiness on commercial chicken nuggets
n=18 Error bars represent the standard deviation for each sample

From the figures above, on average the fast food nuggets had a slightly firmer texture, 25% more cohesive and was 33% more gummier and chewier compared to the frozen nuggets. The frozen nuggets on average had a slightly larger springiness.

Both McDonald's and Burger King have similar textural attributes. The frozen nuggets had different textural attributes between the different companies. This data established the textural attributes for meat based nuggets. The non-melting dairy protein gels and meat alternatives can be compared to the meat products that were analyzed to determine if there are differences in the textural attributes. The formulation of the dairy based meat alternative can be compared to the meat textural attributes and determine if similar meat textural attributes can be produced with a dairy protein gel.

4.1.4. Texture Profile Analysis on Meat Alternative Nuggets

Texture Profile Analysis was used to analyze the texture properties of commercial meat alternative nuggets to determine the textural attributes of commercial meat alternative nuggets. The brands tested were Quron, Morning Star, Gardein, Smart Tenders, Boca, and Cluckpherg. Morning Star, Gardein, Smart Tender, Boca, and Cluckpherg were made from vegetable proteins which was mostly soy. Quron is made from the byproduct of the fungus mycoprotein. These products were tested to determine the textural attributes for the competing commercial meat alternative nuggets on the market.

Figure 4.12 TPA for hardness on meat alternative nuggets
n=18 Error bars represent the standard deviation for each sample

Figure 4.13 TPA for springiness on meat alternative nuggets.
n=18 Error bars represent the standard deviation for each sample

Figure 4.14 TPA for cohesiveness on meat alternative nuggets.
n=18 Error bars represent the standard deviation for each sample

Figure 4.15 TPA for gumminess on meat alternative nuggets.
n=18 Error bars represent the standard deviation for each sample

Figure 4.16 TPA for chewiness on meat alternative nuggets.
n=18 Error bars represent the standard deviation for each sample

From the figures above, on average Quron was at least 10% more firm and chewier, and at least 5% springier and gummier compared to the other meat alternatives. Cluckpherg produced a more cohesive structure compared to all the meat alternatives.

Quron produced the highest overall textural attributes which could be related to the fungus's aligned protein structure (Miri et al., 2005). Using this data from competing products, the production of a dairy based meat alternative can use the above texture attributes as guidelines for the processing parameters of a dairy protein gel base.

4.1.5. A Comparison of the Texture Profile Analysis on Commercial Meat, Meat Alternative and Dairy Protein Gel Products

All of the previous nugget categories were compared using the texture analyzer to compare the textural attributes of all the protein sources. The textural attributes are displayed in the figures below.

Figure 4.17 TPA for hardness on meat products, meat alternative products and non-melting dairy protein gels.

n=48 Error bars represent the standard deviation for each sample

Figure 4.18 TPA for springiness on meat products, meat alternative products and non-melting dairy protein gels.

n=48 Error bars represent the standard deviation for each sample

Figure 4.19 TPA for cohesiveness on meat products, meat alternative products and non-melting dairy protein gels.

n=48 Error bars represent the standard deviation for each sample

Figure 4.20 TPA for gumminess on meat products, meat alternative products and non-melting dairy protein gels.

n=48 Error bars represent the standard deviation for each sample

Figure 4.21 TPA for hardness on meat products, meat alternative products and non-melting dairy protein gels.
n=48 Error bars represent the standard deviation for each sample

Halloumi and juustoleipa produced the highest overall textural measurements excluding the springiness measurement. Queso fresco had very similar texture measurements compared to the meat products. Ricotta had very low texture measurements throughout all the texture parameters. A reason that the texture of the dairy protein gel products is affected because of the moisture content in the dairy protein

gel. In figure 4.21, ricotta has a higher moisture content which produced a less firm structure.

The textural attributes of the non-melting dairy protein gels show promising results for a meat alternative. Further processing may be needed for the non-melting dairy protein gels to produce a dairy based nugget which may affect the final texture of the dairy protein gel but may be needed to produce a chicken nugget-like structure. The decision of the type of non-melting dairy protein gel base will be determined in the following sections.

Figure 4.22 TPA for hardness on meat products, meat alternative products and non-melting dairy protein gels.

n=48 Error bars represent the standard deviation for each sample

4.1.6. Texture Profile Analysis on Meat, Meat Alternatives and Non-Melting Dairy Protein Gels Conclusion

The non-melting dairy protein gel has great potential as a meat alternative. With halloumi and juustoleipa having at least a 75% firmer structure, 10% more cohesive, at least three times more gummier, and more than twice in chewiness texture, the dairy protein gels have a structure that can be processed into a dairy based meat alternative.

4.2 DAIRY PROTEIN GEL FORMULATION AND DETERMINATION

From the texture results, the halloumi and juustoleipa produced the highest textural attributes while ricotta had lower textural attributes out of the dairy protein gels. The dairy protein gels were examined further to determine which dairy protein gel produced a meat-like structure. Experiments were conducted to produce chicken like texture and meat fiber structures using the halloumi method (Figure 4.24) and ricotta method (Figure 6.1). Halloumi was used to produce a firm chicken and tofu-like structure. Shah (2007) conducted experiments on halloumi to produce a high protein dairy food to produce a tofu-like texture. Using a firm dairy protein gel from the halloumi method and a softer dairy protein gel from the ricotta method, the dairy protein gels were tested to determine if a dairy based nugget could be formed and decide which method produced a better product.

4.2.1. Dairy Based Meat Alternative Nugget Formulation: Emulsion Method

Different formulations were used to produce a dairy based ground chicken like textured meat alternative. Several formulations were used to find the optimal dairy based meat alternative. The methods for emulsifying chicken nuggets (Suman and Sharma, 2003) and producing sausages (Xiong et al., 1999) were experimented with to determine if a emulsified dairy based meat alternative could be produced. Also, moisture was an important part to the nugget formulation to produce a “just cooked” texture that was similar to meat nugget moisture levels.

The dairy protein gel was grinded to incorporate flavoring and gums/stabilizers into the system. This experiment tested the emulsion method to determine if flavors, gums/emulsifiers and other ingredients can produce a firm and cohesive meat-like nugget product and contain a similar amount of moisture as meat nuggets. The hypothesis was that an emulsion method would produce the highest texture attributes for the dairy protein gel. The formulation below (Table 4.2) produced an emulsified dairy protein gel to represent a meat alternative product.

4.2.1.1. Methods and Materials

4.2.1.1.1. Moisture Content

The CEM AVC-80 Moisture Analyzer (Mathews, NC) was used to determine the moisture and total solids content of the dairy protein gel samples. The moisture analyzer

was at a power setting of 80% for a time setting of 6 minutes. 2.50 to 4.00 grams of the dairy protein gel samples were analyzed in the moisture analyzer. The sample was allowed to sit at room temperature for two hours before analyzing the samples.

4.2.1.1.2. Emulsion Method Procedure

Both the ricotta and halloumi methods were separately ground using a meat grinder (Mini-12-FS Meat Grinder, Tor-rey, USA) with a 3 mm and 6 mm grind plates. The following ingredients (Table 4.2) were mixed together in a mixer (KitchenAid Inc., St. Joseph, MI) and pressed into a flat layer. The emulsion was then shaped and frozen. The method for the emulsion process was described in more detail by Suman (2003). The dairy based meat alternative was analyzed using the texture analyzer.

Table 4.2 Halloumi style dairy based meat alternative modified formulation from Suman and Sharma (2003).

Ingredients	%
Dairy Protein Gel	75.00
NaCl	1.00
Sugar	1.75
Egg White	1.75
Ice, shaved	6.75
Oil, vegetable	7.00
Sodium Alginate	0.10
Carrageenan	0.75
Nonfat Dry Milk Powder	0.55
Chicken Flavoring	1.85
Nutritional Yeast	1.50
Panko Bread Crumbs	2.00
	100.00

4.2.1.2. Emulsion Method Results

According to the texture analyzer and personally evaluating the product, the texture of both dairy protein gels were not firm enough. Due to the amount of ingredients used in the formulation and the processing steps from grinding, the dairy protein gel products were very soft and had a consistency of a soft dairy protein paste.

The moisture of the dairy protein gel was compared to the commercial chicken nuggets. Higher moisture content was needed in order to compare with meat products on the market such as Tyson and McDonalds chicken nuggets. According to preliminary moisture data (Figure 4.22) collected on commercial chicken nuggets, chicken nuggets contained on average 53.0% moisture. The halloumi method produced a base product that had on average 49.0% moisture (Figure 4.22). The ricotta method produced a base product that had on average 74.0% moisture (Figure 4.22). After processing the base product into a nugget form, the average moisture dropped significantly. The halloumi method dropped to an average of 43% moisture after processing (Figure 4.23), while the ricotta method dropped to an average of 59% moisture (Figure 4.23). The ricotta method had a higher moisture content which was preferred to produce a moist meat-like product. Further research was needed to produce a firmer gel structure with the use of the ricotta method.

Figure 4.23 Dairy based meat alternative moisture contents before processing.
n=9

Figure 4.24 Dairy based meat alternative moisture contents after processing.
n=9

Figure 4.25 Halloumi flow chart.

4.2.2. Dairy Based Meat Alternative Nugget Formulation: Emulsifier Method

Further research was conducted to find another method that produced a firmer dairy protein gel compared to the previous formula. Previous research was conducted by Tristan Zuber which used flavoring and methylcellulose in a ricotta based system to produce a meat like texture with high textural attributes.

4.2.2.1. Methods and Materials

4.2.2.1.1. Texture Profile Analysis

Texture profile analysis was performed on the dairy protein gels using TA-XT2 (Texture Technology Corporation, Scarsdale, NY). The software used for the texture analyzer was Expert Version 1.22 software (Stable Micro Systems, Scarsdale, NY). Each dairy protein gel was cut using a knife (20 mm width by 20 mm length by 15 mm height) and placed in the refrigerator at 4°C for 2 hours. The samples were cut in these dimensions due to the chicken nugget commercial samples that did not have a height above 15 mm. Before the samples were analyzed, the samples were removed from the refrigerator and held at room temperature (25°C) for 30 minutes. Each sample was tested in triplicates. The 75 mm compression plate probe and 50% compression was used for the texture analyzer. The test was performed on a P75-75 mm compression plate. The parameters of the texture analyzer and testing can be found in Table 4.1.

Table 4.1 Texture profile analysis parameters.

Parameter	Programmed Parameter
Text Mode	s TPA
Pre-test	1.2 mm/sec
Compression	50%
Time	5.00 seconds
Trigger Type	Auto
Force	5 g
Stop Plot	Trigger Return
Probe Type	P75- 75 mm compression plate

The texture measurements that were extrapolated from the data were hardness, springiness, cohesiveness, chewiness, gumminess, and adhesiveness (Bourne, 1978). In Figure 4.1, A refers to the force that represents the measurement hardness. Springiness was extrapolated from subtracting the distance of D from B. Cohesiveness was produced by dividing C from E. F refers to the negative area which represents the texture measurement adhesiveness. Gumminess is the hardness multiplied by the cohesiveness. Chewiness was extrapolated by multiplying gumminess by springiness.

4.2.2.1.2. Emulsifier Method Procedure

The ricotta method dairy protein gel was ground using a meat grinder (Mini-12-FS Meat Grinder, Tor-rey, USA) with a 3 mm and 6 mm grind plates. The emulsifier and flavoring (Table 4.8) were mixed together in a mixer (KitchenAid Inc., St. Joseph, MI) and pressed into a flat layer. The dairy protein gel mixture was then shaped and frozen. The dairy based meat alternative was analyzed using the texture analyzer.

4.2.2.2. Emulsifier Results

The dairy protein gel with the emulsifier produced higher textural attributes through the texture analyzer. The dairy protein gel was personally evaluated and a noticeable difference in firmness was recognized. The emulsifier dairy protein gel produced a better product overall compared to the emulsion method. Table 4.3 is the present formulation that was used throughout the experiments in this thesis.

Table 4.3 Ricotta method dairy based meat alternative modified formulation.

Ingredients	%
Dairy Protein Gel	98.00
Methylcellulose	1.00
Chicken Flavoring	1.00
	100.00

4.3 PRELIMINARY RICOTTA METHOD EXPERIMENT

The ricotta method was examined to determine if an optimal formulation could be created to produce high overall texture attributes on the texture analyzer. From the previous experiments, the ricotta method produced a very high moisture level and with the addition of methylcellulose in the system, showed some increase in the firmness. This experiment demonstrates the instrumental textural attributes by the adjustment of the

ricotta method dairy protein gel base mixture. Previous work conducted by Yeung (1997) presented that a firm dairy protein gel can be attained by using a smaller milk to whey percentage and a lower pH such as 5.60. The hypothesis was that the increase in the milk to whey percentage and lower pH will produce a dairy protein gel with higher textural attributes. This experiment investigates the parameters of the milk/whey ratio and pH level of acidifications to produce a dairy protein gel base with high overall instrumental textural attributes.

4.3.1. Experimental Design

A randomized 3x3 factorial experimental design was created with the first factor being milk to whey ratio and the second factor being pH of acidification. Each experiment used approximately 60 gallons of whey and was completed within 10 hours. Milk and whey was weighed and placed in the double jacketed steam kettle for processing. Within three days of manufacture, samples were analyzed for texture and moisture properties.

The treatments were blocked on each day due to the differing composition of the whey collected. The experiment was replicated three times. During each day, all treatment levels were tested. A diagram of the design is shown in Table 4.4.

Table 4.4 Ricotta style dairy based meat alternative.

Ricotta Production Experimental Design			
Factor	Treatment Levels	Day	Response Variables
Milk to Whey Ratio	1%	Day 1	Hardness
	5%	Day 2	Cohesiveness
	10%	Day 3	Springiness
pH of Acidification	5.75- 5.66	Day 4	Gumminess
	5.46- 5.55		Chewiness
	5.35- 5.26		

4.3.2. Ricotta Method Methods and Materials

4.3.2.1. Texture Profile Analysis

Texture profile analysis was performed on the dairy protein gels using TA-XT2 (Texture Technology Corporation, Scarsdale, NY). The software used for the texture analyzer was Expert Version 1.22 software (Stable Micro Systems, Scarsdale, NY). Each dairy protein gel was cut using a knife (20 mm width by 20 mm length by 15 mm height) and placed in the refrigerator at 4⁰C for 2 hours. The samples were cut in these dimensions due to the chicken nugget commercial samples that did not have a height above 15 mm. Before the samples were analyzed, the samples were removed from the refrigerator and placed at room temperature (25⁰C) for 30 minutes. Each sample was tested in triplicates. The 75 mm compression plate probe and 50% compression was used for the texture analyzer. The test was performed on a P75-75 mm compression plate. The parameters of the texture analyzer and testing can be found in Table 4.5.

Table 4.5 Texture profile analysis parameters.

Parameter	Programmed Parameter
Text Mode	s TPA
Pre-test	1.2 mm/sec
Compression	50%
Time	5.00 seconds
Trigger Type	Auto
Force	5 g
Stop Plot	Trigger Return
Probe Type	P75- 75 mm compression plate

The texture measurements that were extrapolated from the data were hardness, springiness, cohesiveness, chewiness, gumminess, and adhesiveness (Bourne, 1978). In Figure 5.1, A refers to the force that represents the measurement hardness. Springiness was extrapolated from subtracting the distance of D from B. Cohesiveness was produced by dividing C from E. F refers to the negative area which represents the texture measurement adhesiveness. Gumminess is the hardness multiplied by the cohesiveness. Chewiness was extrapolated by multiplying gumminess by springiness.

4.3.2.2. Ricotta Method Procedure

Cheddar and mozzarella whey was obtained from the Cal Poly State Creamery for dairy protein gel making. The whey was pasteurized (72°C x 15 s) in a double jacketed steam kettle and allowed to cool overnight. The whey was used within one day of pasteurization. The whey and non-fat pasteurized milk (Costco Brand) was added to the

steam kettle and heated to 54.4⁰C. 1 % by weight (of the milk to whey mixture) of salt was added to the mixture and heated to 85⁰C. The mixture was held for 30 minutes at 85⁰C. Carefully, the mixture was agitated in a clockwise fashion and 2.5% acetic acid (Heinz Distilled White Vinegar) was added until the desired pH was reached. The mixture was allowed to sit for 10 minutes at 85⁰C with no agitation. Curds were strained and placed in cheese hoops with cheese cloth. The curds were pressed for 10 hours at 25 PSI. The dairy protein gel was placed in the refrigerator for 8 hours before removing the dairy protein gel from the molds. Samples were removed and the remaining dairy protein gel was vacuum sealed.

4.4.4. Ricotta Method Experiment Results

A general linear model was used to determine the differences in the instrumental attributes. Tukey's HSD pairwise comparison was used to compare the means of the attributes (Minitab, State College, PA).

There were significant differences for the milk to whey ratio (P-value<0.05) and pH of acidification (P-value<0.05). A 10% milk to whey ratio produced higher texture attributes for hardness, gumminess and chewiness in the ricotta cheese. A pH of 5.35- 5.26 produced higher texture attributes for hardness and chewiness. A milk to whey ratio of 10/90 and pH of 5.75- 5.66, 10/90 and 5.35- 5.26 pH, and 5/95 and 5.35- 5.26 pH produced higher texture attributes for hardness and chewiness. A milk to whey ratio of 5/95 and 10/90 with a pH of 5.35- 5.26 and 5.75- 5.66 produced a large gumminess value. There was no significant mean difference in the texture measurements cohesiveness and springiness, and for moisture between the different treatments.

As the milk/whey ratio increased, there was a noticeable increase in the hardness, chewiness and gumminess. As the pH level of acidification decreases, the texture measurements increased for hardness and gumminess. The pH level 5.75- 5.66 resulted in higher texture measurements which is shown in Yeung's (1997) research. A blend of a milk/whey ratio of 10% and a pH level of acidification of 5.75-5.66 or 5.35-5.26 would produce the firmest, chewiest and gummiest dairy protein gel. Further studies on the decrease of pH and increase in the milk/whey ratio were conducted in phase I to produce a product with the highest overall instrumental texture attributes. Further research was conducted on the process of adding gum and flavor into the dairy protein gel without decreasing the instrumental texture attributes (Section 4.6).

Table 4.6 Average TPA measurements for milk/whey mixture

Milk/Whey Blend	Hardness (g)	Cohesiveness (%)	Springiness (mm)	Chewiness (g)	Gumminess (g)	Moisture (%)
1/99	350.1 b	0.4 a	3.9 a	515.8 b	120.5 b	69.9 a
5/95	864.8 a	0.4 a	4.4 a	1639.0 a	394.0 a	69.9 a
10/90	1114.9 a	0.4 a	5.0 a	2361.0 a	498.0 a	72.3 a

*n= 27 Tukey's HSD of $\alpha=0.05$. Means followed by different letters are significantly different.

Table 4.7 Average TPA measurements for pH acidification level

pH Acidification Level	Hardness (g)	Cohesiveness (%)	Springiness (mm)	Chewiness (g)	Gumminess (g)	Moisture (%)
5.75- 5.66	878.5 a	0.4 a	4.3 a	1820.9 a	401.1 a	70.8 a
5.46- 5.55	496.6 b	0.4 a	4.2 a	1852.0 a	205.8 a	71.4 a
5.35- 5.26	954.6 a	0.4 a	4.7 a	842.7 b	405.6 a	69.8 a

*n= 27 Tukey's HSD of $\alpha=0.05$. Means followed by different letters are significantly different.

Table 4.8 Average TPA measurements for the interaction of the milk/whey mixture and pH level

Interaction of pH and Milk/Whey		Hardness (g)	Cohesiveness (%)	Springiness (mm)	Chewiness (g)	Gumminess (g)	Moisture (%)
5.75-5.66	1/99	411.6 b	0.3 a	4.0 a	650.7 c	140.2 b	71.2 a
5.46-5.55	1/99	188.6 b	0.4 a	2.9 a	170.5 c	66.3 b	71.9 a
5.35-5.26	1/99	450.0 b	0.3 a	4.8 a	726.3 c	155.0 b	66.5 a
5.75-5.66	5/95	519.7 b	0.5 a	4.2 a	1043.4 c	270.0 ab	69.5 a
5.46-5.55	5/95	616.4 b	0.4 a	4.6 a	1049.1 c	251.1 ab	69.6 a
5.35-5.26	5/95	1458.1 a	0.4 a	4.4 a	2824.3 ab	660.1 a	70.6 a
5.75-5.66	10/90	1704.1 a	0.5 a	4.7 a	3768.7 a	792.4 a	71.7 a
5.46-5.55	10/90	684.8 b	0.4 a	5.2 a	1308.6 bc	299.9 ab	72.8 a
5.35-5.26	10/90	955.7 ab	0.4 a	5.0 a	2005.5 abc	401.7 ab	72.4 a

*n= 27 Tukey's HSD of $\alpha=0.05$. Means followed by different letters are significantly different.

Figure 4.26 TPA hardness for preliminary ricotta method.
n=27 Error bars represent the standard deviation for each sample

Figure 4.27 TPA springiness for preliminary ricotta method.
n=27 Error bars represent the standard deviation for each sample

Figure 4.28 TPA cohesiveness for preliminary ricotta method
n=27 Error bars represent the standard deviation for each sample

Figure 4.29 TPA gumminess for preliminary ricotta method.
n=27 Error bars represent the standard deviation for each sample

Figure 4.30 TPA chewiness for preliminary ricotta method
n=27 Error bars represent the standard deviation for each sample

Figure 4.31 Moisture content for preliminary ricotta method
n=27 Error bars represent the standard deviation for each sample

4.4 PRELIMINARY GRINDING AND GUM EXPERIMENT

Emulsification of flavor and gum into the dairy protein gel needed to be investigated in order to understand the effect of grinding and gum inclusion of the dairy protein gel on the instrumental textural attributes. In the meat industry, a meat grinder is used to tenderize, produce different textures and incorporate ingredients into the meat system. The distribution of flavor and gum in a dairy system is important for the flavor to be pronounced throughout the system and the gum was used to stabilize the product. An experiment was designed to determine if there is a difference in the texture of a dairy protein gel when grinded through a meat grinder and the presence of a gum in a dairy protein gel system.

4.4.1. Experimental Design

A 2 x 2 factorial was created to produce the four treatments. The run order was randomized. The final dairy protein gel products were tested using the texture and moisture analyzer.

4.4.2. Grinding and Gum Methods and Materials

4.4.2.1. Texture Profile Analysis

Texture profile analysis was performed on the dairy protein gels using TA-XT2 (Texture Technology Corporation, Scarsdale, NY). The software used for the texture

analyzer was Expert Version 1.22 software (Stable Micro Systems, Scarsdale, NY). Each dairy protein gel was cut using a knife (20 mm width by 20 mm length by 15 mm height) and placed in the refrigerator at 4°C for 2 hours. The samples were cut in these dimensions due to the chicken nugget commercial samples that did not have a height above 15 mm. Before the samples were analyzed, the samples were removed from the refrigerator and placed at room temperature (25°C) for 30 minutes. Each sample was tested in triplicates. The 75 mm compression plate probe and 50% compression was used for the texture analyzer. The test was performed on a P75-75 mm compression plate. The parameters of the texture analyzer and testing can be found in Table 4.9.

Table 4.9 Texture profile analysis parameters.

Parameter	Programmed Parameter
Text Mode	s TPA
Pre-test	1.2 mm/sec
Compression	50%
Time	5.00 seconds
Trigger Type	Auto
Force	5 g
Stop Plot	Trigger Return
Probe Type	P75- 75 mm compression plate

The texture measurements that were extrapolated from the data were hardness, springiness, cohesiveness, chewiness, gumminess, and adhesiveness (Bourne, 1978). In Figure 5.1, A refers to the force that represents the measurement hardness. Springiness was extrapolated from subtracting the distance of D from B. Cohesiveness was produced by dividing C from E. F refers to the negative area which represents the texture

measurement adhesiveness. Gumminess is the hardness multiplied by the cohesiveness. Chewiness was extrapolated by multiplying gumminess by springiness.

4.4.2.2. Grinding and Gum Procedure

Whey was obtained from the Cal Poly State Creamery for dairy protein gel making. The whey was pasteurized ($72^{\circ}\text{C} \times 15 \text{ s}$) in a double jacketed steam kettle and allowed to cool overnight. The whey was used within one day of pasteurization. The whey and non-fat milk (Albertsons Brand) was added to the steam kettle and heated to 54.4°C . Salt was added to the mixture and heated to 85°C . The mixture was held for 30 minutes at 85°C . Carefully, the mixture was agitated in a clockwise fashion and 2.5% acetic acid (Heinz white vinegar) was added until the desired pH was reached. The mixture was allowed to sit for 10 minutes at 85°C with no agitation. Curds were strained and placed in sheet pans about 2 to 2.5 cm high with cheesecloth. The curds were pressed for 30 minutes with 20 lb weights to remove excess whey. Two pounds of dairy protein gel was measured and methylcellulose and flavoring was added. The dairy protein gel mixture was either grinded in the meat grinder or mixed in a Hobart mixer. The dairy protein gel was placed in sanitized sheet pans with cheesecloth and was pressed overnight with 20 lb weights in the refrigerator. Samples were punched out using a cookie cutter from the dairy protein gel mass. The samples were placed in the refrigerator and analysis was performed on the dairy protein gel.

4.4.3. Grinding and Gum Results

A general linear model was used to determine the differences in the instrumental attributes. Tukey's HSD pairwise comparison was used to compare the means of the attributes (Minitab, State College, PA).

There was no significant difference ($P\text{-value} > 0.05$) in the mean texture measurements (Table 4.10) between using a mixer and a grind size of 6 mm. By the addition of gum in the dairy protein gel system, there was an increase ($P\text{-value} < 0.05$) in cohesiveness and springiness (Table 4.11), but resulted in a lower chewiness and gumminess.

Further research was conducted to determine if different grind sizes produce different instrumental texture attributes. Suman (2003) showed that using a smaller grind size (3 mm grind plate) on buffalo meat patties affected the shear force value and the 3 mm grind size was preferred by a sensory panel. Due to the results conducted on buffalo meat patties, a 3 mm grinding plate was purchased to compare to the mixer and 6 mm grinding plate on a dairy system. Also a 4:1 ratio of 3 mm and 6 mm grind size mixture was used to test if inconsistencies within a dairy protein gel system can produce different textures. Further investigation was conducted to determine if a trained panel could distinguish the differences in the grind size and inclusion of gum. The sensory panel was also used to determine if there were any significant correlations between sensory texture attributes and the instrumental texture attributes. The grinding and gum experiment was continued in phase II.

Table 4.10 Average TPA measurements for grind size.

Grind Size	Hardness (g)	Cohesiveness (%)	Springiness (mm)	Chewiness (g)	Gumminess (g)
Mixed	721.3 a	0.3 a	4.3 a	1028.8 a	244.3 a
6 mm	629.3 a	0.3 a	4.3 a	938.8 a	223.9 a

*n= 8 Tukey's HSD of $\alpha=0.05$. Means followed by different letters are significantly different.

Table 4.11 Average TPA measurements for the presence of gum.

Presence of Gum	Hardness (g)	Cohesiveness (%)	Springiness (mm)	Chewiness (g)	Gumminess (g)
Gum	553.8 a	0.4 a	4.7 a	717.4 b	150.7 b
No Gum	796.7 a	0.3 b	3.9 b	1250.2 a	317.4 a

*n= 8 Tukey's HSD of $\alpha=0.05$. Means followed by different letters are significantly different.

Figure 4.32 TPA for Hardness for preliminary grinding and gum experiment
n=8 Error bars represent the standard deviation for each sample

Figure 4.33 TPA for Springiness for preliminary grinding and gum experiment
n=8 Error bars represent the standard deviation for each sample

Figure 4.34 TPA for Cohesiveness for preliminary grinding and gum experiment
n=8 Error bars represent the standard deviation for each sample

Figure 4.35 TPA for Gumminess for preliminary grinding and gum experiment
n=8 Error bars represent the standard deviation for each sample

Figure 4.36 TPA for Chewiness for preliminary grinding and gum experiment
n=8 Error bars represent the standard deviation for each sample

4.5 PRELIMINARY STUDY CONCLUSION

After examining the possibility of creating a dairy protein gel with fibers, a ground meat fiber approach was used to produce a dairy based meat alternative. Meat and meat alternative nuggets have a ground meat texture which was replicated with dairy.

The dairy protein gel base was made using a heat and acid induced dairy gel. The dairy protein gel contained a higher amount of moisture compared to the renneted dairy gels. The heat and acid induced dairy gel was used to produce a dairy meat alternative that had a similar moisture content as meat and meat alternative products. The dairy protein gel's texture attributes were investigated to determine the highest textural attributes depending on the milk to whey percentage and the level of acidification. A milk to whey ratio of 10/90 with a low pH of 5.26-5.35 produced the highest overall texture attributes on the texture analyzer. Yeung (1997) demonstrated that a low pH of 5.6 and a low milk to whey ratio of 10/90 produced higher texture attributes. A decrease in the pH beyond 5.26 and an increase of the milk to a whey ratio from 10/90 to 15/85 was investigated further in the phase I experiments to find the optimal pH and level of acidification to produce the highest overall texture attributes.

In order to distribute the chicken flavoring and emulsifier equally throughout the dairy protein gel, the use of a meat grinder was needed to determine if grinding or mixing produced similar texture attributes. There was no difference in the use of a mixer and meat grinder but research from Suman and Sharma (2003) showed that using a smaller grind size (3 mm grind plate) on buffalo meat patties affected the shear force value and the use of

a 3 mm grind plate was preferred by a sensory panel. A mixer, 3 mm grind plate, 6 mm grind plate and combinations of the grind plates were evaluated in phase II to determine if the final texture attributes was affected. The use of gum in the dairy protein gel was also evaluated in phase II.

5.0 METHODS AND MATERIALS

5.1 MILK FOR DAIRY PROTEIN GEL PRODUCTION

Pasteurized fat free milk was obtained from Costco in San Luis Obispo, California. All the milk that was obtained was used within two days of purchase.

5.2 WHEY FOR DAIRY PROTEIN GEL PRODUCTION

Cheddar, mozzarella, and jack cheese were manufactured in the plant by the Cal Poly Creamery located at California Polytechnic University, San Luis Obispo. Sweet whey was collected from the draining step in the cheese process. The whey was immediately pasteurized (72°C x 15 s) in a double jacketed steam kettle and allowed to cool overnight at 4°C. The whey was used within one day of pasteurization. Before the whey was used, the pH was measured to assure that the pH was between 6.1 and 6.4.

5.3 ACID SOLUTION

Heinz Distilled White Vinegar (5 % acetic acid) was used to adjust the pH in the milk/whey mixtures. The acetic acid was at 50 grain strength. The acid was diluted from 5% to 2.5% acetic solution with deionized water for the entire experiment. The acid solution was prepared by diluting 1.89 L of acid with 1.89 L deionized water and held at 15°C.

5.4 pH METER

The pH was determined using the pHTestr® 10/20/30 pH meter (EUTECH Instruments, Singapore). The pHTestr® 10/20/30 pH meter has a glass probe. It was calibrated before use in the standard solutions of a pH of 4, 7, and 10 before each experiment.

5.5 MOISTURE CONTENT

The CEM AVC-80 Moisture Analyzer (Mathews, NC) was used to determine the moisture and total solids content of the dairy protein gel samples. 10 grams of sample were prepared and placed in a Whirl-Pak® bag. The sample was shredded using a hand cheese shredder and placed back in the Whirl-Pak® bag. The sample was allowed to sit at room temperature (25°C) for two hours before analyzing the samples. The moisture analyzer was placed on a power setting of 80% for a time setting of 6 minutes. Two CEM sample pads were placed on the CEM scale and zeroed out. 2.50 to 4.00 grams of the dairy protein gel samples were analyzed on the CEM sample pads and the sample was analyzed. The testing of the sample was done in duplicate.

5.6 TEXTURE PROFILE ANALYSIS

Texture profile analysis was performed on the dairy protein gels using TA-XT2 (Texture Technology Corporation, Scarsdale, NY). The software used for the texture

analyzer was Expert Version 1.22 software (Stable Micro Systems, Scarsdale, NY). Samples were removed from the refrigerator and cut using a chef knife (20 mm width by 20 mm length by 15 mm height). The samples were placed in labeled Whirl-Pak® bags and placed in the refrigerator at 4⁰ C for 2 hours. The samples were cut in these dimensions due to the chicken nugget commercial samples that did not have a height above 15 mm. Before the samples were analyzed, the samples were removed from the refrigerator and placed at room temperature (25°C) for 30 minutes in the Whirl-Pak® bag. One of the cut samples was placed on the platform of the texture analyzer and the samples were analyzed. Each sample was tested in triplicate. The 75 mm compression plate probe and 50% compression was used for the texture analyzer. The test was performed on a P75-75 mm compression plate. The parameters of the texture analyzer and testing can be found in Table 5.1.

Table 5.1 Texture profile analysis parameters.

Parameter	Programmed Parameter
Text Mode	s TPA
Pre-test	1.2 mm/sec
Compression	50%
Time	5.00 seconds
Trigger Type	Auto
Force	5 g
Stop Plot	Trigger Return
Probe Type	P75- 75 mm compression plate

Figure 5.1 Texture profile analysis graph output from Expert Version 1.22 software.

Figure 5.2 Texture analyzer (Cal Poly 2011)

Figure 5.3 Texture analyzer with dairy protein gel sample

The texture measurements that were extrapolated from the data were hardness, springiness, cohesiveness, chewiness, gumminess, and adhesiveness (Bourne, 1978). In Figure 5.1, A refers to the force that represents the measurement hardness. Springiness was extrapolated from subtracting the distance of D from B. Cohesiveness was produced by dividing C from E. F refers to the negative area which represents the texture measurement adhesiveness. Gumminess is the hardness multiplied by the cohesiveness. Chewiness was extrapolated by multiplying gumminess by springiness.

6.0 PHASE I EXPERIMENT

The development of a dairy protein gel base was tested to understand the textural attributes of the base. The milk to whey percentage and level of acidification were examined to determine the optimal dairy protein gel base with high textural attributes.

6.1 DAIRY PROTEIN GEL PRODUCTION METHODS

Cheddar and mozzarella whey was obtained from the Cal Poly State Creamery for dairy protein gel making. The whey was pasteurized (72⁰C x 15 s) in a double jacketed steam kettle and allowed to cool overnight. The whey was used within one day of pasteurization. The whey and non-fat pasteurized milk (Costco Brand) was added to the steam kettle and heated to 54.4⁰C. 1 % by weight (of the milk to whey mixture) of salt was added to the mixture and heated to 85⁰C. The mixture was held for 30 minutes at 85⁰C. Carefully, the mixture was agitated in a clockwise fashion and 2.5% acetic acid (Heinz Distilled White Vinegar) was added until the desired pH was reached. The mixture was allowed to sit for 10 minutes at 85⁰C with no agitation. Curds were strained and placed in cheese hoops with cheese cloth. The curds were pressed for 10 hours at 25 PSI. The dairy protein gel was placed in the refrigerator for 8 hours before removing the dairy protein gel from the molds. Samples were removed and the remaining dairy protein gel was vacuum sealed.

Figure 6.1 Flow chart for dairy protein gel production.

Figure 6.2 Pasteurizing and removing whey from steam kettle

Figure 6.3 Mixing milk and whey together in steam kettle while increasing heat to 85°C

Figure 6.4 Coagulum flocculating to the top of the kettle after acid is added

Figure 6.5 Coagulum after being pressed

6.2 DAIRY PROTEIN GEL PRODUCTION EXPERIMENTAL DESIGN

A randomized 3x3 factorial experimental design was created with the first factor being milk to whey ratio and the second factor being pH of acidification. Each experiment used approximately 60 gallons of whey and was completed within 10 hours. Milk and

whey was weighed and placed in the double jacketed steam kettle for processing. Within three days of manufacture, samples were analyzed for texture and moisture properties.

The treatments were blocked on each day due to the differing composition of the whey collected. The experiment was replicated four times.

During each day, all treatment levels were tested. A diagram of the design is shown in Table 6.1.

Table 6.1 Dairy protein gel production experimental design and response variables.

Dairy Protein Gel Production Experimental Design			
Factor	Day Variable	Treatment Levels	Response Variables
Milk to Whey Ratio	Day 1 Day 2 Day 3	5/95	Hardness Cohesiveness Springiness Gumminess Chewiness Moisture
		10/90	
		15/85	
pH of Acidification	Day 4	5.7- 5.6	
		5.15- 5.05	
		4.6- 4.5

Figure 6.6 Flow chart for dairy protein gel production experimental design: effect of milk to whey ratio and pH of acidification on textural properties and moisture.

6.3. DAIRY PROTEIN GEL PRODUCTION RESULTS

A general linear model was used to determine the differences in the instrumental attributes. Tukey's HSD pairwise comparison was used to compare the means of the attributes (Minitab, State College, PA).

The milk to whey percentages and acidification levels of the dairy protein gels were tested using the texture analyzer and moisture analyzer. There was a significant difference in the percentage of milk (P-value<0.05) used in the dairy protein gel on the texture values hardness, gumminess and chewiness (Figure 6.7, 6.8, 6.9). As a higher percentage of milk was used, there was an increase in the hardness, gumminess and chewiness.

Figure 6.7 Texture Profile Analysis of the milk to whey ratio factor for hardness
n=36 Error bars represent the standard deviation for each sample

Figure 6.8 Texture Profile Analysis of the milk to whey ratio factor for gumminess
n=36 Error bars represent the standard deviation for each sample

Figure 6.9 Texture Profile Analysis of the milk to whey ratio factor for chewiness
n=36 Error bars represent the standard deviation for each sample

There was also a significant difference in hardness due to the pH level (P-value<0.05) used in the dairy protein gel system (Table 6.10, 6.11, 6.12 and 6.13). As the pH decreased, the hardness of the cheese product increased (Figure 6.10). Also, as the pH decreased below 5.6, the chewiness and gumminess of the cheese product increased (Figure 6.12 and 6.13). For the texture measurement cohesiveness, an increase above a pH of 4.6 produced a more cohesive product (Figure 6.11).

Figure 6.10 Texture Profile Analysis of the pH factor for hardness
n=36 Error bars represent the standard deviation for each sample

Figure 6.11 Texture Profile Analysis of the pH factor for cohesiveness
n=36 Error bars represent the standard deviation for each sample

Figure 6.12 Texture Profile Analysis of the pH factor for gumminess
 n=36 Error bars represent the standard deviation for each sample

Figure 6.13 Texture Profile Analysis of the pH factor for chewiness
 n=36 Error bars represent the standard deviation for each sample

There was a significant difference for the effect of pH depending on the milk percentage (P-value<0.05) used in the dairy protein gel on the texture values hardness, gumminess and chewiness (Figure 6.14, 6.15 and 6.16). As a higher percentage of milk and a pH of 5.15 or lower were used, there was an increase in the hardness, gumminess and chewiness.

Figure 6.14 Texture Profile Analysis of the interaction of the milk to whey ratio and pH level for hardness

n=36 Error bars represent the standard deviation for each sample

Figure 6.15 Texture Profile Analysis of the interaction of the milk to whey ratio and pH level for gumminess

n=36 Error bars represent the standard deviation for each sample

Figure 6.16 Texture Profile Analysis of the interaction of the milk to whey ratio and pH level for chewiness

n=36 Error bars represent the standard deviation for each sample

Milk to whey percentage of 15 and a pH of 4.6 would produce the best product with the highest overall textural measurements. The milk to whey percentage of 15 and pH of 4.6 was used in phase II.

Table 6.2 Texture Profile Analysis of the interaction of milk to whey ratio and pH acidification level

Milk to Whey Ratio	pH Acidification Level	Hardness			Springiness			Cohesiveness			Gumminess		
		(g)			(mm)			(%)			(g)		
15/85	5.6	1566.534	(1143.075)	ab	6.539	(1.715)	a	0.476	(0.041)	a	702.296	(496.377)	abc
15/85	5.15	2958.192	(1859.621)	a	7.173	(1.079)	a	0.491	(0.019)	a	1480.642	(724.897)	a
15/85	4.6	3099.937	(1415.042)	a	7.226	(0.487)	a	0.438	(0.018)	a	1379.376	(982.570)	ab
10/90	5.6	1347.246	(1079.598)	ab	5.919	(0.287)	a	0.477	(0.047)	a	599.099	(480.428)	abc
10/90	5.15	1719.950	(749.525)	ab	5.900	(0.549)	a	0.506	(0.062)	a	871.570	(373.913)	abc
10/90	4.6	2854.541	(1268.603)	ab	6.646	(0.198)	a	0.409	(0.046)	a	986.215	(546.551)	abc
5/95	5.6	848.752	(256.065)	b	5.562	(1.051)	a	0.477	(0.055)	a	402.483	(114.063)	c
5/95	5.15	1585.182	(1198.417)	ab	6.457	(1.582)	a	0.437	(0.041)	a	689.710	(462.624)	abc
5/95	4.6	1037.997	(747.698)	ab	5.389	(0.586)	a	0.424	(0.044)	a	461.143	(352.542)	bc

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=36 Values in () are the standard deviations

Table 6.3 Texture Profile Analysis of the interaction of milk to whey ratio and pH acidification level

Milk to Whey Ratio	pH Acidification Level	Chewiness (g)			Adhesiveness (g)			Moisture (%)		
15/85	5.6	4789.343	(3501.511)	ab	31.352	(24.789)	a	70.985	(2.811)	a
15/85	5.15	11081.199	(4440.857)	a	61.990	(12.807)	a	72.860	(2.180)	a
15/85	4.6	9771.269	(7556.527)	a	35.290	(33.160)	a	70.664	(2.272)	a
10/90	5.6	3928.473	(3644.652)	ab	40.348	(30.143)	a	72.460	(2.043)	a
10/90	5.15	5165.410	(2224.117)	ab	46.013	(7.897)	a	71.222	(3.142)	a
10/90	4.6	6589.977	(3759.242)	ab	31.203	(20.596)	a	71.204	(6.519)	a
5/95	5.6	2239.790	(714.220)	b	50.937	(20.170)	a	73.379	(3.446)	a
5/95	5.15	4918.159	(4604.559)	ab	47.231	(21.830)	a	72.096	(3.468)	a
5/95	4.6	2397.471	(2090.889)	b	42.564	(14.262)	a	76.968	(1.811)	a

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=36 Values in () are the standard deviations

Table 6.4a Texture Profile Analysis means of pH acidification level factor

pH Acidification Level	Hardness (g)			Springiness (mm)			Cohesiveness (%)			Gumminess (g)		
4.6	2330.800	(826.103)	a	6.424	(1.009)	a	0.400	(0.044)	b	942.200	(287.342)	ab
5.15	2087.800	(748.112)	ab	6.530	(1.149)	a	0.500	(0.042)	a	1014.000	(472.334)	a
5.6	1254.200	(378.872)	b	6.162	(1.075)	a	0.500	(0.046)	a	568.000	(177.174)	b

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=36 Values in () are the standard deviations

Table 6.4b Texture Profile Analysis means of pH acidification level factor

pH Acidification Level	Chewiness (g)			Adhesiveness (g)			Moisture (%)		
4.6	6252.900	(487.641)	ab	36.400	(9.041)	a	72.900	(3.829)	a
5.15	7054.900	(1876.319)	a	51.700	(11.006)	a	72.100	(4.185)	a
5.6	3652.500	(1021.974)	b	40.900	(18.376)	a	72.300	(2.438)	a

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=36 Values in () are the standard deviations

Table 6.5a Texture Profile Analysis means of the milk to whey ratio factor

Milk to Whey Ratio	Hardness (g)			Springiness (mm)			Cohesiveness (%)			Gumminess (g)		
5/95	1157.300	(483.201)	b	5.800	(1.148)	a	0.400	(0.047)	a	517.800	(348.412)	b
10/90	1973.900	(721.841)	ab	6.200	(0.983)	ab	0.500	(0.062)	a	819.000	(459.678)	ab
15/85	2541.600	(798.240)	a	7.000	(0.755)	b	0.500	(0.039)	a	1187.400	(771.510)	a

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=36 Values in () are the standard deviations

Table 6.5b Texture Profile Analysis means of the milk to whey ratio factor

Milk to Whey Ratio	Chewiness (g)			Adhesiveness (g)			Moisture (%)		
5/95	3185.100	(2959.139)	b	46.900	(17.412)	a	74.100	(3.259)	a
10/90	5228.000	(3180.579)	b	39.200	(18.335)	a	71.600	(2.522)	a
15/85	8547.300	(5684.210)	a	42.900	(28.377)	a	71.500	(4.092)	a

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=36 Values in () are the standard deviations

6.4 DAIRY PROTEIN GEL PRODUCTION SUMMARY

There was an increase the hardness, gumminess and chewiness due to the increase of the milk percentage in the milk to whey percentage. This could be caused due to the casein content from the additional milk in the milk to whey percentage. Also this could be the result of a higher amount of casein denaturation due to the lower acidification range. The mixture of 15% milk to 85% whey had the highest hardness, gumminess and chewiness values compared to the other levels. Also the higher percent of milk used increased the total solids in the system which may have increased the firmness of the gel (Robinson and Tamime, 1986).

A firmer dairy protein gel was produced using a lower pH. As the pH reaches the isoelectric point at 4.6, the electrostatic repulsion between the casein molecules is reduced which strengthens the bonds between the casein molecules and may increase the firmness of the gel (Lucey et al., 2003). A pH above 4.6 produced a more cohesive product. Below a pH of 4.8, a less cohesive dairy protein gel is produced due to the casein submicelles dissociating into smaller aggregates which can produce nonlinear strands which form a less cohesive structure (Gunasekaran and Ak, 2003). The pH of 5.15 and 5.6 produced a more cohesive structure which was preferred for a dairy protein gel that was going to undergo further processing.

A milk to whey percentage of 15/85 and a pH of 4.6 produced the product with the highest overall textural measurements. The milk to whey percentage of 15 and pH of 4.6 was evaluated further in phase II. A dairy protein gel with the largest overall textural measurements was beneficial for further processing. Further processing decreases the overall textural measurements of the dairy protein gel during the processing step. A

protein structure with higher overall textural measurements will produce a product that is comparable to a meat and meat alternative product.

7.0 PHASE II EXPERIMENT

A dairy protein gel composed of a milk to whey percentage of 15/85 and pH of 4.6 was used in the process to create a dairy based meat nugget. The dairy protein gel from phase 1 was used to determine if different size grinding plates and the presence of a gum can influence the textural attributes of the dairy protein gel. The dairy protein gel base was evaluated by a sensory panel to compare to the texture analyzer results. The dairy protein gel was processed using a meat grinder (Mini-12-FS Meat Grinder, Tor-rey, USA) with a grind size of 3 mm, 6 mm and a blend of 4 parts 6 mm grinded and 1 part 3 mm grinded dairy protein gel. The blend of the grind sizes was used to determine if inconsistencies in the grind size will affect the texture attributes. The objective of this experiment was to investigate if different size grinding plates and the presence of methylcellulose influence the texture of a dairy protein gel.

7.1 DAIRY PROTEIN GEL PROCESSING METHODS

Whey was collected during the production of cheddar cheese from the Cal Poly State Creamery for the making of the dairy protein gel. The whey was pasteurized (72°C x 15 s) in a double jacketed steam kettle and allowed to cool overnight. The whey was used within one day of pasteurization. The whey and pasteurized skim milk (Costco Brand) was added to the steam kettle and heated to 54.4°C. 1 % by weight of the milk to whey mixture of salt was added to the mixture and heated to 85°C. The mixture was held for 30 minutes at 85°C. Carefully, the mixture was agitated in a clockwise fashion and 2.5% acetic acid (Heinz Distilled White Vinegar) was added until the desired pH was reached. The mixture

was allowed to sit for 10 minutes at 85⁰C. Curds were strained using a plastic ricotta scooper and placed in a colander lined with cheesecloth. The dairy protein gel was allowed to drain for five minutes to remove excess whey. The dairy protein gel was placed on sheet pans about 2 to 2.5 cm high lined with cheese cloth. The curds were pressed for 30 minutes with 20 lb weights to remove excess whey. Two pounds of the dairy protein gel was measured and methylcellulose and flavoring was added. The dairy protein gel mixture was either grinded in the meat grinder or mixed in a Hobart mixer. The dairy protein gel was placed in sanitized sheet pans with cheesecloth and was pressed overnight with 20 lb weights in the refrigerator. Samples were punched out using a cookie cutter from the dairy protein gel mass and placed in a 176.7⁰C oven for 15 minutes or until 73.9⁰C was reached. The samples were immediately placed in the blast freezer for 2 hours. The samples were vacuum sealed and placed in the freezer.

Figure 7.1 Flow chart for dairy protein gel processing

Figure 7.2 Coagulum being pressed with 20 lb weights

Figure 7.3 Coagulum being grinded

Figure 7.4 Coagulum being mixed in the Hobart

Figure 7.5 Dairy based meat alternative shaped

Figure 7.6 Dairy base meat alternative vacuum sealed

7.1.1 Dairy Protein Gel Processing Experimental Design

A randomized 4x2 factorial experimental design was created with the first factor being grinding size and the second factor being gum addition. The dairy protein gel formulation with the highest overall textural values from the previous experiment was selected to be processed in this experiment. Dairy protein gel with milk to whey ratio of 15% and a pH of acidification of 4.6 was used in this experiment. Whey was collected and pasteurized within an hour. The cheese was made within 6 hours and processed within 8 hours. Within three days of processing, samples were analyzed for texture and moisture properties.

The treatments were blocked on each day due to the differing composition of the whey collected. A diagram of the design is shown in Table 7.1.

Table 7.1 Dairy protein gel processing experimental design and response variables.

Dairy Protein Gel Processing Experimental Design		
Factor	Treatment Levels	Response Variables
Grind Size	Mixer Only	Hardness Moisture
	3 mm	Cohesiveness
	6 mm	Springiness
	4:1 Ratio of 3 & 6 mm	Gumminess
Gum Addition	No Gum	Chewiness
	Gum	Adhesiveness

7.2 DAIRY PROTEIN GEL PROCESSING FOR SENSORY METHODS

A sensory panel of 12 participants was trained to distinguish the difference in sensory textures (depicted in Table 7.2) in processed dairy protein gel products. The texture analyzer and sensory definitions are described in Table 7.2. The panelists were trained using food texture attribute lexicons from Munoz (1986) and cheese lexicons from Foegeding et al. (2003). The sensory texture lexicons are displayed in Table 7.3.

Three training sessions were used to evaluate and train the panelists. Each dairy based meat alternative nugget was sampled by each panelist in 6 sessions. The sessions were designed to have the panelists evaluate the samples two times in one day to reduce person to person variability. A total of three days were used for the panelists to evaluate the samples. The panel evaluated eight samples per session. The data was analyzed using the sensory analysis software Compusense (Compusense, Guelph, Ontario, Canada),

Minitab (Minitab, State College, PA), and JMP (JMP®, Version 7. SAS Institute Inc., Cary, NC, 1989-2007).

Table 7.2 Descriptive sensory language, texture definitions and sensory technique for food products.

Texture and Sensory Term	Texture Definition	Sensory Definition	Technique
Hardness	The peak force during the compression cycle ⁴	The force required to compress the sample fully.	Compress or bite through sample once with molars or incisors ³
Cohesiveness	The ratio of the peak force area during the second compression to that during the first compression ⁴	The degree to which the chewed mass sticks together in the mouth ¹	Place sample between molars and compress fully ³
Chewiness	Product of gumminess and springiness ⁴	Length of time required to masticate a sample at a constant rate of force application to reduce to a swallowable consistency ²	Place sample in mouth and chew until sample is reduced to a swallowable consistency ²
Adhesiveness	Work necessary to overcome the attractive forces between the surface of the food and surface of other materials with which the food comes in contact ⁶	The amount to which the sample sticks to any of the mouth surfaces such as teeth, gums or palate and is perceived as pasty. ⁵	Place sample in mouth and as the sample is masticated, determine if the sample sticks to any of the mouth surfaces.

¹ (Foegeding et al. 2003)

² (Asato, 2003)

³ (Breuil and Meullenet, 2001)

⁴ (Bourne, 1978)

⁵ (Leighton et al., 2010)

⁶ (Gunasekaran, 2003)

Table 7.3 Lexicon and ratings used by a sensory panel to describe food textures.

Sensory Word	Food Product	Scale Rating
Hardness	Almond	15
	Oscar Meyer Beef Frank	7
	Velveeta	4
	Philly Cream Cheese	1
Cohesiveness	Soft Pretzel	15
	Velveeta	8
	Rice Cake	1
Chewiness	Tootsie Roll	15
	Oscar Meyer Beef Frank	8
	Rye Bread Orowheat	3
	Corn Bread	1
Adhesiveness	Tootsie Roll	15
	Sharp Cheddar Kraft	10
	Muenster	7
	Full Fat Feta	4
	Parmesan	1

7.3 DAIRY PROTEIN GEL PROCESSING CORRELATION BETWEEN SENSORY AND TEXTURE

The texture and sensory data was correlated using Truong's (2002) methods for correlating textural characteristics of cheddar cheese with sensory measurements. The dairy based meat substitute texture data and sensory attributes were averaged and correlated using JMP (JMP®, Version 7. SAS Institute Inc., Cary, NC, 1989-2007) by performing a multivariate analysis and pairwise correlation analysis. The R values and P-values were evaluated.

7.4 DAIRY PROTEIN GEL PROCESSING RESULTS

7.4.1. Dairy Protein Gel Processing Texture Results

A general linear model was used to determine the differences in the instrumental attributes. Tukey's HSD pairwise comparison was used to compare the means of the attributes (Minitab, State College, PA).

The effect of the grind size and the use of gum in a dairy protein gel product was tested. The texture analyzer was used to determine the texture measurements hardness, springiness, cohesiveness, gumminess, chewiness and adhesiveness. Moisture was also analyzed for each treatment. For the interaction of the factors grind size and gum, reference points were used to compare the dairy protein gel system to nuggets on the market. The meat nugget McDonald's and the meat alternative nugget Boca were used to compare to the dairy protein gels.

The texture measurement hardness ($P\text{-value} < 0.05$) was significantly different for the grind size. A 4:1 ratio (6 mm: 3 mm grind) produced the largest hardness value (Figure 7.7). For the interaction of the factors grind size and gum, a 4:1 ratio (6 mm: 3 mm grind) with the addition of the methylcellulose produced the largest hardness value (Figure 7.8). McDonald's produced the largest hardness value of all the dairy protein gel treatments while Boca had a similar instrumental hardness as the dairy protein gels (Figure 7.8).

Figure 7.7 The texture analyzer measurement hardness for the factor grind size
n=24 Error bars represent the standard deviation for each sample

Figure 7.8 The texture analyzer measurement hardness for the interaction of grind size and
gum
n=24 Error bars represent the standard deviation for each sample

The texture measurement springiness was significantly different for the grinding (P-value<0.05) and gum factor (P-value<0.05). A 4:1 ratio (6 mm: 3 mm grind) produced a large springiness value (Figure 7.9). The lack of gum in the dairy protein gel system produced a higher springiness value (Figure 7.10).

Figure 7.9 The texture analyzer measurement springiness for the factor grind size
n=24 Error bars represent the standard deviation for each sample

Figure 7.10 The texture analyzer measurement springiness for the gum factor
n=24 Error bars represent the standard deviation for each sample

The texture measurement cohesiveness was significantly different for the grinding and gum factor and the interaction of both factors ($P\text{-value} < 0.05$). Both a 4:1 ratio (6 mm: 3 mm grind) and the presence of gum in the dairy protein gel system produced a large cohesiveness value (Figure 7.11 and 7.12). The use of both a grind size of 4:1 ratio and the use of gum produced a large cohesiveness value (Figure 7.13). McDonald's produced the largest cohesive value of all the dairy protein gel treatments while Boca had a similar instrumental cohesiveness as the dairy protein gels (Figure 7.13).

Figure 7.11 The texture analyzer measurement cohesiveness for the factor grind size n=24 Error bars represent the standard deviation for each sample

Figure 7.12 The texture analyzer measurement cohesiveness for the gum factor n=24 Error bars represent the standard deviation for each sample

Figure 7.13 The texture analyzer measurement cohesiveness for the interaction of grind size and gum.

n=24 Error bars represent the standard deviation for each sample

Chewiness was significantly different for the grinding factor (P -value<0.05) and the interaction of the grind size and gum factors (P -value<0.05). A 4:1 ratio (6 mm: 3 mm grind) produced a large chewiness value. The 4:1 ratio (6 mm: 3 mm grind) with and without gum produced the largest chewiness value. The increase of chewiness for the 4:1 ratio (6 mm: 3 mm grind) could be due to the inhomogeneous structure of two grind sizes blended together. The inconsistencies in the dairy protein gel structure may have produced a chewier meat-like structure. McDonald's produced the largest cohesive value of all the dairy protein gel treatments while Boca had a similar instrumental cohesiveness as the dairy protein gels (Figure 7.15).

Figure 7.14 The texture analyzer measurement gumminess for the factor grind size
n=24 Error bars represent the standard deviation for each sample

Figure 7.15 The texture analyzer measurement chewiness for the interaction of
grind size and gum
n=24 Error bars represent the standard deviation for each sample

The texture measurement adhesiveness was significantly different for the gum factor ($P\text{-value}<0.05$) and interaction ($P\text{-value}<0.05$) of the two factors. The presence of gum in the dairy protein gel system produced a large adhesiveness value.

Figure 7.16 The texture analyzer measurement adhesiveness for the gum factor
n=24 Error bars represent the standard deviation for each sample

Figure 7.17 The texture analyzer measurement adhesiveness for the interaction of grind size and gum
n=24 Error bars represent the standard deviation for each sample

Moisture was significantly different for the gum factor (P -value<0.05). The presence of gum in the dairy protein gel system produced a higher percent moisture.

Figure 7.18 The texture analyzer measurement moisture for the gum in the dairy protein gel.
n=24 Error bars represent the standard deviation for each sample

Table 7.4a Texture Profile Analysis means of the interaction of grind size and the usage of gum

Grind Size	Use of Gum	Hardness (g)			Springiness (mm)			Cohesiveness (%)			Gumminess (g)		
Mixer	Gum	1036.397	(54.654)	ab	3.433	(0.491)	ab	0.368	(0.025)	bc	380.767	(24.138)	bc
Mixer	No Gum	1351.920	(47.518)	ab	3.517	(0.006)	ab	0.333	(0.006)	cde	450.366	(17.709)	abc
3 mm	Gum	1114.717	(38.304)	ab	2.753	(0.080)	b	0.354	(0.029)	bcd	393.887	(19.363)	bc
3 mm	No Gum	1235.353	(226.866)	ab	3.067	(0.232)	ab	0.283	(0.021)	de	346.940	(36.949)	bc
6 mm	Gum	1157.407	(115.246)	ab	3.087	(0.211)	ab	0.425	(0.023)	ab	490.250	(29.491)	abc
6 mm	No Gum	1016.640	(309.365)	b	3.657	(0.438)	ab	0.269	(0.026)	e	276.476	(101.780)	c
4:1 mm	Gum	1494.963	(456.494)	ab	3.230	(0.437)	ab	0.485	(0.053)	a	740.845	(286.000)	a
4:1 mm	No Gum	1682.867	(254.441)	a	3.803	(0.482)	a	0.385	(0.033)	bc	653.634	(156.032)	ab

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n= 24 Values in () are the standard deviations

Table 7.4b Texture Profile Analysis means of the interaction of grind size and the usage of gum

Grind Size	Use of Gum	Chewiness (g)			Adhesiveness (g)			Moisture (%)		
Mixer	Gum	1315.175	(263.459)	ab	494.000	(119.855)	ab	70.100	(0.240)	bc
Mixer	No Gum	1583.758	(61.224)	ab	57.487	(16.462)	c	69.200	(0.000)	d
3 mm	Gum	1085.526	(84.700)	b	346.743	(80.736)	bc	70.500	(0.255)	ab
3 mm	No Gum	1069.109	(194.150)	b	66.583	(15.481)	c	68.500	(0.078)	d
6 mm	Gum	1515.249	(167.062)	ab	467.770	(76.481)	ab	70.500	(0.148)	ab
6 mm	No Gum	981.950	(232.808)	b	58.263	(4.003)	c	68.800	(0.573)	d
4:1 mm	Gum	2471.709	(1163.299)	a	673.827	(245.752)	a	71.400	(1.407)	a
4:1 mm	No Gum	2439.059	(275.264)	a	63.200	(14.211)	c	70.000	(0.163)	bc

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n= 24 Values in () are the standard deviations

Table 7.5a Texture Profile Analysis means of the grind size factor

Grind Size	Hardness (g)			Springiness (mm)			Cohesiveness (%)			Gumminess (g)		
Mixer	1194.158	(178.786)	b	3.475	(0.314)	ab	0.350	(0.025)	b	415.566	(42.564)	b
3 mm	1175.035	(159.813)	b	2.910	(0.232)	b	0.319	(0.045)	b	370.414	(36.841)	b
6 mm	1087.023	(222.576)	b	3.372	(0.438)	ab	0.347	(0.088)	b	383.363	(134.912)	b
4:1 mm	1588.915	(346.183)	a	3.517	(0.518)	a	0.435	(0.068)	a	697.240	(211.515)	a

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n= 24 Values in () are the standard deviations

Table 7.5b Texture Profile Analysis means of the grind size factor

Grind Size	Chewiness (g)			Adhesiveness (g)			Moisture (%)		
Mixer	1449.466	(225.620)	b	275.743	(96.217)	a	69.600	(0.532)	b
3 mm	1077.317	(134.269)	b	206.663	(85.312)	a	69.500	(1.196)	b
6 mm	1248.599	(343.753)	b	263.017	(89.012)	a	69.600	(1.050)	b
4:1 mm	2455.384	(756.263)	a	368.513	(124.021)	a	70.700	(1.407)	a

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n= 24 Values in () are the standard deviations

Table 7.6a Texture Profile Analysis means of the gum factor

Use of Gum	Hardness (g)	Springiness (mm)	Cohesiveness (%)	Gumminess (g)
Gum	1200.871 (273.164) a	3.511 (0.394) a	0.408 (0.062) a	501.437 (194.926) a
No Gum	1321.695 (319.653) a	3.126 (0.412) b	0.318 (0.052) b	431.854 (169.334) a

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n= 24 Values in () are the standard deviations

Table 7.6b Texture Profile Analysis means of the gum factor

Use of Gum	Chewiness (g)	Adhesiveness (g)	Moisture (%)
Gum	1596.914 (754.020) a	495.585 (175.384) a	70.600 (0.672) a
No Gum	1518.469 (630.108) a	61.383 (12.147) b	69.100 (0.616) b

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n= 24 Values in () are the standard deviations

7.4.2. Dairy Protein Gel Processing Instrumental Summary

The increase in the grind size produced an increased instrumental hardness, chewiness and gumminess. This can be explained by the larger particle size that was formed from the grinding process (Suman and Sharma, 2003). The 4:1 ratio (6 mm: 3 mm grind) produced the firmest (P-value<0.05) dairy protein gel product which may be related to the inhomogeneous grinded curd structure.

The increase in the grind size or the use of only a mixer increased the instrumental springiness. The 4:1 ratio (6 mm: 3 mm grind), mixer, and 6 mm produced a large (P-value<0.05) springiness value compared to the 3 mm. The larger curd size may have produced a cohesive curd mass that resists deformation (Gunasekaran and Ak, 2003). The lack of gum in the dairy protein gel system produced a higher (P-value<0.05) springiness value. The lack of gum also decreased the water absorption. The dairy protein gel system can promote a larger amount of cross-linking of the proteins which produces a network of proteins that are highly resistant to deformation (Bryant et al. 1995; Lobato-Calleros et al., 2001).

An increase in the grind size increased the instrumental cohesiveness. The 4:1 ratio (6 mm: 3 mm grind) produced a large (P-value<0.05) cohesiveness value compared to the other grind sizes. The usage of gum in the dairy protein gel system produced a cohesive (P-value<0.05) texture. A 4:1 ratio (6 mm: 3 mm grind) with gum produced a very cohesive (P-value<0.05) product.

The increase of the grind size with or without the addition of gum produced a chewier product. The 4:1 ratio (6 mm: 3 mm grind) with and without the addition of gum produced the largest instrumental chewiness.

The usage of gum in the dairy protein gel system produced a higher instrumental adhesiveness. The gum had a higher moisture ($P\text{-value} < 0.05$) meaning that more water was bound in the dairy protein gel system. The adhesiveness increases with the use of a gum in the system which can be related to the amount of water that is bound in the system (Ulu, 2006).

7.4.3. Dairy Protein Gel Processing Sensory Results

The sensory texture attributes hardness, cohesiveness, chewiness and adhesiveness were evaluated by a sensory panel. A general linear model was used to determine the differences in the instrumental attributes. Tukey's HSD pairwise comparison was used to compare the means of the attributes (Minitab, State College, PA).

For the interaction of the factors grind size and gum, reference points were used to compare the dairy protein gel system to nuggets on the market. The meat nugget McDonald's and the meat alternative nugget Boca were used to compare to the dairy protein gels.

There was a significant difference in the grind size ($P\text{-value} < 0.05$) used on the dairy protein gel system on the sensory attributes hardness, cohesiveness, chewiness and adhesiveness (Figure 7.19). A 6 mm and 4:1 ratio (6 mm: 3 mm grind) produced higher attribute ratings for the attributes hardness, chewiness and adhesiveness. A grind size of 6 mm had a higher cohesiveness attribute rating compared to the 4:1 ratio (6 mm: 3 mm grind).

Figure 7.19 Sensory attributes for the grind size factor
*n=12

There was no significant differences in the usage of gum in the dairy protein gel system on the sensory attributes hardness, cohesiveness, chewiness and adhesiveness (Figure 7.20).

Figure 7.20 Sensory attributes for the gum factor
*n=12

There was a significant difference in the interaction of the grind size and gum factors ($P\text{-value} < 0.05$) used in the dairy protein gel system on the sensory attributes hardness, cohesiveness, chewiness and adhesiveness (Figure 7.21, 7.22, 7.23 and 7.24). A 4:1 ratio (6 mm: 3 mm grind) with no gum added to the system produced higher attribute ratings for hardness, cohesiveness, chewiness and adhesiveness. A grind size of 6 mm with no gum produced higher attribute ratings for hardness and cohesiveness. A grind size of 6 mm with the addition of gum produced higher attribute ratings for chewiness and adhesiveness. The use of a 3 mm grind size with no gum and the mixer with or without the addition of gum produced the lowest attribute ratings for all attributes.

Boca and McDonald's produced the largest hardness values of all the dairy protein gel treatments (Figure 7.21). McDonald's was considered less firm compared to Boca. For cohesiveness, 6 mm and the 4:1 ratio grind size without the use of gum produced a larger cohesiveness value compared to McDonald's and Boca (Figure 7.22). The 4:1 ratio and 6 mm grind size produced a similar chewiness value as the references values (Figure 7.23). For adhesiveness, Boca and McDonald's produced a smaller adhesiveness value compared to the 6 mm grind with addition of gum (Figure 7.24). McDonald's was not considered an adhesive product while Boca had some adhesive attributes.

Figure 7.21 The sensory measurement hardness for the interaction of grind size and gum
n=12 Error bars represent the standard deviation for each sample

Figure 7.22 The sensory measurement cohesiveness for the interaction of grind size and gum
n=12 Error bars represent the standard deviation for each sample

Figure 7.23 The sensory measurement chewiness for the interaction of grind size and gum
n=12 Error bars represent the standard deviation for each sample

Figure 7.24 The sensory measurement adhesiveness for the interaction of grind size and gum
n=12 Error bars represent the standard deviation for each sample

Table 7.7a Sensory attribute means for the interaction of the grind size and gum usage factors

Grind Size	Use of Gum	Hardness			Cohesiveness			Chewiness			Adhesiveness		
Mixer	Gum	28.800	(14.867)	c	22.200	(9.878)	e	24.500	(13.260)	d	36.100	(26.335)	ab
Mixer	No Gum	35.100	(17.836)	bc	32.000	(13.937)	d	31.700	(17.460)	cd	35.500	(22.070)	ab
3 mm	Gum	45.900	(14.219)	a	53.800	(14.212)	b	50.400	(24.716)	ab	39.100	(18.757)	ab
3 mm	No Gum	31.800	(17.091)	c	26.900	(11.616)	de	27.000	(11.135)	cd	34.400	(21.393)	b
6 mm	Gum	42.700	(10.859)	ab	57.700	(15.799)	ab	49.100	(23.893)	ab	48.900	(23.956)	a
6 mm	No Gum	49.700	(13.145)	a	62.600	(18.501)	a	60.000	(33.379)	a	44.000	(19.081)	ab
4:1 mm	Gum	41.300	(16.714)	ab	44.300	(21.341)	c	38.400	(23.748)	bc	44.100	(22.188)	ab
4:1 mm	No Gum	49.600	(12.321)	a	62.300	(17.537)	ab	57.300	(32.795)	a	45.400	(24.686)	ab

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=12 Values in () are the standard deviations

Table 7.7b Sensory attribute means for the grind size factor

Grind Size	Hardness			Cohesiveness			Chewiness			Adhesiveness		
Mixer	31.900	(16.629)	c	27.100	(12.982)	d	28.100	(15.847)	c	35.800	(24.170)	c
3 mm	38.900	(17.185)	b	40.300	(18.700)	c	38.700	(22.400)	b	36.700	(20.151)	bc
6 mm	46.200	(12.500)	a	60.100	(17.286)	a	54.500	(29.384)	a	46.400	(21.680)	a
4:1 mm	45.400	(15.201)	a	53.300	(21.427)	b	47.800	(30.016)	a	44.700	(23.355)	ab

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=12 Values in () are the standard deviations

Table 7.8 Sensory attribute means for the gum usage factor

Use of Gum	Hardness			Cohesiveness			Chewiness			Adhesiveness		
Gum	39.700	(15.628)	a	44.500	(20.927)	a	40.600	(24.117)	a	42.000	(23.316)	a
No Gum	41.500	(17.256)	a	45.900	(22.754)	a	44.000	(29.374)	a	39.800	(22.281)	a

Tukey's HSD Pairwise Comparison of $\alpha=0.05$. The means followed by different letters are significantly different.

*n=12 Values in () are the standard deviations

7.4.4. Dairy Protein Gel Processing Sensory Summary

The sensory texture attributes hardness, cohesiveness, chewiness, and adhesiveness were significant depending on the grind size of the dairy protein gel samples. The increase in grind size increased the sensory attributes hardness, cohesiveness, chewiness and adhesiveness. The 4:1 ratio (6 mm: 3 mm grind) and 6 mm grind size produced the largest hardness, chewiness and adhesiveness values, while the 6 mm grind size produced the largest cohesiveness value. There was no gum effect for the sensory data.

7.4.4. Correlation Between Sensory Attributes and Texture Measurements

The averaged texture measurements were correlated with the averaged sensory attributes. The R values did not produce any significant correlations between the texture analyzer and sensory attributes (Table 7.9).

Table 7.9 Multivariate correlation coefficients between texture analyzer measurements and sensory attributes

Texture	Correlation Coefficients			
	Sensory Hardness	Sensory Cohesiveness	Sensory Chewiness	Sensory Adhesiveness
TPA Hardness	0.24	0.17	0.12	0.24
TPA Cohesiveness	0.08	0.13	0.00	0.51
TPA Chewiness	0.23	0.20	0.12	0.44
TPA Adhesiveness	-0.17	-0.11	-0.21	0.27

*P-value<0.05

**P-value<0.10

*n=12

7.4.6. Correlation Between Sensory Attributes and Texture Measurements Summary

Between the instrumental measurements and sensory attributes, the larger grind size produced significant results. Both instrument and sensory showed a similar trend for the texture attributes. The instrumental and sensory data was analyzed to determine if both the instrument and sensory data was correlated. There was no significant correlation ($P\text{-value} > 0.05$) between the instrumental and sensory data. The lack of correlation between the texture analyzer and sensory results could be explained by the statistically significant differences of the correlation attributes hardness ($P\text{-value} < 0.05$) (Figure 7.21) (Table 7.10), cohesiveness ($P\text{-value} < 0.05$) (Figure 7.22) (Table 7.10), chewiness ($P\text{-value} < 0.05$) (Figure 7.23) (Table 7.10), and adhesiveness ($P\text{-value} < 0.05$) (Figure 7.24) (Table 7.10) by the panel's variability for each treatment. The instrumental texture attributes may not be an accurate predictor for the sensory texture attributes when comparing food lexicons from a different food system to a dairy based system. The lack of correlation was also reported by Meullenet, et al. (1998).

In the sensory texture attribute figures below, there was a lot of variation by the panelists for each treatment (Table 7.10). The panelists were a significant source ($P\text{-value} < 0.05$) of variation for the texture attributes cohesiveness and chewiness (Table 7.10). All the samples were different for each attribute ($P\text{-value} < 0.05$) except for the sensory attribute adhesiveness ($P\text{-value} > 0.05$) suggesting that the sensory attributes were affected by the grind size and/or addition of gum. The replication of the samples were not a source of variation (Table 7.10). The lack of variation in the replication suggested that the panel was reproducible in the ratings of the samples. The judge by

sample interaction showed variation for all the sensory attributes (P-value<0.05) meaning that there was inconsistencies among the judges on the panel. This was also noted by Guinard (1997) for texture and mouth feel attributes. There was no variation in the sample by replication interaction (P-value>0.05) which indicates there was no difference in the sample-to-sample variation (Table 7.10). The variation in the panelists suggests that the panelists were not well trained due to the lack of time for training. Several more days would be needed to effectively train the panelists to reduce the variation for each treatment. Also the lack of correlation could be explained by the compression percentage of the texture analyzer. The compression percentage of the texture analyzer was set to 50% for all the samples evaluated in this thesis. The optimal correlations conditions between sensory and the texture analyzer of dairy protein gel structures should be typically compressed to 70% of the samples height or beyond the macroscopic fracture (Gunasekaran and Ak, 2003). There was no previous research conducted on this specific type of dairy protein gel used in this experiment so 50% compression was used. The increase in the compression percentage of the texture analyzer may have shown some correlations between the texture analyzer and sensory results.

Table 7.10- Analysis of variance of the texture attribute ratings (8 judges): degrees of freedom (df), F-ratios, and error mean squares (MSE)

Texture Attribute	F-ratios						MSE
	Judges	Replications	Samples	J x R	J x S	R x S	
Hardness	1.64	1.46	4.46**	5.27***	5.57***	1.71	54.50
Cohesiveness	4.76**	2.80	19.16***	0.85	3.05***	1.51	93.69
Chewiness	2.94*	0.89	7.71***	3.81***	2.91***	0.94	206.8
Adhesiveness	0.26	0.61	0.96	11.53***	4.67***	1.33	144.6
df	7	2	7	14	49	14	98

*, **, *** significant at $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively

Figure 7.25 Sensory variability between samples for hardness of the grind size x gum factor

Figure 7.26 Sensory variability between samples for cohesiveness of the grind size x gum factor

Figure 7.27 Sensory variability between samples for chewiness of the grind size x gum factor

Figure 7.28 Sensory variability between samples for adhesiveness of the grind size x gum factor

8.0 PHASE III EXPERIMENT

A dairy based meat alternative grinded with a 6 mm grind plate with the use of gum from phase II was used to be evaluated by chicken nugget consumers. An acceptability test was performed on untrained consumers of chicken nuggets to determine if the dairy based meat alternative was acceptable compared to chicken nuggets and meat alternatives on the market. Texture, flavor, and appearance were evaluated by the consumers.

8.1 DAIRY BASED MEAT ALTERNATIVE ACCEPTABILITY TEST

Untrained consumers of chicken nuggets were recruited from Cal Poly San Luis Obispo. The 41 participants were selected to evaluate the dairy based meat alternative chicken nuggets compared to frozen, fast food, and meat alternative nuggets on the market. Four commercial nuggets were sampled by each panelist. The commercial samples were McDonald's (fast food), Foster Farms (frozen), Boca Nuggets (soy based meat alternative), and Quorn nuggets (fungus based meat alternative). The participants assessed the acceptability of five types of nuggets for the overall quality, appearance, overall flavor, chicken flavor intensity, moistness, texture, firmness, and chewiness of the nuggets. The consumers used a 9-point hedonic scale (1 is dislike extremely, 5 is neither like nor dislike, 9 like extremely) to assess the overall quality, appearance, overall flavor, and texture of the nuggets. A 5-point just about right intensity scale (1 is much too weak, 3 is just about right, 5 is much too strong) was used to assess the chicken flavor intensity, moistness, firmness

and chewiness of the nuggets. The samples were randomized to each panelist using the program Compusense (Compusense, Guelph, Ontario, Canada).

A general linear model was used to determine the differences in the sensory attributes. Tukey's HSD pairwise comparison was used to compare the means of the attributes (Minitab, State College, PA).

The consumers were also separated into target consumers and non-target consumers. Target consumers consumed nuggets at least once a month, at least once every two weeks, and more than once a week. Non-target consumers consumed nuggets less than once a month. The target and non-target consumers were analyzed using the ANOVA and chi square tests.

A general linear model was used on the 9-hedonic scale questions to assess the sensory attribute means. A chi square was used on the 5-point just about right intensity scale to assess the sensory attributes and the demographic information. The data analyzed with a chi square was reorganized into two groups. The first group consisted of the "just about right" attribute descriptor. The second group consisted of the "much too strong", "somewhat too strong", "somewhat too weak", and "much too weak" attribute descriptors. This was done to analyze the percentage of consumers that thought the nugget attribute was considered sufficient versus the consumers that thought there was something wrong with the product. The data was analyzed using SSPS (SPSS for Windows, Rel. 11.0.1. 2010. Chicago: SPSS Inc.).

8.2 DAIRY BASED MEAT ALTERNATIVE ACCEPTABILITY TEST RESULTS

8.2.1. Acceptability Test Results

The acceptability of a dairy based meat alternative was assessed by an untrained panel. The dairy based meat alternative was least liked ($P\text{-value} < 0.05$) by the consumers. All of the commercial nuggets have a better appearance ($P\text{-value} < 0.05$) compared to the dairy based meat alternative. Boca, McDonald's and the dairy based meat alternative were considered to have too strong of a chicken flavor ($P\text{-value} < 0.05$) compared to the other nuggets. The dairy based meat alternative and McDonald's were considered more moist ($P\text{-value} < 0.05$) compared to the other commercial nuggets. The dairy based meat alternative's texture was less liked ($P\text{-value} < 0.05$) by the consumers. McDonald's had a slightly softer texture ($P\text{-value} < 0.05$) compared to the other products. All the nuggets were considered to have an adequate chewiness level.

Figure 8.1 Mean responses to sensory attributes of meat and meat alternative products
*n=41

Table 8.1a Mean hedonic responses and Tukey's HSD pairwise comparison ($\alpha=0.05$) for overall quality, appearance, overall texture and chicken flavor for meat and meat alternative products.

Nugget	Overall Quality	Appearance	Overall Flavor	Chicken Flavor
Boca	4.68 (2.00) bc	5.82 (1.63) a	4.53 (2.08) bc	3.79 (0.99) a
McDonald's	6.13 (2.04) a	6.39 (1.91) a	5.82 (1.94) ab	3.47 (0.76) ab
Moofu	3.53 (2.01) c	3.34 (1.79) b	3.45 (1.88) c	3.68 (1.36) ab
Quron	5.76 (2.06) ab	6.61 (1.55) a	5.71 (2.26) ab	3.11 (0.80) bc
Tyson	6.32 (2.13) a	6.53 (1.59) a	6.16 (2.18) a	2.84 (0.79) c

The means followed by different letters within each column are significantly different (P-value<0.05).

Means based on 41 observations

Values in () are the standard deviations

Table 8.1b Mean hedonic responses and Tukey's HSD pairwise comparison ($\alpha=0.05$) for moistness, overall texture, firmness and chewiness of meat and meat alternative products.

Nugget	Moistness			Overall Texture			Firmness			Chewiness		
Boca	2.92	(0.85)	b	5.39	(1.81)	a	2.63	(0.75)	b	2.84	(1.05)	a
McDonald's	3.50	(0.80)	a	5.74	(1.77)	a	3.26	(0.89)	a	2.47	(0.73)	a
Moofu	3.55	(0.86)	a	3.89	(2.02)	b	2.71	(1.25)	b	2.95	(1.09)	a
Quron	2.87	(0.62)	b	5.97	(1.73)	a	2.76	(0.71)	ab	2.84	(0.64)	a
Tyson	2.74	(0.60)	b	6.11	(1.91)	a	2.68	(0.62)	b	2.79	(0.78)	a

The means followed by different letters within each column are significantly different (P-value<0.05).

Means based on 41 observations

Values in () are the standard deviations

8.2.2. Analysis of Consumer Acceptability Results

The panelist were separated into two groups that represented the amount of meat and non-meat nuggets that was consumed by each panelist. The panelists were separated into target consumers (eat nuggets at least once a month) and non-target consumers (eat nuggets less than once a month).

Although the F-test (Table 8.2) shows no significant differences between the nuggets and the target and non-target consumers, the Tukey's HSD pairwise comparison show significant differences between the nuggets and the target and non-target consumers. Comparisons were made using Tukey's HSD pairwise comparison. There was a significant difference for the interaction of the target and non-target consumers and the nuggets tested (P-value<0.05). McDonald's and Tyson were considered to have the best overall quality by target consumers while Tyson and Quorn were considered to have the best overall quality by non-target consumers (Table 8.2). The Moofu nugget was considered to have the least overall quality compared to the other nuggets for both target and non-target

consumers (Table 8.2). The Moofu nugget was very close in quality compared to Boca (soy product) by target consumers (Table 8.2).

Table 8.2 Mean hedonic scale scores and Tukey's HSD pairwise comparison ($\alpha=0.05$) for the overall quality for target and non-target consumers.

Nugget Type	Target Consumers			Non-Target Consumers			P-values
Boca	3.80	(1.81)	abc	4.60	(1.96)	abc	0.671
McDonald's	6.30	(1.70)	ab	6.26	(2.18)	ab	0.671
Moofu	3.20	(1.32)	c	3.90	(2.04)	bc	0.671
Quron	4.70	(2.67)	abc	5.60	(2.06)	abc	0.671
Tyson	6.40	(2.37)	a	6.20	(2.32)	ab	0.671

The means followed by different letters within and between each column are significantly different (P-value<0.05).

Means based on 41 observations

Values in () are the standard deviations

Although the F-test (Table 8.3) shows no significant differences between the nuggets and the target and non-target consumers, the Tukey's HSD pairwise comparison showed significant differences between the nuggets and the target and non-target consumers. Comparisons were made using Tukey's HSD pairwise comparison. There was a significant difference for the interaction of the target and non-target consumers and the nuggets tested (P-value<0.05). Tyson and McDonald's were considered to have the best appearance compared to the other nuggets by the target consumers (Table 8.3). Non-target consumers preferred McDonald's, Quron's, and Tyson's appearance (Table 8.3). The Moofu nugget's appearance was considered to be the least liked by target and non-target consumers (Table 8.3).

Table 8.3 Mean hedonic scale scores and Tukey's HSD pairwise comparison ($\alpha=0.05$) for the appearance for target and non-target consumers.

Nugget Type	Target Consumers			Non-Target Consumers			P-values
Boca	5.20	(1.69)	abc	5.90	(1.45)	a	0.313
McDonald's	6.90	(1.29)	a	6.30	(2.13)	a	0.313
Moofu	3.40	(0.52)	bc	3.50	(1.96)	c	0.313
Quron	5.70	(1.42)	ab	6.70	(1.59)	a	0.313
Tyson	6.80	(1.40)	a	6.70	(1.44)	a	0.313

The means followed by different letters within and between each column are significantly different (P-value<0.05).

Means based on 41 observations

Values in () are the standard deviations

Although the F-test (Table 8.4) shows no significant differences between the nuggets and the target and non-target consumers, the Tukey's HSD pairwise comparison showed significant differences between the nuggets and the target and non-target consumers. Comparisons were made using Tukey's HSD pairwise comparison. There was a significant difference for the interaction of the target and non-target consumers and the nuggets tested (P-value<0.05). Both target and non-target consumers preferred Tyson and McDonald's flavor (Table 8.4).

Table 8.4 Mean hedonic scale scores and Tukey's HSD pairwise comparison ($\alpha=0.05$) for the overall flavor for target and non-target consumers.

Nugget Type	Target Consumers			Non-Target Consumers			P-values
Boca	3.80	(1.75)	abc	4.40	(2.08)	abc	0.560
McDonald's	6.30	(1.64)	a	5.80	(2.11)	ab	0.560
Moofu	2.70	(1.06)	c	3.80	(1.78)	bc	0.560
Quron	4.80	(2.49)	abc	5.50	(2.31)	ab	0.560
Tyson	6.20	(2.04)	ab	6.00	(2.27)	ab	0.560

The means followed by different letters within and between each column are significantly different (P-value<0.05).

Means based on 41 observations

Values in () are the standard deviations

Over half of the target consumers thought that Boca's, McDonald's, and Tyson's nugget flavor was just right (Table 5.15). 75% of the target consumers preferred Boca's flavor compared to the non-target consumers. Over half of the non-target consumers believed that Boca, McDonalds and Tyson had the right amount of flavor. Both target and non-target consumers thought the dairy based meat alternative's flavor was not preferable.

Table 8.5 Just about right scale flavor intensity response for target and non-target consumers.

Nugget	Attribute	Target Consumers N=19	Non-Target Consumers N=22	P-values
Boca Nugget	Just Right	75.00%	25.00%	0.070*
	Not Right	39.40%	60.60%	0.070*
McDonald's Nugget	Just Right	52.60%	47.40%	0.453
	Not Right	40.90%	59.10%	0.453
Moofu Nugget	Just Right	0%	0%	---
	Not Right	46.30%	53.70%	---
Quron Nugget	Just Right	46.20%	53.80%	0.975
	Not Right	46.70%	53.30%	0.975
Tyson Nugget	Just Right	51.90%	48.10%	0.326
	Not Right	35.70%	64.30%	0.326

**significant at the .05 level

*significant at the .10 level

At least half of the target consumers thought that Boca's, dairy based meat alternative, and Tyson's moisture level was just right (Table 8.6). Non-target consumers thought that McDonald's moisture level was just right. Target consumers believed that McDonald's moisture level was not right. On the other hand, the non-target consumers thought that Boca's, the dairy based meat alternative's, and Tyson's moisture level was not right.

Table 8.6 Just about right scale moistness response for target and non-target consumers.

Nugget	Attribute	Target Consumers N=19	Non-Target Consumers N=22	P-values
Boca Nugget	Just Right	52.20%	47.80%	0.397
	Not Right	38.90%	61.10%	0.397
McDonald's Nugget	Just Right	42.10%	57.90%	0.613
	Not Right	50.00%	50.00%	0.613
Moofu Nugget	Just Right	50.00%	50.00%	0.763
	Not Right	44.80%	55.20%	0.763
Quron Nugget	Just Right	46.20%	53.80%	0.975
	Not Right	46.70%	53.30%	0.975
Tyson Nugget	Just Right	51.90%	48.10%	0.326
	Not Right	35.70%	64.30%	0.326

**significant at the .05 level

*significant at the .10 level

Although the F-test (Table 8.7) shows no significant differences between the nuggets and the target and non-target consumers, the Tukey's HSD pairwise comparison showed significant differences between the nuggets and the target and non-target consumers. Comparisons were made using Tukey's HSD pairwise comparison. There was no significant difference due to the interaction of the target and non-target consumers and the nugget that was tested, but Tukey's HSD showed that there was a significant difference.

There was a significant difference for the interaction of the target and non-target consumers and the nuggets tested (P-value<0.05). Target consumers preferred McDonalds overall texture (Table 8.7) while non-target consumers preferred Tyson's, Quorn's, and McDonald's overall texture. The Moofu's overall texture was least liked by both target and non-target consumers (Table 8.7).

Table 8.7 Mean hedonic scale scores and Tukey's HSD pairwise comparison ($\alpha=0.05$) for the overall texture for target and non-target consumers.

Nugget Type	Target Consumers			Non-Target Consumers			P-values
Boca	5.10	(1.37)	ab	5.10	(1.77)	ab	0.771
McDonald's	6.30	(1.25)	a	5.80	(1.94)	a	0.771
Moofu	4.10	(1.91)	ab	4.00	(2.16)	b	0.771
Quron	5.60	(1.71)	ab	5.80	(1.71)	a	0.771
Tyson	5.40	(2.46)	ab	6.10	(1.93)	a	0.771

The means followed by different letters within and between each column are significantly different (P-value<0.05).

Means based on 41 observations

Values in () are the standard deviations

Half of the consumers thought that Boca and McDonalds had a good texture (Figure 8.8). A little over half of the non-target consumers thought that Quron's and Tyson's was just right. At least half of the consumers thought that Quron's and Tyson's texture was not right. Non-target consumers believed that Boca's and McDonald's texture was not right. The dairy based meat alternative's texture was just about right.

Table 8.8 Just about right scale firmness response for target and non-target consumers.

Nugget	Attribute	Target Consumers N=19	Non-Target Consumers N=22	P-values
Boca Nugget	Just Right	50.00%	50.00%	0.678
	Not Right	43.50%	56.50%	0.678
McDonald's Nugget	Just Right	53.80%	46.20%	0.511
	Not Right	42.90%	57.10%	0.511
Moofu Nugget	Just Right	45.50%	54.40%	0.945
	Not Right	46.70%	53.30%	0.945
Quron Nugget	Just Right	36.80%	63.20%	0.257
	Not Right	54.50%	45.50%	0.257
Tyson Nugget	Just Right	44.80%	55.20%	0.763
	Not Right	50.00%	50.00%	0.763

**significant at the .05 level

*significant at the .10 level

Target consumers believed that the McDonald's and Tyson's chewiness was just right (Figure 8.9). Non-target consumers thought that Boca's, dairy based meat alternative, and Quron's chewiness was just right. Non-target consumers thought that Quron had a better chewiness than the target consumers. Target consumers believed that Boca's, dairy based meat alternative's, and Quron's chewiness was not right. Non-target consumers thought that McDonald's and Tyson's chewiness was not right.

Table 8.9 Just about right scale chewiness response for target and non-target consumers.

Nugget	Attribute	Target Consumers N=19	Non-Target Consumers N=22	P-values
Boca Nugget	Just Right	42.90%	57.10%	0.747
	Not Right	48.10%	51.90%	0.747
McDonald's Nugget	Just Right	50.00%	50.00%	0.735
	Not Right	44.40%	55.60%	0.735
Moofu Nugget	Just Right	35.70%	64.30%	0.326
	Not Right	51.90%	48.10%	0.326
Quron Nugget	Just Right	27.80%	72.20%	.035**
	Not Right	60.90%	39.10%	.035**
Tyson Nugget	Just Right	47.80%	52.20%	0.829
	Not Right	44.40%	55.60%	0.829

**significant at the .05 level

*significant at the .10 level

Target consumers expressed that there was some possibility to purchase the dairy based meat alternative (Figure 8.10). Non-target consumers had a slight possibility to purchase the dairy based meat alternative. The acceptability of the dairy based nugget was determined by the willingness to purchase rating score over 4 (some possibility will purchase). Both target and non-target consumers considered the dairy based nugget to be an acceptable product due to the sensory scores over 5 (fair possibility will purchase) on the hedonic scale.

Table 8.10 Mean hedonic scale scores: willingness to purchase the dairy based meat alternative response means for target and non-target consumers.

Question Type	Target Consumers	Non-Target Consumers	P-values
Willingness to Purchase	5.84	5.32	0.572

**significant at the .05 level

*significant at the .10 level

n=41

8.2.3. Acceptability Test Summary

The dairy based meat alternative was considered a good product by mostly target consumers compared to the other meat alternatives, but needs to be worked on to improve the appearance, texture and flavor. The bread coating was a major factor in the overall texture and appearance of the product. The bread coating is a confounding variable that was not taken into much consideration when producing the Moofu nugget. The main focus was on the interior of the dairy based meat alternative. The results may have been skewed or not representative of the interior texture of the nugget. A better bread coating needs to be worked on in the near future to mimic the bread coatings on the market if further sensory tests are conducted.

The selected panel may not have been a good representative of the meat alternative market. The panelists were selected on their consumption of chicken nuggets. A further screening process should be conducted to get a larger panel that consumes either both chicken nuggets and meat alternatives or just meat alternatives alone. The results show above that the Moofu nugget is not a comparable product to the fast food meat and frozen meat nuggets on the market, but is a comparable product to the meat alternatives on the market.

The Quron nugget was highly rated by the non-target consumers. This fungus based meat alternative was preferred by both target and non-target consumers and was a good competitor to the meat based nuggets. Further research and work should be done to create a dairy based meat alternative that has a similar texture as the fungus based nugget.

9.0 Conclusions

The dairy based meat alternative was produced from a dairy protein gel. The dairy protein gel formulation was tested to determine the optimal milk to whey ratio and pH based on the textural measurements: hardness, cohesiveness, springiness, gumminess, chewiness and adhesiveness. This condition that resulted in the highest overall texture measurements was identified for further study. The optimal formula was a milk to whey ratio of 15/85 and a pH level of 4.6.

The optimal conditions were used to determine the best processing methods to produce a dairy based meat alternative with textural attributes similar to meat and meat alternatives on the market. The dairy protein gel was processed with a meat grinder with the grinding plates at 3 mm, 6 mm, a 4:1 ratio (6 mm: 3 mm) and the use of only a mixer. Also the usage of gum was tested in the grinded dairy protein gel. The dairy based meat alternative was tested in a trained sensory panel and on the texture analyzer. The results revealed that a large grind size produced the highest texture attributes overall. Further research concluded that the sensory texture data and instrumental data were not significantly correlated ($P\text{-value} > 0.05$). The final dairy based meat alternative formulation used a larger grind size with the addition of gum.

The dairy based meat alternative was assessed by untrained consumers of meat and meat alternative nuggets. The dairy nugget was compared to four other meat and meat alternative nuggets on the market. The dairy based meat alternative was considered a very good product but needs some work to compete with meat nuggets on the market.

10.0 Discussion

By looking at the research conducted in this thesis, a dairy based meat alternative can be produced to feature some of the attributes of meat products. Even though only the production of a dairy based nugget was discussed, preliminary studies suggest the dairy protein gel base can be used to produce other types of meat products and snacking items. Jerky, chicken breasts and fruit sticks were produced too. Other meat products such as meat emulsions, fish patties, and snack bars could also be evaluated to determine if a wider range of products can be produced.

Due to the moisture content and small curd size, the dairy protein gel can produce different shapes by pressing the product at different pressure with different size weights for a specific period of time. There was a lot of experimentation conducted on the usage of different size weights and pressure to produce the optimal dairy based nuggets. Further experimentation concluded that the amount of pressure applied produced different meat products. A chicken-like product needed a heavier weight to remove enough whey from the system to allow a doughy ground chicken-like product to form. The chicken-like product was pressed for about 24 hours. For jerky, an even heavier weight was used to remove most of the excess weigh out of the system so the product could form a jerky product faster while giving a chewy like texture found in most jerky like products. The jerky was pressed for 24 hours and then drained and pressed again for another 24 hours. By understanding how to press the coagulum, different types of texture can be produced.

The acceptability test showed that the Moofu nugget was an acceptable product but needed work on the texture, flavor and appearance. The Moofu product has the

opportunity to shine in the market as an innovative product, especially, the large population of explorative food consumers would be interested in this product. Specific work on fine tuning the texture attributes and flavor to compete with the Quorn nugget would be beneficial. Also, the appearance of the Moofu nugget can be easily fixed by finding research papers on the application of bread coatings on comminuted meat. The Moofu nugget is a novel product that has the ability to beat its competitors in the market place (especially soy based products). If marketing is done on the Moofu nugget as a dairy based meat alternative, consumers will be interested in purchasing this product.

11.0 Limitations

The phase I experiments produced very low yields so there may have been some variability in the final texture results. The level of acidification did not have a broader range of pH levels which may have eliminated the ability to find the optimal pH range for the dairy protein gel. The pressing of the curd was consistent but the amount of curd due to yield may have had an effect on the final texture measurements.

The phase II experiments may have had similar variability issues due to the pressing of the final product. The grinded dairy protein gel was exactly measured in 2 lbs for each treatment and was pressed with same amount of weight, but the pressure of the weight may not have distributed evenly throughout the dairy protein gel. Also the temperature of the curds may have affected the measurements due to the temperature at which the curds were pressed. This may have produced different heights of nuggets. The pressing may have caused some variability in the nugget depending on where the weights were placed on the product.

The preparation of the meat and meat substitute nuggets for the texture analyzer may produce different results due to the breading that was on the nugget and the height of the nugget. The texture analyzer was always set to 50% compression but there may be some variability between each nugget.

12.0 Further Research

Research should be conducted to find the optimal milk to whey and pH level of acidification range. With the research presented from this project and from Chi Yuen Yeung's research, an optimal range can be found.

A new method or procedure should be produced to prevent the sinking of the curd. This was expressed in Yeung's (1997) research and is still an issue in the production of the dairy protein gel.

Further research should be conducted on the grinding of a dairy protein gel. The grind size should be looked at from a microscopic level to evaluate the grinded dairy protein gel coagulum size. This may help to determine if there is any relationship between coagulum size and the texture attributes.

Flavor development and new bread coating systems should be investigated for the dairy based meat alternative. A vegetarian chicken flavor should be used in the nugget instead of a meat based chicken flavor.

Further product development should be conducted to produce a fiber-like dairy protein gel that has the ability to not melt. The use of gums and whey proteins should be looked into to assist in melt restriction for the dairy protein fibers.

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14.0 Appendices

14.1 PRELIMINARY DAIRY PROTEIN GEL RESEARCH MINITAB OUTPUT

General Linear Model: Hardness versus DAY, Milk, pH

Factor	Type	Levels	Values
DAY	random	3	1, 2, 3
Milk	fixed	3	0.01, 0.05, 0.10
pH	fixed	3	5.26, 5.46, 5.66

Analysis of Variance for Hardness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
DAY	2	39796	115886	57943	0.82	0.459
Milk	2	2129354	2577788	1288894	18.20	0.000
pH	2	1004834	983298	491649	6.94	0.007
Milk*pH	4	1958693	1958693	489673	6.92	0.002
Error	16	1132866	1132866	70804		
Total	26	6265543				

S = 266.090 R-Sq = 81.92% R-Sq(adj) = 70.62%

Unusual Observations for Hardness

Obs	Hardness	Fit	SE Fit	Residual	St Resid
4	1037.15	1557.34	172.62	-520.19	-2.57 R
14	1280.05	784.02	172.62	496.03	2.45 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
0.10	8	1114.9	A
0.05	9	864.8	A
0.01	10	350.1	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Hardness
All Pairwise Comparisons among Levels of Milk
Milk = 0.01 subtracted from:

Milk	Lower	Center	Upper	
0.05	189.7	514.7	839.7	(-----*-----)
0.10	427.5	764.8	1102.2	(-----*-----)
				0 350 700 1050

Milk = 0.05 subtracted from:

Milk	Lower	Center	Upper
0.10	-88.53	250.1	588.8

(-----*-----)

0 350 700 1050

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.26	10	954.6	A
5.66	9	878.5	A
5.46	8	496.6	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Hardness

All Pairwise Comparisons among Levels of pH

pH = 5.26 subtracted from:

pH	Lower	Center	Upper
5.46	-792.3	-458.0	-123.7
5.66	-405.5	-76.1	253.2

(-----*-----)

(-----*-----)

-500 0 500 1000

pH = 5.46 subtracted from:

pH	Lower	Center	Upper
5.66	38.14	381.9	725.6

(-----*-----)

-500 0 500 1000

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
0.10	5.66	2	1704.1	A
0.05	5.26	3	1458.1	A
0.10	5.26	3	955.7	A B
0.10	5.46	3	684.8	B
0.05	5.46	3	616.4	B
0.05	5.66	3	519.7	B
0.01	5.26	4	450.0	B
0.01	5.66	4	411.6	B
0.01	5.46	2	188.6	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Hardness

All Pairwise Comparisons among Levels of Milk*pH

Milk = 0.01

pH = 5.26 subtracted from:

Milk = 0.01
pH = 5.46 subtracted from:

Milk = 0.01
pH = 5.66 subtracted from:

Milk = 0.05
pH = 5.26 subtracted from:

pH = 5.46 subtracted from:

Milk = 0.05

pH = 5.66 subtracted from:

Milk = 0.10

pH = 5.26 subtracted from:

Milk = 0.10

pH = 5.46 subtracted from:

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Main Effects Plot for Hardness

Fitted Means

Interaction Plot for Hardness

Fitted Means

General Linear Model: Springiness versus DAY, Milk, pH

Factor	Type	Levels	Values
DAY	random	3	1, 2, 3
Milk	fixed	3	0.01, 0.05, 0.10
pH	fixed	3	5.26, 5.46, 5.66

Analysis of Variance for Springiness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
DAY	2	0.146	0.485	0.243	0.19	0.827
Milk	2	4.033	5.052	2.526	2.00	0.168
pH	2	1.089	1.392	0.696	0.55	0.587
Milk*pH	4	3.785	3.785	0.946	0.75	0.573
Error	16	20.238	20.238	1.265		
Total	26	29.292				

S = 1.12468 R-Sq = 30.91% R-Sq(adj) = 0.00%

Unusual Observations for Springiness

Obs	Springiness	Fit	SE Fit	Residual	St Resid
12	2.55000	4.40456	0.72959	-1.85456	-2.17 R
21	6.13333	4.19929	0.60705	1.93404	2.04 R

R denotes an observation with a large standardized residual.

* WARNING * No multiple comparisons were calculated for the following terms
which contain or interact with random factors.

DAY

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
0.10	8	5.0	A
0.05	9	4.4	A
0.01	10	3.9	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Springiness

All Pairwise Comparisons among Levels of Milk

Milk = 0.01 subtracted from:

Milk	Lower	Center	Upper	
0.05	-0.8587	0.5149	1.888	(-----*-----)
0.10	-0.3218	1.1040	2.530	(-----*-----)

-----+-----+-----+-----
0.0 1.0 2.0

Milk = 0.05 subtracted from:

Milk	Lower	Center	Upper
0.10	-0.8423	0.5891	2.020

-----+-----+-----+-----
 (-----*-----)
 -----+-----+-----+-----
 0.0 1.0 2.0

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.26	10	4.7	A
5.66	9	4.3	A
5.46	8	4.2	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Springiness

All Pairwise Comparisons among Levels of pH

pH = 5.26 subtracted from:

pH	Lower	Center	Upper
5.46	-1.952	-0.5390	0.8739
5.66	-1.811	-0.4190	0.9730

+-----+-----+-----+-----
 (-----*-----)
 (-----*-----)
 +-----+-----+-----+-----
 -2.0 -1.0 0.0 1.0

pH = 5.46 subtracted from:

pH	Lower	Center	Upper
5.66	-1.333	0.1201	1.573

+-----+-----+-----+-----
 (-----*-----)
 +-----+-----+-----+-----
 -2.0 -1.0 0.0 1.0

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
0.10	5.46	3	5.2	A
0.10	5.26	3	5.0	A
0.01	5.26	4	4.8	A
0.10	5.66	2	4.7	A
0.05	5.46	3	4.6	A
0.05	5.26	3	4.4	A
0.05	5.66	3	4.2	A
0.01	5.66	4	4.0	A
0.01	5.46	2	2.9	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Springiness

All Pairwise Comparisons among Levels of Milk*pH

Milk = 0.01

pH = 5.26 subtracted from:

Milk = 0.01
pH = 5.46 subtracted from:

Milk = 0.01
pH = 5.66 subtracted from:

Milk = 0.05
pH = 5.26 subtracted from:

Milk = 0.05

pH = 5.46 subtracted from:

Milk	pH	Lower	Center	Upper
0.05	5.66	-3.617	-0.3511	2.915
0.10	5.26	-2.784	0.4822	3.748
0.10	5.46	-2.645	0.6211	3.887
0.10	5.66	-3.529	0.1706	3.870

-----+-----+-----+-----+
(-----*-----)
(-----*-----)
(-----*-----)
(-----*-----)
-----+-----+-----+-----+
-3.5 0.0 3.5 7.0

Milk = 0.05

pH = 5.66 subtracted from:

Milk	pH	Lower	Center	Upper
0.10	5.26	-2.433	0.8333	4.099
0.10	5.46	-2.294	0.9722	4.238
0.10	5.66	-3.178	0.5217	4.221

-----+-----+-----+-----+
(-----*-----)
(-----*-----)
(-----*-----)
-----+-----+-----+-----+
-3.5 0.0 3.5 7.0

Milk = 0.10

pH = 5.26 subtracted from:

Milk	pH	Lower	Center	Upper
0.10	5.46	-3.127	0.1389	3.405
0.10	5.66	-4.011	-0.3116	3.388

-----+-----+-----+-----+
(-----*-----)
(-----*-----)
-----+-----+-----+-----+
-3.5 0.0 3.5 7.0

Milk = 0.10

pH = 5.46 subtracted from:

Milk	pH	Lower	Center	Upper
0.10	5.66	-4.150	-0.4505	3.249

-----+-----+-----+-----+
(-----*-----)
-----+-----+-----+-----+
-3.5 0.0 3.5 7.0

Main Effects Plot for Springiness
Fitted Means

Interaction Plot for Springiness
Fitted Means

General Linear Model: Cohesiveness versus DAY, Milk, pH

Factor	Type	Levels	Values
DAY	random	3	1, 2, 3
Milk	fixed	3	0.01, 0.05, 0.10
pH	fixed	3	5.26, 5.46, 5.66

Analysis of Variance for Cohesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
DAY	2	0.007742	0.001768	0.000884	0.10	0.904
Milk	2	0.064617	0.045378	0.022689	2.62	0.104
pH	2	0.003356	0.005031	0.002516	0.29	0.752
Milk*pH	4	0.032634	0.032634	0.008158	0.94	0.465
Error	16	0.138611	0.138611	0.008663		
Total	26	0.246960				

S = 0.0930764 R-Sq = 43.87% R-Sq(adj) = 8.79%

Unusual Observations for Cohesiveness

Obs	Cohesiveness	Fit	SE Fit	Residual	St Resid
19	0.475402	0.306603	0.056084	0.168799	2.27 R

R denotes an observation with a large standardized residual.

* WARNING * No multiple comparisons were calculated for the following terms
which contain or interact with random factors.

DAY

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
0.05	9	0.4	A
0.10	8	0.4	A
0.01	10	0.4	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Cohesiveness

All Pairwise Comparisons among Levels of Milk

Milk = 0.01 subtracted from:

Milk	Lower	Center	Upper	
0.05	-0.02315	0.09052	0.2042	(-----*-----)
0.10	-0.03267	0.08533	0.2033	(-----*-----)

-----+-----+-----+-----+-----
-0.10 0.00 0.10 0.20

Milk = 0.05 subtracted from:

Milk	Lower	Center	Upper
0.10	-0.1237	-0.005195	0.1133

(-----*-----)

-0.10 0.00 0.10 0.20

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.66	9	0.4	A
5.46	8	0.4	A
5.26	10	0.4	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Cohesiveness

All Pairwise Comparisons among Levels of pH

pH = 5.26 subtracted from:

pH	Lower	Center	Upper
5.46	-0.09614	0.02079	0.1377
5.66	-0.08164	0.03356	0.1488

(-----*-----)

(-----*-----)

-0.070 0.000 0.070 0.140

pH = 5.46 subtracted from:

pH	Lower	Center	Upper
5.66	-0.1075	0.01276	0.1330

(-----*-----)

-0.070 0.000 0.070 0.140

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
0.05	5.66	3	0.5	A
0.10	5.66	2	0.5	A
0.05	5.26	3	0.4	A
0.10	5.26	3	0.4	A
0.01	5.46	2	0.4	A
0.10	5.46	3	0.4	A
0.05	5.46	3	0.4	A
0.01	5.66	4	0.3	A
0.01	5.26	4	0.3	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Cohesiveness

All Pairwise Comparisons among Levels of Milk*pH

Milk = 0.01

pH = 5.26 subtracted from:

Milk = 0.01
pH = 5.46 subtracted from:

Milk = 0.01
pH = 5.66 subtracted from:

Milk = 0.05
pH = 5.26 subtracted from:

Milk = 0.05

pH = 5.46 subtracted from:

Milk = 0.05

pH = 5.66 subtracted from:

Milk = 0.10

pH = 5.26 subtracted from:

Milk = 0.10

pH = 5.46 subtracted from:

General Linear Model: Gumminess versus DAY, Milk, pH

Factor	Type	Levels	Values
DAY	random	3	1, 2, 3
Milk	fixed	3	0.01, 0.05, 0.10
pH	fixed	3	5.26, 5.46, 5.66

Analysis of Variance for Gumminess, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
DAY	2	2892	1638	819	0.03	0.970
Milk	2	560355	648267	324134	11.97	0.001
pH	2	211504	210249	105124	3.88	0.042
Milk*pH	4	421889	421889	105472	3.89	0.021
Error	16	433273	433273	27080		
Total	26	1629913				

S = 164.559 R-Sq = 73.42% R-Sq(adj) = 56.80%

Unusual Observations for Gumminess

Obs	Gumminess	Fit	SE Fit	Residual	St Resid
4	327.821	671.761	106.751	-343.940	-2.75 R
14	600.016	311.535	106.751	288.481	2.30 R

R denotes an observation with a large standardized residual.

* WARNING * No multiple comparisons were calculated for the following terms
which contain or interact with random factors.

DAY

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
0.10	8	498.0	A
0.05	9	394.0	A
0.01	10	120.5	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Gumminess

All Pairwise Comparisons among Levels of Milk

Milk = 0.01 subtracted from:

Milk	Lower	Center	Upper
0.05	72.57	273.5	474.5
0.10	168.86	377.5	586.1

Milk	Lower	Center	Upper
0.10	-105.5	103.9	313.4

(-----*-----)

0 200 400 600

pH	N	Mean	Grouping
5.26	10	405.6	A
5.66	9	401.1	A
5.46	8	205.8	A

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Gumminess
All Pairwise Comparisons among Levels of pH
pH = 5.26 subtracted from:

pH Lower Center Upper

5.66 -17.20 195.4 407.9

(-----+-----+-----+)

-250 0 250 500

Milk	pH	N	Mean	Grouping
0.10	5.66	2	792.4	A
0.05	5.26	3	660.1	A
0.10	5.26	3	401.7	A B
0.10	5.46	3	299.9	A B
0.05	5.66	3	270.9	A B
0.05	5.46	3	251.1	A B
0.01	5.26	4	155.0	B
0.01	5.66	4	140.2	B
0.01	5.46	2	66.3	B

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Gumminess
All Pairwise Comparisons among Levels of Milk*pH
Milk = 0.01
pH = 5.26 subtracted from:

Milk = 0.01
pH = 5.46 subtracted from:

Milk = 0.01
pH = 5.66 subtracted from:

Milk = 0.05
pH = 5.26 subtracted from:

pH = 5.46 subtracted from:

Milk = 0.05

pH = 5.66 subtracted from:

Milk = 0.10

pH = 5.26 subtracted from:

Milk = 0.10

pH = 5.46 subtracted from:

Milk pH Lower Center Upper

0.10 5.66 -48.78 492.5 1034

(-----*)-----)

-600 0 600 1200

General Linear Model: Chewiness versus DAY, Milk, pH

Factor	Type	Levels	Values
DAY	random	3	1, 2, 3
Milk	fixed	3	0.01, 0.05, 0.10
pH	fixed	3	5.26, 5.46, 5.66

Analysis of Variance for Chewiness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
DAY	2	209747	12513	6257	0.02	0.981
Milk	2	11979868	14545643	7272822	22.04	0.000
pH	2	5294261	5322137	2661068	8.06	0.004
Milk*pH	4	8797031	8797031	2199258	6.66	0.002
Error	16	5280368	5280368	330023		
Total	26	31561275				

S = 574.476 R-Sq = 83.27% R-Sq(adj) = 72.81%

Unusual Observations for Chewiness

Obs	Chewiness	Fit	SE Fit	Residual	St Resid
4	1620.53	2810.97	372.67	-1190.44	-2.72 R

R denotes an observation with a large standardized residual.

* WARNING * No multiple comparisons were calculated for the following terms
which contain or interact with random factors.

DAY

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
0.10	8	2361.0	A
0.05	9	1639.0	A
0.01	10	515.8	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Chewiness

All Pairwise Comparisons among Levels of Milk

Milk = 0.01 subtracted from:

Milk	Lower	Center	Upper	
0.05	421.5	1123	1825	(-----*-----)
0.10	1116.9	1845	2573	(-----*-----)

0 700 1400 2100

Milk = 0.05 subtracted from:

Milk	Lower	Center	Upper
0.10	-9.159	722.0	1453

-----+-----+-----+-----
 (-----*-----)
 -----+-----+-----+-----
 0 700 1400 2100

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.26	10	1852.0	A
5.66	9	1820.9	A
5.46	8	842.7	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Chewiness

All Pairwise Comparisons among Levels of pH

pH = 5.26 subtracted from:

pH	Lower	Center	Upper
5.46	-1731	-1009	-287.6
5.66	-742	-31	679.9

-----+-----+-----+-----
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----
 -1000 0 1000

pH = 5.46 subtracted from:

pH	Lower	Center	Upper
5.66	236.1	978.2	1720

-----+-----+-----+-----
 (-----*-----)
 -----+-----+-----+-----
 -1000 0 1000

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
0.10	5.66	2	3768.7	A
0.05	5.26	3	2824.3	A B
0.10	5.26	3	2005.5	A B C
0.10	5.46	3	1308.6	B C
0.05	5.46	3	1049.1	C
0.05	5.66	3	1043.4	C
0.01	5.26	4	726.3	C
0.01	5.66	4	650.7	C
0.01	5.46	2	170.5	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Chewiness

All Pairwise Comparisons among Levels of Milk*pH

Milk = 0.01

pH = 5.26 subtracted from:

Milk = 0.01
pH = 5.46 subtracted from:

Milk = 0.01
pH = 5.66 subtracted from:

Milk = 0.05
pH = 5.26 subtracted from:

pH = 5.46 subtracted from:

Milk = 0.05

pH = 5.66 subtracted from:

Milk = 0.10

pH = 5.26 subtracted from:

Milk = 0.10

pH = 5.46 subtracted from:

Milk	pH	Lower	Center	Upper	
0.10	5.66	570.5	2460	4350	(-----*-----)
					-2500 0 2500 5000

General Linear Model: Fat versus DAY, Milk, pH

Factor	Type	Levels	Values
DAY	random	3	1, 2, 3
Milk	fixed	3	0.01, 0.05, 0.10
pH	fixed	3	5.26, 5.46, 5.66

Analysis of Variance for Fat, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
DAY	2	9.180	4.401	2.201	0.67	0.524
Milk	2	6.144	2.905	1.453	0.44	0.649
pH	2	53.209	45.718	22.859	6.99	0.007
Milk*pH	4	15.796	15.796	3.949	1.21	0.346
Error	16	52.289	52.289	3.268		
Total	26	136.618				

S = 1.80779 R-Sq = 61.73% R-Sq(adj) = 37.80%

Unusual Observations for Fat

Obs	Fat	Fit	SE Fit	Residual	St Resid
4	13.5000	10.2755	1.1727	3.2245	2.34 R
6	7.3000	10.5143	1.1727	-3.2143	-2.34 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
0.01	10	10.0	A
0.10	8	9.4	A
0.05	9	9.2	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Fat

All Pairwise Comparisons among Levels of Milk
Milk = 0.01 subtracted from:

Milk	Lower	Center	Upper	
0.05	-2.971	-0.7630	1.445	(-----*-----)
0.10	-2.908	-0.6166	1.675	(-----*-----)

-3.0 -1.5 0.0 1.5

Milk = 0.05 subtracted from:

Milk	Lower	Center	Upper	
0.10	-2.154	0.1464	2.447	(-----*-----)

-3.0 -1.5 0.0 1.5

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.26	10	11.4	A
5.46	8	8.9	B
5.66	9	8.3	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Fat

All Pairwise Comparisons among Levels of pH

pH = 5.26 subtracted from:

pH	Lower	Center	Upper
5.46	-4.685	-2.414	-0.1424
5.66	-5.293	-3.055	-0.8180

-----+-----+-----+-----+
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----+
 -4.0 -2.0 0.0 2.0

pH = 5.46 subtracted from:

pH	Lower	Center	Upper
5.66	-2.977	-0.6419	1.693

-----+-----+-----+-----+
 (-----*-----)
 -----+-----+-----+-----+
 -4.0 -2.0 0.0 2.0

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
0.01	5.26	4	13.3	A
0.10	5.26	3	10.5	A B
0.05	5.26	3	10.3	A B
0.05	5.46	3	9.4	A B
0.10	5.46	3	8.9	A B
0.10	5.66	2	8.7	A B
0.01	5.46	2	8.5	A B
0.01	5.66	4	8.2	B
0.05	5.66	3	8.0	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Fat

All Pairwise Comparisons among Levels of Milk*pH

Milk = 0.01

pH = 5.26 subtracted from:

Milk	pH	Lower	Center	Upper
0.01	5.46	-10.52	-4.768	0.9798
0.01	5.66	-9.66	-5.044	-0.4286
0.05	5.26	-7.91	-2.981	1.9527
0.05	5.46	-8.76	-3.831	1.1027
0.05	5.66	-10.22	-5.289	-0.3556
0.10	5.26	-7.68	-2.742	2.1916
0.10	5.46	-9.30	-4.364	0.5694
0.10	5.66	-10.30	-4.556	1.1923

+-----+-----+-----+-----+
 (-----*-----)
 (-----*-----)
 (-----*-----)
 (-----*-----)
 (-----*-----)
 (-----*-----)
 (-----*-----)
 (-----*-----)
 +-----+-----+-----+-----+
 -10.0 -5.0 0.0 5.0

Milk = 0.01

pH = 5.46 subtracted from:

Milk = 0.01

pH = 5.66 subtracted from:

Milk = 0.05

pH = 5.26 subtracted from:

Milk = 0.05

pH = 5.46 subtracted from:

Milk = 0.05

pH = 5.66 subtracted from:

Milk = 0.10
 pH = 5.26 subtracted from:

Milk = 0.10
 pH = 5.46 subtracted from:

General Linear Model: Moisture versus DAY, Milk, pH

Factor	Type	Levels	Values
DAY	random	3	1, 2, 3
Milk	fixed	3	0.01, 0.05, 0.10
pH	fixed	3	5.26, 5.46, 5.66

Analysis of Variance for Moisture, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
DAY	2	25.081	8.502	4.251	0.43	0.655
Milk	2	40.301	30.885	15.443	1.58	0.237
pH	2	13.436	11.063	5.531	0.56	0.579
Milk*pH	4	47.702	47.702	11.925	1.22	0.342
Error	16	156.722	156.722	9.795		
Total	26	283.242				

S = 3.12972 R-Sq = 44.67% R-Sq(adj) = 10.09%

Unusual Observations for Moisture

Obs	Moisture	Fit	SE Fit	Residual	St Resid
4	64.8700	69.7685	2.0303	-4.8985	-2.06 R
5	75.8800	70.9567	1.9962	4.9233	2.04 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
0.10	8	72.3	A
0.05	9	69.9	A
0.01	10	69.9	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Moisture

All Pairwise Comparisons among Levels of Milk

Milk = 0.01 subtracted from:

Milk	Lower	Center	Upper	
0.05	-3.787	0.03534	3.858	(-----*-----)
0.10	-1.552	2.41565	6.383	(-----*-----)

-3.0 0.0 3.0 6.0

Milk = 0.05 subtracted from:

Milk	Lower	Center	Upper	
0.10	-1.603	2.380	6.364	(-----*-----)

-3.0 0.0 3.0 6.0

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.46	8	71.4	A
5.66	9	70.8	A
5.26	10	69.8	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Moisture

All Pairwise Comparisons among Levels of pH

pH = 5.26 subtracted from:

pH	Lower	Center	Upper	
5.46	-2.338	1.5941	5.526	(-----*-----)
5.66	-2.898	0.9751	4.849	(-----*-----)

-3.0 0.0 3.0 6.0

pH = 5.46 subtracted from:

pH	Lower	Center	Upper	
5.66	-4.662	-0.6190	3.424	(-----*-----)

-3.0 0.0 3.0 6.0

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
0.10	5.46	3	72.8	A
0.10	5.26	3	72.4	A
0.01	5.46	2	71.9	A
0.10	5.66	2	71.7	A
0.01	5.66	4	71.2	A
0.05	5.26	3	70.6	A
0.05	5.46	3	69.6	A
0.05	5.66	3	69.5	A
0.01	5.26	4	66.5	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Moisture

All Pairwise Comparisons among Levels of Milk*pH

Milk = 0.01

pH = 5.26 subtracted from:

Milk	pH	Lower	Center	Upper	
0.01	5.46	-4.555	5.396	15.35	(-----*-----)
0.01	5.66	-3.230	4.761	12.75	(-----*-----)
0.05	5.26	-4.401	4.141	12.68	(-----*-----)
0.05	5.46	-5.432	3.109	11.65	(-----*-----)
0.05	5.66	-5.528	3.013	11.56	(-----*-----)
0.10	5.26	-2.643	5.898	14.44	(-----*-----)
0.10	5.46	-2.226	6.316	14.86	(-----*-----)
0.10	5.66	-4.761	5.190	15.14	(-----*-----)

-----+-----+-----+-----+
-8.0 0.0 8.0 16.0

Milk = 0.01

pH = 5.46 subtracted from:

Milk	pH	Lower	Center	Upper	
0.01	5.66	-10.38	-0.635	9.107	(-----*-----)
0.05	5.26	-11.55	-1.256	9.039	(-----*-----)
0.05	5.46	-12.58	-2.287	8.007	(-----*-----)
0.05	5.66	-12.68	-2.383	7.911	(-----*-----)
0.10	5.26	-9.79	0.502	10.796	(-----*-----)
0.10	5.46	-9.37	0.919	11.214	(-----*-----)
0.10	5.66	-11.34	-0.206	10.925	(-----*-----)

-----+-----+-----+-----+
-8.0 0.0 8.0 16.0

Milk = 0.01

pH = 5.66 subtracted from:

Milk	pH	Lower	Center	Upper	
0.05	5.26	-9.16	-0.620	7.915	(-----*-----)
0.05	5.46	-10.19	-1.652	6.883	(-----*-----)
0.05	5.66	-10.28	-1.748	6.788	(-----*-----)
0.10	5.26	-7.40	1.137	9.673	(-----*-----)
0.10	5.46	-6.98	1.555	10.090	(-----*-----)
0.10	5.66	-9.31	0.429	10.171	(-----*-----)

-----+-----+-----+-----+
-8.0 0.0 8.0 16.0

Milk = 0.05

pH = 5.26 subtracted from:

Milk	pH	Lower	Center	Upper	
0.05	5.46	-10.12	-1.032	8.057	(-----*-----)
0.05	5.66	-10.22	-1.127	7.961	(-----*-----)
0.10	5.26	-7.33	1.758	10.846	(-----*-----)
0.10	5.46	-6.91	2.175	11.264	(-----*-----)
0.10	5.66	-9.24	1.049	11.343	(-----*-----)

-----+-----+-----+-----+
-8.0 0.0 8.0 16.0

Milk = 0.05

pH = 5.46 subtracted from:

Milk	pH	Lower	Center	Upper	
0.05	5.66	-9.185	-0.09583	8.993	(-----*-----)
0.10	5.26	-6.300	2.78917	11.878	(-----*-----)
0.10	5.46	-5.882	3.20667	12.296	(-----*-----)
0.10	5.66	-8.213	2.08093	12.375	(-----*-----)

-----+-----+-----+-----+
-8.0 0.0 8.0 16.0

Milk = 0.05

pH = 5.66 subtracted from:

Milk	pH	Lower	Center	Upper	
0.10	5.26	-6.204	2.885	11.97	(-----*-----)
0.10	5.46	-5.786	3.302	12.39	(-----*-----)
0.10	5.66	-8.117	2.177	12.47	(-----*-----)

-----+-----+-----+-----+
-8.0 0.0 8.0 16.0

Milk = 0.10

pH = 5.26 subtracted from:

Milk	pH	Lower	Center	Upper	
0.10	5.46	-8.67	0.4175	9.506	(-----*-----)
0.10	5.66	-11.00	-0.7082	9.586	(-----*-----)

-----+-----+-----+-----+
-8.0 0.0 8.0 16.0

Milk = 0.10

pH = 5.46 subtracted from:

Milk	pH	Lower	Center	Upper	
0.10	5.66	-11.42	-1.126	9.168	(-----*-----)

-----+-----+-----+-----+
-8.0 0.0 8.0 16.0

Milk = 10 subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
4.60	12	2330.8	A
5.15	12	2087.8	A B
5.60	12	1254.2	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Hardness

All Pairwise Comparisons among Levels of pH

pH = 4.60 subtracted from:

pH = 5.15 subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
15	4.60	4	3099.9	A
15	5.15	4	2958.2	A
10	4.60	4	2854.5	A B
10	5.15	4	1719.9	A B
5	5.15	4	1585.2	A B
15	5.60	4	1566.5	A B
10	5.60	4	1347.2	A B
5	4.60	4	1038.0	A B
5	5.60	4	848.8	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Hardness

All Pairwise Comparisons among Levels of Milk*pH

Milk = 5

pH = 4.60 subtracted from:

Milk = 5
pH = 5.15 subtracted from:

Milk = 5
pH = 5.60 subtracted from:

Milk = 10
pH = 4.60 subtracted from:

Milk = 10
pH = 5.15 subtracted from:

Milk	pH	Lower	Center	Upper
10	5.60	-2471	-372.7	1726
15	4.60	-719	1380.0	3479
15	5.15	-861	1238.2	3337
15	5.60	-2252	-153.4	1945

-----+-----+-----+-----+-----+
 (-----*-----)
 (-----*-----)
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----+-----+
 -2500 0 2500 5000

Milk = 10
 pH = 5.60 subtracted from:

Milk	pH	Lower	Center	Upper
15	4.60	-346	1752.7	3851
15	5.15	-488	1610.9	3710
15	5.60	-1879	219.3	2318

-----+-----+-----+-----+-----+
 (-----*-----)
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----+-----+
 -2500 0 2500 5000

Milk = 15
 pH = 4.60 subtracted from:

Milk	pH	Lower	Center	Upper
15	5.15	-2241	-142	1957.0
15	5.60	-3632	-1533	565.4

-----+-----+-----+-----+-----+
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----+-----+
 -2500 0 2500 5000

Milk = 15
 pH = 5.15 subtracted from:

Milk	pH	Lower	Center	Upper
15	5.60	-3490	-1392	707.1

-----+-----+-----+-----+-----+
 (-----*-----)
 -----+-----+-----+-----+-----+
 -2500 0 2500 5000

General Linear Model: Springiness versus Milk, pH, Day

Factor	Type	Levels	Values
Milk	fixed	3	5, 10, 15
pH	fixed	3	4.60, 5.15, 5.60
Day	random	4	1, 2, 3, 4

Analysis of Variance for Springiness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Milk	2	8.754	8.754	4.377	4.37	0.024
pH	2	1.732	1.732	0.866	0.86	0.434
Day	3	2.105	2.105	0.702	0.70	0.561
Milk*pH	4	3.515	3.515	0.879	0.88	0.492
Error	24	24.048	24.048	1.002		
Total	35	40.154				

S = 1.00100 R-Sq = 40.11% R-Sq(adj) = 12.66%

Unusual Observations for Springiness

Obs	Springiness	Fit	SE Fit	Residual	St Resid
6	3.54333	5.84141	0.57793	-2.29808	-2.81 R
32	8.65333	6.84794	0.57793	1.80539	2.21 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
15	12	7.0	A
10	12	6.2	A B
5	12	5.8	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Springiness

All Pairwise Comparisons among Levels of Milk

Milk = 5 subtracted from:

Milk	Lower	Center	Upper	
10	-0.6676	0.3525	1.373	(-----+-----+-----+-----)
15	0.1567	1.1768	2.197	(-----*-----)
				(-----*-----)
				(-----+-----+-----+-----)
				0.00 0.80 1.60

Milk = 10 subtracted from:

Milk	Lower	Center	Upper	
15	-0.1958	0.8243	1.844	(-----+-----+-----+-----)
				(-----*-----)
				(-----+-----+-----+-----)
				0.00 0.80 1.60

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.15	12	6.5	A
4.60	12	6.4	A
5.60	12	6.0	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Springiness

All Pairwise Comparisons among Levels of pH

pH = 4.60 subtracted from:

pH	Lower	Center	Upper	
5.15	-0.931	0.0894	1.1095	(-----+-----+-----+-----)
5.60	-1.434	-0.4141	0.6059	(-----*-----)

-0.80 0.00 0.80

pH = 5.15 subtracted from:

pH	Lower	Center	Upper	
5.60	-1.524	-0.5036	0.5165	(-----+-----+-----+-----)
				(-----*-----)

-0.80 0.00 0.80

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
15	4.60	4	7.2	A
15	5.15	4	7.2	A
10	4.60	4	6.6	A
15	5.60	4	6.5	A
5	5.15	4	6.5	A
10	5.60	4	5.9	A
10	5.15	4	5.9	A
5	5.60	4	5.6	A
5	4.60	4	5.4	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Springiness

All Pairwise Comparisons among Levels of Milk*pH

Milk = 5

pH = 4.60 subtracted from:

Milk = 5
pH = 5.15 subtracted from:

Milk = 5
pH = 5.60 subtracted from:

Milk = 10
pH = 4.60 subtracted from:

Milk = 10
pH = 5.15 subtracted from:

Milk = 10
pH = 5.60 subtracted from:

Milk = 15
pH = 4.60 subtracted from:

Milk = 15
pH = 5.15 subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.15	12	0.5	A
5.60	12	0.5	A
4.60	12	0.4	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Cohesiveness

All Pairwise Comparisons among Levels of pH

pH = 4.60 subtracted from:

pH	Lower	Center	Upper
5.15	0.009031	0.05445	0.09988
5.60	0.007059	0.05248	0.09791

-0.040 0.000 0.040 0.080

pH = 5.15 subtracted from:

pH	Lower	Center	Upper
5.60	-0.04740	-0.001972	0.04345

-0.040 0.000 0.040 0.080

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
10	5.15	4	0.5	A
15	5.15	4	0.5	A
5	5.60	4	0.5	A
10	5.60	4	0.5	A
15	5.60	4	0.5	A
15	4.60	4	0.4	A
5	5.15	4	0.4	A
5	4.60	4	0.4	A
10	4.60	4	0.4	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Cohesiveness

All Pairwise Comparisons among Levels of Milk*pH

Milk = 5

pH = 4.60 subtracted from:

Milk	pH	Lower	Center	Upper
5	5.15	-0.0946	0.01260	0.11980
5	5.60	-0.0549	0.05235	0.15955
10	4.60	-0.1229	-0.01566	0.09154
10	5.15	-0.0251	0.08213	0.18933
10	5.60	-0.0550	0.05225	0.15945
15	4.60	-0.0931	0.01408	0.12128
15	5.15	-0.0402	0.06705	0.17425
15	5.60	-0.0559	0.05127	0.15847

-0.12 0.00 0.12 0.24

Milk = 5
pH = 5.15 subtracted from:

Milk	pH	Lower	Center	Upper	
5	5.60	-0.0675	0.03975	0.14696	(-----*-----)
10	4.60	-0.1355	-0.02826	0.07894	(-----*-----)
10	5.15	-0.0377	0.06953	0.17674	(-----*-----)
10	5.60	-0.0676	0.03965	0.14685	(-----*-----)
15	4.60	-0.1057	0.00148	0.10868	(-----*-----)
15	5.15	-0.0528	0.05445	0.16165	(-----*-----)
15	5.60	-0.0685	0.03867	0.14587	(-----*-----)
					-----+-----+-----+-----+-----
					-0.12 0.00 0.12 0.24

Milk = 5
pH = 5.60 subtracted from:

Milk	pH	Lower	Center	Upper	
10	4.60	-0.1752	-0.06801	0.03919	(-----*-----)
10	5.15	-0.0774	0.02978	0.13698	(-----*-----)
10	5.60	-0.1073	-0.00010	0.10710	(-----*-----)
15	4.60	-0.1455	-0.03827	0.06893	(-----*-----)
15	5.15	-0.0925	0.01470	0.12190	(-----*-----)
15	5.60	-0.1083	-0.00109	0.10612	(-----*-----)
					-----+-----+-----+-----+-----
					-0.12 0.00 0.12 0.24

Milk = 10
pH = 4.60 subtracted from:

Milk	pH	Lower	Center	Upper	
10	5.15	-0.00941	0.09779	0.2050	(-----*-----)
10	5.60	-0.03930	0.06791	0.1751	(-----*-----)
15	4.60	-0.07746	0.02974	0.1369	(-----*-----)
15	5.15	-0.02449	0.08271	0.1899	(-----*-----)
15	5.60	-0.04028	0.06693	0.1741	(-----*-----)
					-----+-----+-----+-----+-----
					-0.12 0.00 0.12 0.24

Milk = 10
pH = 5.15 subtracted from:

Milk	pH	Lower	Center	Upper	
10	5.60	-0.1371	-0.02988	0.07732	(-----*-----)
15	4.60	-0.1753	-0.06805	0.03915	(-----*-----)
15	5.15	-0.1223	-0.01508	0.09212	(-----*-----)
15	5.60	-0.1381	-0.03087	0.07634	(-----*-----)
					-----+-----+-----+-----+-----
					-0.12 0.00 0.12 0.24

Milk	pH	Lower	Center	Upper	
15	4.60	-0.1454	-0.03817	0.06904	(-----*-----)
15	5.15	-0.0924	0.01480	0.12201	(-----*-----)
15	5.60	-0.1082	-0.00098	0.10622	(-----*-----)

-0.12 0.00 0.12 0.24

Milk	pH	Lower	Center	Upper	
15	5.15	-0.05423	0.05297	0.1602	(-----*-----)
15	5.60	-0.07002	0.03719	0.1444	(-----*-----)

Milk	pH	Lower	Center	Upper
15	5.60	-0.1230	-0.01578	0.09142

General Linear Model: Gumminess versus Milk, pH, Day

Factor	Type	Levels	Values
Milk	fixed	3	5, 10, 15
pH	fixed	3	4.60, 5.15, 5.60
Day	random	4	1, 2, 3, 4

Analysis of Variance for Gumminess, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Milk	2	2699719	2699719	1349859	8.71	0.001
pH	2	1376653	1376653	688326	4.44	0.023
Day	3	4553308	4553308	1517769	9.79	0.000
Milk*pH	4	556599	556599	139150	0.90	0.481
Error	24	3720590	3720590	155025		
Total	35	12906868				

S = 393.732 R-Sq = 71.17% R-Sq(adj) = 57.96%

Unusual Observations for Gumminess

Obs	Gumminess	Fit	SE Fit	Residual	St Resid
20	1262.26	502.89	227.32	759.38	2.36 R
22	510.95	1384.43	227.32	-873.48	-2.72 R
35	2827.43	2072.37	227.32	755.06	2.35 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
15	12	1187.4	A
10	12	819.0	A B
5	12	517.8	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Gumminess

All Pairwise Comparisons among Levels of Milk

Milk = 5 subtracted from:

Milk	Lower	Center	Upper	
10	-100.0	301.2	702.4	(-----*-----)
15	268.4	669.7	1070.9	(-----*-----)

0 350 700 1050

Milk = 10 subtracted from:

Milk	Lower	Center	Upper	
15	-32.75	368.5	769.7	(-----*-----)

0 350 700 1050

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.15	12	1014.0	A
4.60	12	942.2	A B
5.60	12	568.0	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Gumminess

All Pairwise Comparisons among Levels of pH

pH = 4.60 subtracted from:

pH	Lower	Center	Upper	
5.15	-329.5	71.7	472.95	(-----*-----)
5.60	-775.5	-374.3	26.94	(-----*-----)

-800 -400 0 400

pH = 5.15 subtracted from:

pH	Lower	Center	Upper	
5.60	-847.2	-446.0	-44.79	(-----*-----)

-800 -400 0 400

Milk	pH	N	Mean	Grouping
15	5.15	4	1480.6	A
15	4.60	4	1379.4	A B
10	4.60	4	986.2	A B C
10	5.15	4	871.6	A B C
15	5.60	4	702.3	A B C
5	5.15	4	689.7	A B C
10	5.60	4	599.1	A B C
5	4.60	4	461.1	B C
5	5.60	4	402.5	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Gumminess

All Pairwise Comparisons among Levels of Milk*pH

Milk = 5

pH = 4.60 subtracted from:

Milk	pH	Lower	Center	Upper	
5	5.15	-718	228.57	1175.5	(-----*-----)
5	5.60	-1006	-58.66	888.3	(-----*-----)
10	4.60	-422	525.07	1472.0	(-----*-----)
10	5.15	-536	410.43	1357.4	(-----*-----)
10	5.60	-809	137.96	1084.9	(-----*-----)
15	4.60	-29	918.23	1865.2	(-----*-----)
15	5.15	73	1019.50	1966.4	(-----*-----)
15	5.60	-706	241.15	1188.1	(-----*-----)

Milk = 5

pH = 5.15 subtracted from:

Milk	pH	Lower	Center	Upper	
5	5.60	-1234	-287.2	659.7	(-----*-----)
10	4.60	-650	296.5	1243.4	(-----*-----)
10	5.15	-765	181.9	1128.8	(-----*-----)
10	5.60	-1038	-90.6	856.3	(-----*-----)
15	4.60	-257	689.7	1636.6	(-----*-----)
15	5.15	-156	790.9	1737.9	(-----*-----)
15	5.60	-934	12.6	959.5	(-----*-----)

-1200 0 1200 2400

Milk = 5

pH = 5.60 subtracted from:

Milk	pH	Lower	Center	Upper	
10	4.60	-363.2	583.7	1531	(-----*-----)
10	5.15	-477.8	469.1	1416	(-----*-----)
10	5.60	-750.3	196.6	1144	(-----*-----)
15	4.60	30.0	976.9	1924	(-----*-----)
15	5.15	131.2	1078.2	2025	(-----*-----)
15	5.60	-647.1	299.8	1247	(-----*-----)

Milk = 10
pH = 4.60 subtracted from:

Milk = 10
pH = 5.15 subtracted from:

Milk = 10
pH = 5.60 subtracted from:

Milk = 15
pH = 4.60 subtracted from:

Milk = 15
pH = 5.15 subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.15	12	7054.9	A
4.60	12	6252.9	A B
5.60	12	3652.5	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Chewiness

All Pairwise Comparisons among Levels of pH

pH = 4.60 subtracted from:

pH	Lower	Center	Upper
5.15	-2242	802	3846.5
5.60	-5645	-2600	444.1

-6000 -3000 0 3000

pH = 5.15 subtracted from:

pH	Lower	Center	Upper
5.60	-6447	-3402	-357.9

-6000 -3000 0 3000

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
15	5.15	4	11081.2	A
15	4.60	4	9771.3	A
10	4.60	4	6590.0	A B
10	5.15	4	5165.4	A B
5	5.15	4	4918.2	A B
15	5.60	4	4789.3	A B
10	5.60	4	3928.5	A B
5	4.60	4	2397.5	B
5	5.60	4	2239.8	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Chewiness

All Pairwise Comparisons among Levels of Milk*pH

Milk = 5

pH = 4.60 subtracted from:

Milk	pH	Lower	Center	Upper
5	5.15	-4665	2520.7	9706
5	5.60	-7343	-157.7	7028
10	4.60	-2993	4192.5	11378
10	5.15	-4417	2767.9	9953
10	5.60	-5654	1531.0	8716
15	4.60	188	7373.8	14559
15	5.15	1498	8683.7	15869
15	5.60	-4793	2391.9	9577

-8000 0 8000

Milk = 5
pH = 5.15 subtracted from:

Milk = 5
pH = 5.60 subtracted from:

Milk = 10
pH = 4.60 subtracted from:

Milk = 10
pH = 5.15 subtracted from:

Milk = 10
pH = 5.60 subtracted from:

Milk = 15
 pH = 4.60 subtracted from:

Milk	pH	Lower	Center	Upper	
15	5.15	-5875	1310	8495	(-----*-----)
15	5.60	-12167	-4982	2203	(-----*-----)

-----+-----+-----+-----
 -8000 0 8000

Milk = 15
 pH = 5.15 subtracted from:

Milk	pH	Lower	Center	Upper	
15	5.60	-13477	-6292	893.5	(-----*-----)

-----+-----+-----+-----
 -8000 0 8000

General Linear Model: Adhesiveness versus Milk, pH, Day

Factor	Type	Levels	Values
Milk	fixed	3	5, 10, 15
pH	fixed	3	4.60, 5.15, 5.60
Day	random	4	1, 2, 3, 4

Analysis of Variance for Adhesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Milk	2	358.1	358.1	179.0	0.39	0.679
pH	2	1501.9	1501.9	751.0	1.65	0.213
Day	3	2162.4	2162.4	720.8	1.58	0.219
Milk*pH	4	1308.4	1308.4	327.1	0.72	0.587
Error	24	10917.7	10917.7	454.9		
Total	35	16248.5				

S = 21.3285 R-Sq = 32.81% R-Sq(adj) = 2.01%

Unusual Observations for Adhesiveness

Obs	Adhesiveness	Fit	SE Fit	Residual	St Resid
21	77.9467	42.9647	12.3140	34.9820	2.01 R
28	67.9333	30.2096	12.3140	37.7238	2.17 R
35	16.5200	51.8512	12.3140	-35.3312	-2.03 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
5	12	46.9	A
15	12	42.9	A
10	12	39.2	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Adhesiveness
 All Pairwise Comparisons among Levels of Milk
 Milk = 5 subtracted from:

Milk = 10 subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
5.15	12	51.7	A
5.60	12	40.9	A
4.60	12	36.4	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Adhesiveness
 All Pairwise Comparisons among Levels of pH
 pH = 4.60 subtracted from:

pH = 5.15 subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
15	5.15	4	62.0	A
5	5.60	4	50.9	A
5	5.15	4	47.2	A
10	5.15	4	46.0	A
5	4.60	4	42.6	A
10	5.60	4	40.3	A
15	4.60	4	35.3	A
15	5.60	4	31.4	A
10	4.60	4	31.2	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Adhesiveness
All Pairwise Comparisons among Levels of Milk*pH
Milk = 5
pH = 4.60 subtracted from:

Milk = 5
pH = 5.15 subtracted from:

Milk = 5
pH = 5.60 subtracted from:

Milk = 10
pH = 4.60 subtracted from:

Milk = 10
pH = 5.15 subtracted from:

Milk = 10
pH = 5.60 subtracted from:

Milk = 15
pH = 4.60 subtracted from:

Milk = 15
pH = 5.15 subtracted from:

General Linear Model: Moisture versus Milk, pH, Day

Factor	Type	Levels	Values
Milk	fixed	3	5, 10, 15
pH	fixed	3	4.60, 5.15, 5.60
Day	random	4	1, 2, 3, 4

Analysis of Variance for Moisture, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Milk	2	53.421	53.421	26.711	3.19	0.059
pH	2	5.125	5.125	2.563	0.31	0.739
Day	3	103.896	103.896	34.632	4.14	0.017
Milk*pH	4	61.296	61.296	15.324	1.83	0.156
Error	24	200.716	200.716	8.363		
Total	35	424.454				

S = 2.89191 R-Sq = 52.71% R-Sq(adj) = 31.04%

Unusual Observations for Moisture

Obs	Moisture	Fit	SE Fit	Residual	St Resid
22	81.9650	74.9579	1.6696	7.0071	2.97 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	N	Mean	Grouping
5	12	74.1	A
10	12	71.6	A
15	12	71.5	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Moisture

All Pairwise Comparisons among Levels of Milk

Milk = 5 subtracted from:

Milk	Lower	Center	Upper	
10	-5.466	-2.519	0.4278	(-----*-----)
15	-5.591	-2.645	0.3024	(-----*-----)

-5.0 -2.5 0.0 2.5

Milk = 10 subtracted from:

Milk	Lower	Center	Upper	
15	-3.072	-0.1253	2.822	(-----*-----)

-5.0 -2.5 0.0 2.5

Grouping Information Using Tukey Method and 95.0% Confidence

pH	N	Mean	Grouping
4.60	12	72.9	A
5.60	12	72.3	A
5.15	12	72.1	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Moisture

All Pairwise Comparisons among Levels of pH

pH = 4.60 subtracted from:

pH	Lower	Center	Upper	
5.15	-3.833	-0.8860	2.061	(-----+-----+-----+-----)
5.60	-3.618	-0.6708	2.276	(-----*-----)
				(-----*-----)
				(-----+-----+-----+-----)

-2.0 0.0 2.0

pH = 5.15 subtracted from:

pH	Lower	Center	Upper	
5.60	-2.732	0.2153	3.162	(-----+-----+-----+-----)
				(-----*-----)
				(-----+-----+-----+-----)

-2.0 0.0 2.0

Grouping Information Using Tukey Method and 95.0% Confidence

Milk	pH	N	Mean	Grouping
5	4.60	4	77.0	A
5	5.60	4	73.4	A
15	5.15	4	72.9	A
10	5.60	4	72.5	A
5	5.15	4	72.1	A
10	5.15	4	71.2	A
10	4.60	4	71.2	A
15	5.60	4	71.0	A
15	4.60	4	70.7	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Moisture

All Pairwise Comparisons among Levels of Milk*pH

Milk = 5

pH = 4.60 subtracted from:

Milk	pH	Lower	Center	Upper	
5	5.15	-11.83	-4.872	2.0830	(-----+-----+-----+-----)
5	5.60	-10.54	-3.590	3.3655	(-----*-----)
10	4.60	-12.72	-5.765	1.1905	(-----*-----)
10	5.15	-12.70	-5.746	1.2088	(-----*-----)
10	5.60	-11.46	-4.508	2.4467	(-----*-----)
15	4.60	-13.26	-6.304	0.6511	(-----*-----)
15	5.15	-11.06	-4.108	2.8467	(-----*-----)
15	5.60	-12.94	-5.983	0.9721	(-----*-----)
					(-----+-----+-----+-----)

-7.0 0.0 7.0

Milk = 5
pH = 5.15 subtracted from:

Milk = 5
pH = 5.60 subtracted from:

Milk = 10
pH = 4.60 subtracted from:

Milk = 10
pH = 5.15 subtracted from:

Milk = 10
pH = 5.60 subtracted from:

Milk = 15
pH = 4.60 subtracted from:

Milk	pH	Lower	Center	Upper	
15	5.15	-4.759	2.1956	9.151	(-----*-----)
15	5.60	-6.634	0.3210	7.276	(-----*-----)

-----+-----+-----+-----
-7.0 0.0 7.0

Milk = 15
pH = 5.15 subtracted from:

Milk	pH	Lower	Center	Upper	
15	5.60	-8.830	-1.875	5.080	(-----*-----)

-----+-----+-----+-----
-7.0 0.0 7.0

14.3 RICOTTA PROCESSING MATERIALS AND METHODS

14.3.1. Ricotta Processing Instrumental Texture Output

General Linear Model: Hardness versus Grind, Gum

Factor	Type	Levels	Values
Grind	fixed	4	3 mm, 4:1, 6 mm, Mix
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Hardness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Grind	3	897922	897922	299307	5.44	0.009
Gum	1	87591	87591	87591	1.59	0.225
Grind*Gum	3	166256	166256	55419	1.01	0.415
Error	16	880591	880591	55037		
Total	23	2032359				

S = 234.599 R-Sq = 56.67% R-Sq(adj) = 37.72%

Unusual Observations for Hardness

Obs	Hardness	Fit	SE Fit	Residual	St Resid
23	984.28	1494.96	135.45	-510.68	-2.67 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	N	Mean	Grouping
4:1	6	1588.9	A
Mix	6	1194.2	B
3 mm	6	1175.0	B
6 mm	6	1087.0	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Hardness
 All Pairwise Comparisons among Levels of Grind
 Grind = 3 mm subtracted from:

Grind	Lower	Center	Upper
4:1	26.0	413.88	801.8
6 mm	-475.9	-88.01	299.9
Mix	-368.8	19.12	407.0

-----+-----+-----+-----
 (-----*-----)
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----
 -500 0 500

Grind = 4:1 subtracted from:

Grind	Lower	Center	Upper
6 mm	-889.8	-501.9	-114.0
Mix	-782.6	-394.8	-6.9

-----+-----+-----+-----
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----
 -500 0 500

Grind = 6 mm subtracted from:

Grind	Lower	Center	Upper
Mix	-280.8	107.1	495.0

-----+-----+-----+-----
 (-----*-----)
 -----+-----+-----+-----
 -500 0 500

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
No Gum	12	1321.7	A
Gum	12	1200.9	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Hardness

All Pairwise Comparisons among Levels of Gum

Gum = Gum subtracted from:

Gum	Lower	Center	Upper	
No Gum	-82.21	120.8	323.9	(-----+-----+-----+-----)
				(-----*-----)
				(-----+-----+-----+-----)
				0 120 240

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	Gum	N	Mean	Grouping
4:1	No Gum	3	1682.9	A
4:1	Gum	3	1495.0	A B
Mix	No Gum	3	1351.9	A B
3 mm	No Gum	3	1235.4	A B
6 mm	Gum	3	1157.4	A B
3 mm	Gum	3	1114.7	A B
Mix	Gum	3	1036.4	A B
6 mm	No Gum	3	1016.6	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Hardness

All Pairwise Comparisons among Levels of Grind*Gum

Grind = 3 mm

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
3 mm	No Gum	-543.0	120.64	784.3	(-----+-----+-----+-----)
					(-----*-----)
4:1	Gum	-283.4	380.25	1043.9	(-----+-----+-----+-----)
					(-----*-----)
4:1	No Gum	-95.5	568.15	1231.8	(-----+-----+-----+-----)
					(-----*-----)
6 mm	Gum	-621.0	42.69	706.4	(-----+-----+-----+-----)
					(-----*-----)
6 mm	No Gum	-761.8	-98.08	565.6	(-----+-----+-----+-----)
					(-----*-----)
Mix	Gum	-742.0	-78.32	585.4	(-----+-----+-----+-----)
					(-----*-----)
Mix	No Gum	-426.5	237.20	900.9	(-----+-----+-----+-----)
					(-----*-----)
					(-----+-----+-----+-----)
					-700 0 700

Grind = 3 mm

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
4:1	Gum	-404.1	259.6	923.3	(-----+-----+-----+-----)
					(-----*-----)
4:1	No Gum	-216.2	447.5	1111.2	(-----+-----+-----+-----)
					(-----*-----)
6 mm	Gum	-741.6	-77.9	585.7	(-----+-----+-----+-----)
					(-----*-----)
6 mm	No Gum	-882.4	-218.7	445.0	(-----+-----+-----+-----)
					(-----*-----)
Mix	Gum	-862.6	-199.0	464.7	(-----+-----+-----+-----)
					(-----*-----)
Mix	No Gum	-547.1	116.6	780.3	(-----+-----+-----+-----)
					(-----*-----)
					(-----+-----+-----+-----)
					-700 0 700

Grind = 4:1

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
4:1	No Gum	-476	187.9	851.6	(-----*-----)
6 mm	Gum	-1001	-337.6	326.1	(-----*-----)
6 mm	No Gum	-1142	-478.3	185.4	(-----*-----)
Mix	Gum	-1122	-458.6	205.1	(-----*-----)
Mix	No Gum	-807	-143.0	520.6	(-----*-----)
					-----+-----+-----+-----
					-700 0 700

Grind = 4:1

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
6 mm	Gum	-1189	-525.5	138.226	(-----*-----)
6 mm	No Gum	-1330	-666.2	-2.541	(-----*-----)
Mix	Gum	-1310	-646.5	17.216	(-----*-----)
Mix	No Gum	-995	-330.9	332.739	(-----*-----)
					-----+-----+-----+-----
					-700 0 700

Grind = 6 mm

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
6 mm	No Gum	-804.5	-140.8	522.9	(-----*-----)
Mix	Gum	-784.7	-121.0	542.7	(-----*-----)
Mix	No Gum	-469.2	194.5	858.2	(-----*-----)
					-----+-----+-----+-----
					-700 0 700

Grind = 6 mm

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
Mix	Gum	-643.9	19.76	683.4	(-----*-----)
Mix	No Gum	-328.4	335.28	999.0	(-----*-----)
					-----+-----+-----+-----
					-700 0 700

Grind = Mix

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
Mix	No Gum	-348.2	315.5	979.2	(-----*-----)
					-----+-----+-----+-----
					-700 0 700

General Linear Model: Springiness versus Grind, Gum

Factor	Type	Levels	Values
Grind	fixed	4	3 mm, 4:1, 6 mm, Mix
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Springiness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Grind	3	1.4008	1.4008	0.4669	3.89	0.029
Gum	1	0.8894	0.8894	0.8894	7.40	0.015
Grind*Gum	3	0.2488	0.2488	0.0829	0.69	0.571
Error	16	1.9227	1.9227	0.1202		
Total	23	4.4615				

S = 0.346651 R-Sq = 56.91% R-Sq(adj) = 38.05%

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	N	Mean	Grouping
4:1	6	3.5	A
Mix	6	3.5	A B
6 mm	6	3.4	A B
3 mm	6	2.9	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Springiness
 All Pairwise Comparisons among Levels of Grind
 Grind = 3 mm subtracted from:

Grind	Lower	Center	Upper	
4:1	0.0335	0.6067	1.180	(-----*-----)
6 mm	-0.1115	0.4617	1.035	(-----*-----)
Mix	-0.0082	0.5650	1.138	(-----*-----)

-0.60 0.00 0.60 1.20

Grind = 4:1 subtracted from:

Grind	Lower	Center	Upper	
6 mm	-0.7182	-0.1450	0.4282	(-----*-----)
Mix	-0.6148	-0.0417	0.5315	(-----*-----)

-0.60 0.00 0.60 1.20

Grind = 6 mm subtracted from:

Grind	Lower	Center	Upper	
Mix	-0.4698	0.1033	0.6765	(-----*-----)

-0.60 0.00 0.60 1.20

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
No Gum	12	3.5	A
Gum	12	3.1	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Springiness
 All Pairwise Comparisons among Levels of Gum
 Gum = Gum subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	Gum	N	Mean	Grouping
4:1	No Gum	3	3.8	A
6 mm	No Gum	3	3.7	A B
Mix	No Gum	3	3.5	A B
Mix	Gum	3	3.4	A B
4:1	Gum	3	3.2	A B
6 mm	Gum	3	3.1	A B
3 mm	No Gum	3	3.1	A B
3 mm	Gum	3	2.8	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Springiness
 All Pairwise Comparisons among Levels of Grind*Gum
 Grind = 3 mm
 Gum = Gum subtracted from:

Grind = 3 mm

Gum = No Gum subtracted from:

Grind = 4:1

Gum = Gum subtracted from:

Grind = 4:1

Gum = No Gum subtracted from:

Grind = 6 mm

Gum = Gum subtracted from:

Grind = 6 mm

Gum = No Gum subtracted from:

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper
Mix	No Gum	-0.8973	0.08333	1.064

(-----*-----)

-1.2 0.0 1.2 2.4

General Linear Model: Cohesiveness versus Grind, Gum

Factor	Type	Levels	Values
Grind	fixed	4	3 mm, 4:1, 6 mm, Mix
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Cohesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Grind	3	0.045526	0.045526	0.015175	17.19	0.000
Gum	1	0.048834	0.048834	0.048834	55.33	0.000
Grind*Gum	3	0.011767	0.011767	0.003922	4.44	0.019
Error	16	0.014122	0.014122	0.000883		
Total	23	0.120249				

S = 0.0297087 R-Sq = 88.26% R-Sq(adj) = 83.12%

Unusual Observations for Cohesiveness

Obs	Cohesiveness	Fit	SE Fit	Residual	St Resid
23	0.423517	0.485123	0.017152	-0.061605	-2.54 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	N	Mean	Grouping
4:1	6	0.4	A
Mix	6	0.4	B
6 mm	6	0.3	B
3 mm	6	0.3	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Cohesiveness
 All Pairwise Comparisons among Levels of Grind
 Grind = 3 mm subtracted from:

Grind	Lower	Center	Upper	
4:1	0.06740	0.11652	0.16564	(----*----)
6 mm	-0.02074	0.02838	0.07750	(----*----)
Mix	-0.01733	0.03179	0.08091	(----*----)

-0.10 0.00 0.10 0.20

Grind = 4:1 subtracted from:

Grind	Lower	Center	Upper	
6 mm	-0.1373	-0.08814	-0.03902	(----*----)
Mix	-0.1338	-0.08473	-0.03561	(----*----)

-0.10 0.00 0.10 0.20

Grind = 6 mm subtracted from:

Grind	Lower	Center	Upper	
Mix	-0.04571	0.003412	0.05253	(----*----)

-0.10 0.00 0.10 0.20

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
Gum	12	0.4	A
No Gum	12	0.3	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Cohesiveness
 All Pairwise Comparisons among Levels of Gum
 Gum = Gum subtracted from:

Gum	Lower	Center	Upper	
No Gum	-0.1159	-0.09022	-0.06451	(-----*-----)

-0.105 -0.070 -0.035 0.000

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	Gum	N	Mean	Grouping
4:1	Gum	3	0.5	A
6 mm	Gum	3	0.4	A B
4:1	No Gum	3	0.4	B C
Mix	Gum	3	0.4	B C
3 mm	Gum	3	0.4	B C D
Mix	No Gum	3	0.3	C D E
3 mm	No Gum	3	0.3	D E
6 mm	No Gum	3	0.3	E

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Cohesiveness
 All Pairwise Comparisons among Levels of Grind*Gum
 Grind = 3 mm
 Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper
3 mm	No Gum	-0.1547	-0.07066	0.013390
4:1	Gum	0.0471	0.13111	0.215161
4:1	No Gum	-0.0528	0.03126	0.115309
6 mm	Gum	-0.0132	0.07089	0.154934
6 mm	No Gum	-0.1688	-0.08479	-0.000743
Mix	Gum	-0.0702	0.01380	0.097847
Mix	No Gum	-0.1049	-0.02088	0.063167

Grind	Gum	-----+-----+-----+-----
3 mm	No Gum	(-----*-----)
4:1	Gum	(-----*-----)
4:1	No Gum	(-----*-----)
6 mm	Gum	(-----*-----)
6 mm	No Gum	(-----*-----)
Mix	Gum	(-----*-----)
Mix	No Gum	(-----*-----)
		-----+-----+-----+-----
		-0.16 0.00 0.16

Grind = 3 mm
 Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper
4:1	Gum	0.11772	0.20177	0.28582
4:1	No Gum	0.01787	0.10192	0.18596
6 mm	Gum	0.05750	0.14154	0.22559
6 mm	No Gum	-0.09818	-0.01413	0.06991
Mix	Gum	0.00041	0.08446	0.16850
Mix	No Gum	-0.03427	0.04978	0.13382

Grind	Gum	-----+-----+-----+-----
4:1	Gum	(-----*-----)
4:1	No Gum	(-----*-----)
6 mm	Gum	(-----*-----)
6 mm	No Gum	(-----*-----)
Mix	Gum	(-----*-----)
Mix	No Gum	(-----*-----)
		-----+-----+-----+-----
		-0.16 0.00 0.16

Grind = 4:1

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
4:1	No Gum	-0.1839	-0.0999	-0.0158	(----*----)
6 mm	Gum	-0.1443	-0.0602	0.0238	(----*----)
6 mm	No Gum	-0.3000	-0.2159	-0.1319	(-----*-----)
Mix	Gum	-0.2014	-0.1173	-0.0333	(-----*-----)
Mix	No Gum	-0.2360	-0.1520	-0.0679	(-----*-----)

-----+-----+-----+-----
-0.16 0.00 0.16

Grind = 4:1

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper
6 mm	Gum	-0.0444	0.0396	0.12367
6 mm	No Gum	-0.2001	-0.1161	-0.03201
Mix	Gum	-0.1015	-0.0175	0.06658
Mix	No Gum	-0.1362	-0.0521	0.03190

Grind	Gum	
6 mm	Gum	(----*----)
6 mm	No Gum	(-----*-----)
Mix	Gum	(----*----)
Mix	No Gum	(-----*-----)

-----+-----+-----+-----
-0.16 0.00 0.16

Grind = 6 mm

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper
6 mm	No Gum	-0.2397	-0.1557	-0.07163
Mix	Gum	-0.1411	-0.0571	0.02696
Mix	No Gum	-0.1758	-0.0918	-0.00772

Grind	Gum	
6 mm	No Gum	(----*----)
Mix	Gum	(----*----)
Mix	No Gum	(----*----)

-----+-----+-----+-----
-0.16 0.00 0.16

Grind = 6 mm

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
Mix	Gum	0.01454	0.09859	0.1826	(----*----)
Mix	No Gum	-0.02014	0.06391	0.1480	(----*----)

-----+-----+-----+-----
-0.16 0.00 0.16

Grind = Mix

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper
Mix	No Gum	-0.1187	-0.03468	0.04937

General Linear Model: Gumminess versus Grind, Gum

Factor	Type	Levels	Values
Grind	fixed	4	3 mm, 4:1, 6 mm, Mix
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Gumminess, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Grind	3	431875	431875	143958	9.60	0.001
Gum	1	29051	29051	29051	1.94	0.183
Grind*Gum	3	61479	61479	20493	1.37	0.289
Error	16	240015	240015	15001		
Total	23	762420				

S = 122.478 R-Sq = 68.52% R-Sq(adj) = 54.75%

Unusual Observations for Gumminess

Obs	Gumminess	Fit	SE Fit	Residual	St Resid
23	416.860	740.845	70.713	-323.985	-3.24 R
24	958.257	740.845	70.713	217.412	2.17 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	N	Mean	Grouping
4:1	6	697.2	A
Mix	6	415.6	B
6 mm	6	383.4	B
3 mm	6	370.4	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Gumminess

All Pairwise Comparisons among Levels of Grind

Grind = 3 mm subtracted from:

Grind	Lower	Center	Upper	
4:1	124.3	326.83	529.3	(-----*-----)
6 mm	-189.6	12.95	215.5	(-----*-----)
Mix	-157.4	45.15	247.7	(-----*-----)

-----+-----+-----+-----
-300 0 300

Grind = 4:1 subtracted from:

Grind	Lower	Center	Upper	
6 mm	-516.4	-313.9	-111.4	(-----*-----)
Mix	-484.2	-281.7	-79.2	(-----*-----)

-----+-----+-----+-----
-300 0 300

Grind = 6 mm subtracted from:

Grind	Lower	Center	Upper	
Mix	-170.3	32.20	234.7	(-----*-----)
				-----+-----+-----+-----+
				-300 0 300

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
Gum	12	501.4	A
No Gum	12	431.9	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Gumminess

All Pairwise Comparisons among Levels of Gum

Gum = Gum subtracted from:

Gum	Lower	Center	Upper	
No Gum	-175.6	-69.58	36.42	(-----*-----)
				-----+-----+-----+-----+
				-120 -60 0

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	Gum	N	Mean	Grouping
4:1	Gum	3	740.8	A
4:1	No Gum	3	653.6	A B
6 mm	Gum	3	490.3	A B C
Mix	No Gum	3	450.4	A B C
3 mm	Gum	3	393.9	B C
Mix	Gum	3	380.8	B C
3 mm	No Gum	3	346.9	B C
6 mm	No Gum	3	276.5	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Gumminess

All Pairwise Comparisons among Levels of Grind*Gum

Grind = 3 mm

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
3 mm	No Gum	-393.4	-46.9	299.5	(-----*-----)
4:1	Gum	0.5	347.0	693.5	(-----*-----)
4:1	No Gum	-86.7	259.7	606.2	(-----*-----)
6 mm	Gum	-250.1	96.4	442.9	(-----*-----)
6 mm	No Gum	-463.9	-117.4	229.1	(-----*-----)
Mix	Gum	-359.6	-13.1	333.4	(-----*-----)
Mix	No Gum	-290.0	56.5	403.0	(-----*-----)
					-----+-----+-----+-----+
					-500 0 500 1000

Grind = 3 mm

Gum = No Gum subtracted from:

Grind = 4:1

Gum = Gum subtracted from:

Grind = 4:1

Gum = No Gum subtracted from:

Grind = 6 mm

Gum = Gum subtracted from:

Grind = 6 mm

Gum = No Gum subtracted from:

Grind = Mix

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper
Mix	No Gum	-276.9	69.60	416.1

-----+-----+-----+-----+
(-----*-----)
-----+-----+-----+-----+
-500 0 500 1000

General Linear Model: Chewiness versus Grind, Gum

Factor	Type	Levels	Values
Grind	fixed	4	3 mm, 4:1, 6 mm, Mix
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Chewiness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Grind	3	6863172	6863172	2287724	11.23	0.000
Gum	1	36922	36922	36922	0.18	0.676
Grind*Gum	3	499897	499897	166632	0.82	0.503
Error	16	3258343	3258343	203646		
Total	23	10658334				

S = 451.272 R-Sq = 69.43% R-Sq(adj) = 56.05%

Unusual Observations for Chewiness

Obs	Chewiness	Fit	SE Fit	Residual	St Resid
23	1138.03	2471.71	260.54	-1333.68	-3.62 R
24	3277.24	2471.71	260.54	805.53	2.19 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	N	Mean	Grouping
4:1	6	2455.4	A
Mix	6	1449.5	B
6 mm	6	1248.6	B
3 mm	6	1077.3	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Chewiness
 All Pairwise Comparisons among Levels of Grind
 Grind = 3 mm subtracted from:

Grind	Lower	Center	Upper	
4:1	631.9	1378.1	2124.2	(-----*-----)
6 mm	-574.9	171.3	917.4	(-----*-----)
Mix	-374.0	372.1	1118.3	(-----*-----)

-----+-----+-----+-----+
 -1200 0 1200 2400

Grind = 4:1 subtracted from:

Grind	Lower	Center	Upper	
6 mm	-1953	-1207	-460.6	(-----*-----)
Mix	-1752	-1006	-259.8	(-----*-----)

-----+-----+-----+-----+
 -1200 0 1200 2400

Grind = 6 mm subtracted from:

Grind	Lower	Center	Upper	
Mix	-545.3	200.9	947.0	(-----*-----)

-----+-----+-----+-----+
 -1200 0 1200 2400

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
Gum	12	1596.9	A
No Gum	12	1518.5	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Chewiness
 All Pairwise Comparisons among Levels of Gum
 Gum = Gum subtracted from:

Gum	Lower	Center	Upper	
No Gum	-469.0	-78.45	312.1	(-----*-----)

-----+-----+-----+-----+
 -250 0 250

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	Gum	N	Mean	Grouping
4:1	Gum	3	2471.7	A
4:1	No Gum	3	2439.1	A
Mix	No Gum	3	1583.8	A B
6 mm	Gum	3	1515.2	A B
Mix	Gum	3	1315.2	A B
3 mm	Gum	3	1085.5	B
3 mm	No Gum	3	1069.1	B
6 mm	No Gum	3	981.9	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Chewiness

All Pairwise Comparisons among Levels of Grind*Gum

Grind = 3 mm

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
3 mm	No Gum	-1293	-16.4	1260	(-----*-----)
4:1	Gum	110	1386.2	2663	(-----*-----)
4:1	No Gum	77	1353.5	2630	(-----*-----)
6 mm	Gum	-847	429.7	1706	(-----*-----)
6 mm	No Gum	-1380	-103.6	1173	(-----*-----)
Mix	Gum	-1047	229.6	1506	(-----*-----)
Mix	No Gum	-778	498.2	1775	(-----*-----)

-1500 0 1500

Grind = 3 mm

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
4:1	Gum	126	1402.60	2679	(-----*-----)
4:1	No Gum	93	1369.95	2647	(-----*-----)
6 mm	Gum	-831	446.14	1723	(-----*-----)
6 mm	No Gum	-1364	-87.16	1189	(-----*-----)
Mix	Gum	-1031	246.07	1523	(-----*-----)
Mix	No Gum	-762	514.65	1791	(-----*-----)

-1500 0 1500

Grind = 4:1

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
4:1	No Gum	-1309	-33	1244.0	(-----*-----)
6 mm	Gum	-2233	-956	320.2	(-----*-----)
6 mm	No Gum	-2766	-1490	-213.1	(-----*-----)
Mix	Gum	-2433	-1157	120.1	(-----*-----)
Mix	No Gum	-2165	-888	388.7	(-----*-----)

-1500 0 1500

Grind = 4:1

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
6 mm	Gum	-2200	-924	352.8	(-----*-----)
6 mm	No Gum	-2734	-1457	-180.5	(-----*-----)
Mix	Gum	-2401	-1124	152.8	(-----*-----)
Mix	No Gum	-2132	-855	421.4	(-----*-----)
					-----+-----+-----+-----
					-1500 0 1500

Grind = 6 mm

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
6 mm	No Gum	-1810	-533.3	743.4	(-----*-----)
Mix	Gum	-1477	-200.1	1076.6	(-----*-----)
Mix	No Gum	-1208	68.5	1345.2	(-----*-----)
					-----+-----+-----+-----
					-1500 0 1500

Grind = 6 mm

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
Mix	Gum	-943.4	333.2	1610	(-----*-----)
Mix	No Gum	-674.8	601.8	1878	(-----*-----)
					-----+-----+-----+-----
					-1500 0 1500

Grind = Mix

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----
Mix	No Gum	-1008	268.6	1545	(-----*-----)
					-----+-----+-----+-----
					-1500 0 1500

General Linear Model: Adhesiveness versus Grind, Gum

Factor	Type	Levels	Values
Grind	fixed	4	3 mm, 4:1, 6 mm, Mix
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Adhesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Grind	3	81061	81061	27020	2.46	0.100
Gum	1	1131187	1131187	1131187	103.00	0.000
Grind*Gum	3	83205	83205	27735	2.53	0.094
Error	16	175711	175711	10982		
Total	23	1471164				

S = 104.795 R-Sq = 88.06% R-Sq(adj) = 82.83%

Unusual Observations for Adhesiveness

Obs	Adhesiveness	Fit	SE Fit	Residual	St Resid
23	390.900	673.827	60.503	-282.927	-3.31 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	N	Mean	Grouping
4:1	6	368.5	A
Mix	6	275.7	A
6 mm	6	263.0	A
3 mm	6	206.7	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Adhesiveness

All Pairwise Comparisons among Levels of Grind

Grind = 3 mm subtracted from:

Grind	Lower	Center	Upper	
4:1	-11.4	161.85	335.1	(-----*-----)
6 mm	-116.9	56.35	229.6	(-----*-----)
Mix	-104.2	69.08	242.3	(-----*-----)

-----+-----+-----+-----+-----+-----+-----
 -200 0 200 400

Grind = 4:1 subtracted from:

Grind	Lower	Center	Upper	
6 mm	-278.8	-105.5	67.77	(-----*-----)
Mix	-266.0	-92.8	80.50	(-----*-----)

-----+-----+-----+-----+-----+-----+-----
 -200 0 200 400

Grind = 6 mm subtracted from:

Grind	Lower	Center	Upper
Mix	-160.5	12.73	186.0

(-----*-----)

-200 0 200 400

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
Gum	12	495.6	A
No Gum	12	61.4	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Adhesiveness
All Pairwise Comparisons among Levels of Gum
Gum = Gum subtracted from:

Gum	Lower	Center	Upper
No Gum	-524.9	-434.2	-343.5

(-----*-----)

-450 -300 -150 0

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	Gum	N	Mean	Grouping
4:1	Gum	3	673.8	A
Mix	Gum	3	494.0	A B
6 mm	Gum	3	467.8	A B
3 mm	Gum	3	346.7	B C
3 mm	No Gum	3	66.6	C
4:1	No Gum	3	63.2	C
6 mm	No Gum	3	58.3	C
Mix	No Gum	3	57.5	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Adhesiveness
All Pairwise Comparisons among Levels of Grind*Gum
Grind = 3 mm
Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper
3 mm	No Gum	-576.6	-280.2	16.306
4:1	Gum	30.6	327.1	623.549
4:1	No Gum	-580.0	-283.5	12.923
6 mm	Gum	-175.4	121.0	417.493
6 mm	No Gum	-584.9	-288.5	7.986
Mix	Gum	-149.2	147.3	443.723
Mix	No Gum	-585.7	-289.3	7.209

(-----*-----) (-----*-----)
(-----*-----) (-----*-----)
(-----*-----) (-----*-----)
(-----*-----)

-500 0 500

Grind = 3 mm

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
4:1	Gum	310.8	607.243	903.7	(-----*-----)
4:1	No Gum	-299.8	-3.383	293.1	(-----*-----)
6 mm	Gum	104.7	401.187	697.7	(-----*-----)
6 mm	No Gum	-304.8	-8.320	288.1	(-----*-----)
Mix	Gum	131.0	427.417	723.9	(-----*-----)
Mix	No Gum	-305.6	-9.097	287.4	(-----*-----)
					-----+-----+-----+-----
					-500 0 500

Grind = 4:1

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
4:1	No Gum	-907.1	-610.6	-314.2	(-----*-----)
6 mm	Gum	-502.5	-206.1	90.4	(-----*-----)
6 mm	No Gum	-912.0	-615.6	-319.1	(-----*-----)
Mix	Gum	-476.3	-179.8	116.6	(-----*-----)
Mix	No Gum	-912.8	-616.3	-319.9	(-----*-----)
					-----+-----+-----+-----
					-500 0 500

Grind = 4:1

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
6 mm	Gum	108.1	404.570	701.0	(-----*-----)
6 mm	No Gum	-301.4	-4.937	291.5	(-----*-----)
Mix	Gum	134.3	430.800	727.3	(-----*-----)
Mix	No Gum	-302.2	-5.713	290.8	(-----*-----)
					-----+-----+-----+-----
					-500 0 500

Grind = 6 mm

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
6 mm	No Gum	-706.0	-409.5	-113.0	(-----*-----)
Mix	Gum	-270.2	26.2	322.7	(-----*-----)
Mix	No Gum	-706.7	-410.3	-113.8	(-----*-----)
					-----+-----+-----+-----
					-500 0 500

Grind = 6 mm

Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
Mix	Gum	139.3	435.737	732.2	(-----*-----)
Mix	No Gum	-297.2	-0.777	295.7	(-----*-----)
					-----+-----+-----+-----
					-500 0 500

Grind = Mix

Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	
Mix	No Gum	-733.0	-436.5	-140.0	(-----*-----)

-----+-----+-----+-----
-500 0 500

General Linear Model: Moisture1 versus Grind, Gum

Factor	Type	Levels	Values
Grind	fixed	4	3 mm, 4:1, 6 mm, Mix
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Moisture1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Grind	3	5.5566	5.5566	1.8522	11.92	0.000
Gum	1	13.9766	13.9766	13.9766	89.98	0.000
Grind*Gum	3	1.0941	1.0941	0.3647	2.35	0.111
Error	16	2.4853	2.4853	0.1553		
Total	23	23.1125				

S = 0.394117 R-Sq = 89.25% R-Sq(adj) = 84.54%

Unusual Observations for Moisture1

Obs	Moisture1	Fit	SE Fit	Residual	St Resid
22	72.4000	71.4050	0.2275	0.9950	3.09 R
23	70.4100	71.4050	0.2275	-0.9950	-3.09 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind	N	Mean	Grouping
4:1	6	70.7	A
Mix	6	69.6	B
6 mm	6	69.6	B
3 mm	6	69.5	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Moisture1
 All Pairwise Comparisons among Levels of Grind
 Grind = 3 mm subtracted from:

Grind	Lower	Center	Upper	
4:1	0.5409	1.1925	1.8441	(-----*-----)
6 mm	-0.5191	0.1325	0.7841	(-----*-----)
Mix	-0.5191	0.1325	0.7841	(-----*-----)

-----+-----+-----+-----
 -1.0 0.0 1.0

Grind = 4:1 subtracted from:

Grind	Lower	Center	Upper	
6 mm	-1.712	-1.060	-0.4084	(-----*-----)
Mix	-1.712	-1.060	-0.4084	(-----*-----)

-----+-----+-----+-----
 -1.0 0.0 1.0

Grind = 6 mm subtracted from:

Grind	Lower	Center	Upper	
Mix	-0.6516	0.000000	0.6516	(-----*-----)

-----+-----+-----+-----
 -1.0 0.0 1.0

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
Gum	12	70.6	A
No Gum	12	69.1	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Moisture1
 All Pairwise Comparisons among Levels of Gum
 Gum = Gum subtracted from:

Gum	Lower	Center	Upper	
No Gum	-1.867	-1.526	-1.185	(-----*-----)

-+-----+-----+-----+-----
 -1.80 -1.20 -0.60 0.00

Grind	Gum	N	Mean	Grouping
4:1	Gum	3	71.4	A
3 mm	Gum	3	70.5	A B
6 mm	Gum	3	70.5	A B
Mix	Gum	3	70.1	B C
4:1	No Gum	3	70.0	B C
Mix	No Gum	3	69.2	C D
6 mm	No Gum	3	68.8	D
3 mm	No Gum	3	68.5	D

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Moisture1
All Pairwise Comparisons among Levels of Grind*Gum
Grind = 3 mm
Gum = Gum subtracted from:

Grind = 4:1
 Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----+-
6 mm	Gum	-0.595	0.520	1.63496	(---*---)
6 mm	No Gum	-2.315	-1.200	-0.08504	(---*---)
Mix	Gum	-1.010	0.105	1.21996	(---*---)
Mix	No Gum	-1.900	-0.785	0.32996	(---*---)
					-----+-----+-----+-----+-
					-2.5 0.0 2.5 5.0

Grind = 6 mm
 Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----+-
6 mm	No Gum	-2.835	-1.720	-0.6050	(---*---)
Mix	Gum	-1.530	-0.415	0.7000	(---*---)
Mix	No Gum	-2.420	-1.305	-0.1900	(---*---)
					-----+-----+-----+-----+-
					-2.5 0.0 2.5 5.0

Grind = 6 mm
 Gum = No Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----+-
Mix	Gum	0.1900	1.3050	2.420	(---*---)
Mix	No Gum	-0.7000	0.4150	1.530	(---*---)
					-----+-----+-----+-----+-
					-2.5 0.0 2.5 5.0

Grind = Mix
 Gum = Gum subtracted from:

Grind	Gum	Lower	Center	Upper	-----+-----+-----+-----+-
Mix	No Gum	-2.005	-0.8900	0.2250	(---*---)
					-----+-----+-----+-----+-
					-2.5 0.0 2.5 5.0

14.3.2. Ricotta Processing Sensory Texture Output

General Linear Model: Hardness Res versus Panelist, Day, Grind Size, Gum

Factor	Type	Levels	Values
Panelist	random	10	Dan Zhao, Hadi Eshpari, Haibin Guo, Jenifer Tharani, Kristen Herberg, Mariella Poveda, Matt Arnold, Megan Cleveland, Taki Chrysovergis, Xiomara Elias
Day	fixed	3	1, 2, 3
Grind Size	fixed	4	3 mm, 4:1 mm, 6 mm, Mixer
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Hardness Residuals, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Panelist	9	0.0	0.0	0.0	0.00	1.000
Day	2	736.1	736.1	368.0	1.48	0.254
Panelist*Day	18	4476.3	4476.3	248.7	1.76	0.032
Grind Size	3	10670.1	10670.1	3556.7	25.20	0.000
Gum	1	180.6	180.6	180.6	1.28	0.259
Grind Size*Gum	3	9008.9	9008.9	3003.0	21.28	0.000
Error	203	28648.1	28648.1	141.1		
Total	239	53720.1				

S = 11.8795 R-Sq = 46.67% R-Sq(adj) = 37.21%

Unusual Observations for Hardness Residuals

Obs	Hardness Residuals	Fit	SE Fit	Residual	St Resid
58	-16.2854	7.0433	4.6644	-23.3288	-2.14 R
62	10.3146	-12.2500	4.6644	22.5646	2.07 R
84	33.2750	-2.2092	4.6644	35.4842	3.25 R
85	-33.1250	-7.4608	4.6644	-25.6642	-2.35 R
87	36.3250	10.5742	4.6644	25.7508	2.36 R
91	29.5750	5.8088	4.6644	23.7663	2.18 R
94	-33.4250	-8.1646	4.6644	-25.2604	-2.31 R
98	38.7208	9.9308	4.6644	28.7900	2.64 R
104	42.0708	11.0608	4.6644	31.0100	2.84 R
114	32.7208	10.1558	4.6644	22.5650	2.07 R
136	32.2687	10.3400	4.6644	21.9287	2.01 R
159	34.7458	11.5700	4.6644	23.1758	2.12 R
168	33.6458	2.9421	4.6644	30.7037	2.81 R
221	12.8667	-12.4942	4.6644	25.3608	2.32 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind Size	N	Mean	Grouping
6 mm	60	7.3	A
4:1 mm	60	4.1	A B
3 mm	60	-1.0	B
Mixer	60	-10.4	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Hardness Residuals
 All Pairwise Comparisons among Levels of Grind Size
 Grind Size = 3 mm subtracted from:

Grind Size = 4:1 mm subtracted from:

Grind Size = 6 mm subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
No Gum	120	0.9	A
Gum	120	-0.9	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Hardness Residuals
 All Pairwise Comparisons among Levels of Gum
 Gum = Gum subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

Grind Size	Gum	N	Mean	Grouping
6 mm	No Gum	30	11.2	A
4:1 mm	No Gum	30	9.8	A
3 mm	Gum	30	8.7	A
6 mm	Gum	30	3.3	A B
4:1 mm	Gum	30	-1.6	B C
Mixer	No Gum	30	-6.9	C D
3 mm	No Gum	30	-10.6	C D
Mixer	Gum	30	-13.9	D

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Hardness Residuals

All Pairwise Comparisons among Levels of Grind Size*Gum

Grind Size = 3 mm

Gum = Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
3 mm	No Gum	-28.68	-19.29	-9.90
4:1 mm	Gum	-19.67	-10.28	-0.89
4:1 mm	No Gum	-8.26	1.13	10.52
6 mm	Gum	-14.71	-5.32	4.07
6 mm	No Gum	-6.89	2.50	11.89
Mixer	Gum	-31.92	-22.53	-13.14
Mixer	No Gum	-24.92	-15.53	-6.14

Grind Size = 3 mm

Gum = No Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
4:1 mm	Gum	-0.38	9.012	18.403
4:1 mm	No Gum	11.03	20.423	29.815
6 mm	Gum	4.58	13.973	23.365
6 mm	No Gum	12.40	21.795	31.186
Mixer	Gum	-12.63	-3.240	6.151
Mixer	No Gum	-5.63	3.760	13.151

Grind Size = 4:1 mm
 Gum = Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
4:1 mm	No Gum	2.02	11.41	20.803
6 mm	Gum	-4.43	4.96	14.353
6 mm	No Gum	3.39	12.78	22.175
Mixer	Gum	-21.64	-12.25	-2.860
Mixer	No Gum	-14.64	-5.25	4.140

Grind Size = 4:1 mm
 Gum = No Gum subtracted from:

Grind Size = 6 mm
 Gum = Gum subtracted from:

Grind Size = 6 mm
 Gum = No Gum subtracted from:

Grind Size = Mixer
 Gum = Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper	
Mixer	No Gum	-2.391	7.000	16.39	-----+-----+-----+-----
					(----*----)
					-----+-----+-----
					-20 0 20

General Linear Model: Cohesiveness versus Panelist, Day, Grind Size, Gum

Factor	Type	Levels	Values
Panelist	random	10	Dan Zhao, Hadi Eshpari, Haibin Guo, Jenifer Tharani, Kristen Herberg, Mariella Poveda, Matt Arnold, Megan Cleveland, Taki Chrysovergis, Xiomara Elias
Day	fixed	3	1, 2, 3
Grind Size	fixed	4	3 mm, 4:1 mm, 6 mm, Mixer
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Cohesiveness Residuals, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Panelist	9	0.0	0.0	0.0	0.00	1.000
Day	2	331.6	331.6	165.8	1.35	0.284
Panelist*Day	18	2205.9	2205.9	122.6	0.79	0.714
Grind Size	3	40674.7	40674.7	13558.2	87.06	0.000
Gum	1	258.0	258.0	258.0	1.66	0.200
Grind Size*Gum	3	22529.1	22529.1	7509.7	48.22	0.000
Error	203	31615.5	31615.5	155.7		
Total	239	97614.9				

S = 12.4796 R-Sq = 67.61% R-Sq(adj) = 61.87%

Unusual Observations for Cohesiveness Residuals

Cohesiveness					
Obs	Residuals	Fit	SE Fit	Residual	St Resid
36	-22.6521	0.7048	4.9000	-23.3569	-2.04 R
40	57.2479	23.0998	4.9000	34.1481	2.98 R
80	44.2917	13.6123	4.9000	30.6794	2.67 R
84	28.9417	0.1860	4.9000	28.7556	2.51 R
85	-38.9583	-10.1340	4.9000	-28.8244	-2.51 R
86	-38.1583	-14.9890	4.9000	-23.1694	-2.02 R
87	54.4417	21.9560	4.9000	32.4856	2.83 R
92	27.0917	-2.2952	4.9000	29.3869	2.56 R
95	-6.7083	19.4748	4.9000	-26.1831	-2.28 R
146	-31.3708	9.6277	4.9000	-40.9985	-3.57 R
151	48.5792	16.8560	4.9000	31.7231	2.76 R
157	17.7792	-12.0652	4.9000	29.8444	2.60 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind Size	N	Mean	Grouping
6 mm	60	15.5	A
4:1 mm	60	7.6	B
3 mm	60	-3.9	C
Mixer	60	-19.1	D

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Cohesiveness Residuals
 All Pairwise Comparisons among Levels of Grind Size
 Grind Size = 3 mm subtracted from:

Grind Size	Lower	Center	Upper	
4:1 mm	5.62	11.51	17.411	(--*--)
6 mm	13.54	19.44	25.333	(--*--)
Mixer	-21.06	-15.16	-9.265	(--*--)

+-----+-----+-----+-----
 -40 -20 0 20

Grind Size = 4:1 mm subtracted from:

Grind Size	Lower	Center	Upper	
6 mm	2.03	7.92	13.82	(--*--)
Mixer	-32.57	-26.68	-20.78	(--*--)

+-----+-----+-----+-----
 -40 -20 0 20

Grind Size = 6 mm subtracted from:

Grind Size	Lower	Center	Upper	
Mixer	-40.50	-34.60	-28.70	(--*--)

+-----+-----+-----+-----
 -40 -20 0 20

Grind Size = 3 mm

Gum = No Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
4:1 mm	Gum	5.31	15.175	25.041
4:1 mm	No Gum	27.70	37.570	47.436
6 mm	Gum	21.78	31.645	41.511
6 mm	No Gum	27.08	36.945	46.811
Mixer	Gum	-15.33	-5.462	4.404
Mixer	No Gum	-5.01	4.855	14.721

Grind Size = 4:1 mm

Gum = Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
4:1 mm	No Gum	12.53	22.40	32.26
6 mm	Gum	6.60	16.47	26.34
6 mm	No Gum	11.90	21.77	31.64
Mixer	Gum	-30.50	-20.64	-10.77
Mixer	No Gum	-20.19	-10.32	-0.45

Grind Size = 4:1 mm

Gum = No Gum subtracted from:

Grind Size = 6 mm

Gum = Gum subtracted from:

Grind

Size	Gum	Lower	Center	Upper	
6 mm	No Gum	-4.57	5.30	15.17	(---*---)
Mixer	Gum	-46.97	-37.11	-27.24	(---*---)
Mixer	No Gum	-36.66	-26.79	-16.92	(---*---)

-30 0 30

Grind Size = 6 mm

Gum = No Gum subtracted from:

Grind

Size	Gum	Lower	Center	Upper	
Mixer	Gum	-52.27	-42.41	-32.54	(---*---)
Mixer	No Gum	-41.96	-32.09	-22.22	(---*---)

-30 0 30

Grind Size = Mixer

Gum = Gum subtracted from:

Grind

Size	Gum	Lower	Center	Upper	
Mixer	No Gum	0.4509	10.32	20.18	(---*---)

-30 0 30

General Linear Model: Chewiness Re versus Panelist, Day, Grind Size, Gum

Factor	Type	Levels	Values
Panelist	random	10	Dan Zhao, Hadi Eshpari, Haibin Guo, Jenifer Tharani, Kristen Herberg, Mariella Poveda, Matt Arnold, Megan Cleveland, Taki Chrysovergis, Xiomara Elias
Day	fixed	3	1, 2, 3
Grind Size	fixed	4	3 mm, 4:1 mm, 6 mm, Mixer
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Chewiness Residuals, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Panelist	9	0.0	0.0	0.0	0.00	1.000
Day	2	1280.7	1280.7	640.3	0.95	0.405
Panelist*Day	18	12119.0	12119.0	673.3	2.20	0.004
Grind Size	3	27822.6	27822.6	9274.2	30.27	0.000
Gum	1	421.5	421.5	421.5	1.38	0.242
Grind Size*Gum	3	20292.6	20292.6	6764.2	22.08	0.000
Error	203	62197.0	62197.0	306.4		
Total	239	124133.3				

S = 17.5040 R-Sq = 49.90% R-Sq(adj) = 41.01%

Unusual Observations for Chewiness Residuals

Chewiness						
Obs	Residuals	Fit	SE Fit	Residual	St Resid	
39	57.7896	23.7281	6.8728	34.0615	2.12	R
80	57.5354	12.5340	6.8728	45.0015	2.80	R
84	41.8354	-10.3865	6.8728	52.2219	3.24	R
85	-48.2646	-15.7548	6.8728	-32.5098	-2.02	R
87	56.7354	16.1802	6.8728	40.5552	2.52	R
89	-46.3146	-12.8981	6.8728	-33.4165	-2.08	R
91	59.3854	14.3652	6.8728	45.0202	2.80	R
127	56.1188	21.4510	6.8728	34.6677	2.15	R
136	56.4688	15.2548	6.8728	41.2140	2.56	R
149	47.1708	-6.5069	6.8728	53.6777	3.33	R
198	-29.7542	8.2435	6.8728	-37.9977	-2.36	R
199	83.8958	45.6969	6.8728	38.1990	2.37	R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind Size	N	Mean	Grouping
6 mm	60	14.5	A
4:1 mm	60	3.9	B
3 mm	60	-3.2	B
Mixer	60	-15.1	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Chewiness Residuals

All Pairwise Comparisons among Levels of Grind Size

Grind Size = 3 mm subtracted from:

Grind Size	Lower	Center	Upper	
4:1 mm	-1.16	7.11	15.379	(---*---)
6 mm	9.46	17.73	26.000	(---*---)
Mixer	-20.14	-11.87	-3.599	(---*---)

-20 0 20

Grind Size = 4:1 mm subtracted from:

Grind Size	Lower	Center	Upper	
6 mm	2.35	10.62	18.89	(---*---)
Mixer	-27.25	-18.98	-10.71	(---*---)

-20 0 20

Grind Size = 6 mm subtracted from:

Grind Size	Lower	Center	Upper	
Mixer	-37.87	-29.60	-21.33	(---*---)

-20 0 20

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
No Gum	120	1.3	A
Gum	120	-1.3	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Chewiness Residuals
 All Pairwise Comparisons among Levels of Gum
 Gum = Gum subtracted from:

Gum	Lower	Center	Upper	
No Gum	-1.805	2.650	7.106	(-----+-----+-----+-----)
				(-----*-----)
				(-----+-----+-----+-----)
				0.0 2.5 5.0

Grouping Information Using Tukey Method and 95.0% Confidence

Grind Size	Gum	N	Mean	Grouping
6 mm	No Gum	30	20.2	A
4:1 mm	No Gum	30	14.1	A
3 mm	Gum	30	10.8	A
6 mm	Gum	30	8.8	A
4:1 mm	Gum	30	-6.4	B
Mixer	No Gum	30	-11.7	B
3 mm	No Gum	30	-17.3	B
Mixer	Gum	30	-18.5	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Chewiness Residuals
 All Pairwise Comparisons among Levels of Grind Size*Gum
 Grind Size = 3 mm
 Gum = Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
3 mm	No Gum	-41.87	-28.03	-14.20
4:1 mm	Gum	-30.98	-17.15	-3.31
4:1 mm	No Gum	-10.51	3.33	17.17
6 mm	Gum	-15.83	-2.00	11.84
6 mm	No Gum	-4.42	9.42	23.26
Mixer	Gum	-43.10	-29.26	-15.42
Mixer	No Gum	-36.35	-22.52	-8.68

Grind Size	Gum	-----+-----+-----+-----
3 mm	No Gum	(----*----)
4:1 mm	Gum	(---*-----)
4:1 mm	No Gum	(-----*-----)
6 mm	Gum	(---*-----)
6 mm	No Gum	(---*-----)
Mixer	Gum	(---*-----)
Mixer	No Gum	(---*-----)
		-----+-----+-----+-----
		-30 0 30

Grind Size = 3 mm
 Gum = No Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
4:1 mm	Gum	-2.95	10.887	24.72
4:1 mm	No Gum	17.53	31.363	45.20
6 mm	Gum	12.20	26.038	39.88
6 mm	No Gum	23.62	37.453	51.29
Mixer	Gum	-15.06	-1.225	12.61
Mixer	No Gum	-8.32	5.518	19.36

Grind Size = 4:1 mm
 Gum = Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
4:1 mm	No Gum	6.64	20.48	34.314
6 mm	Gum	1.31	15.15	28.989
6 mm	No Gum	12.73	26.57	40.404
Mixer	Gum	-25.95	-12.11	1.726
Mixer	No Gum	-19.21	-5.37	8.469

Grind Size = 4:1 mm
 Gum = No Gum subtracted from:

Grind Size = 6 mm

Gum = Gum subtracted from:

Grind

Size	Gum	Lower	Center	Upper
6 mm	No Gum	-2.42	11.41	25.25
Mixer	Gum	-41.10	-27.26	-13.43
Mixer	No Gum	-34.36	-20.52	-6.68

Grind Size = 6 mm

Gum = No Gum subtracted from:

Grind

Size	Gum	Lower	Center	Upper
Mixer	Gum	-52.52	-38.68	-24.84
Mixer	No Gum	-45.77	-31.93	-18.10

Grind Size = Mixer

Gum = Gum subtracted from:

Grind

Size	Gum	Lower	Center	Upper
Mixer	No Gum	-7.094	6.743	20.58

General Linear Model: Adhesiveness versus Panelist, Day, Grind Size, Gum

Factor	Type	Levels	Values
Panelist	random	10	Dan Zhao, Hadi Eshpari, Haibin Guo, Jenifer Tharani, Kristen Herberg, Mariella Poveda, Matt Arnold, Megan Cleveland, Taki Chrysovergis, Xiomara Elias
Day	fixed	3	1, 2, 3
Grind Size	fixed	4	3 mm, 4:1 mm, 6 mm, Mixer
Gum	fixed	2	Gum, No Gum

Analysis of Variance for Adhesiveness Residuals, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Panelist	9	0.0	0.0	0.00	0.00	1.000
Day	2	2917.7	2917.7	1458.9	1.10	0.356
Panelist*Day	18	23968.5	23968.5	1331.6	3.38	0.000
Grind Size	3	3033.4	3033.4	1011.1	2.57	0.056
Gum	1	98.8	98.8	98.8	0.25	0.617
Grind Size*Gum	3	220.2	220.2	73.4	0.19	0.906
Error	203	80011.8	80011.8	394.1		
Total	239	110250.4				

S = 19.8531 R-Sq = 27.43% R-Sq(adj) = 14.56%

Unusual Observations for Adhesiveness Residuals

Adhesiveness					
Obs	Residuals	Fit	SE Fit	Residual	St Resid
25	48.7292	1.6992	7.7951	47.0300	2.58 R
27	-33.7708	6.6825	7.7951	-40.4533	-2.22 R
83	51.5146	-5.4946	7.7951	57.0092	3.12 R
111	41.4708	-4.8092	7.7951	46.2800	2.53 R
144	49.6458	8.5704	7.7951	41.0754	2.25 R
165	48.0250	1.6183	7.7951	46.4067	2.54 R
193	79.8979	37.8929	7.7951	42.0050	2.30 R
195	-5.2021	42.8763	7.7951	-48.0783	-2.63 R
201	42.3979	-17.2696	7.7951	59.6675	3.27 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Grind Size	N	Mean	Grouping
6 mm	60	4.4	A
4:1 mm	60	2.4	A
Mixer	60	-2.3	A
3 mm	60	-4.5	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Adhesiveness Residuals

All Pairwise Comparisons among Levels of Grind Size

Grind Size = 3 mm subtracted from:

Grind Size	Lower	Center	Upper	
4:1 mm	-2.503	6.877	16.26	(-----*-----)
6 mm	-0.527	8.853	18.23	(-----*-----)
Mixer	-7.270	2.111	11.49	(-----*-----)

-----+-----+-----+-----+
-10 0 10 20

Grind Size = 4:1 mm subtracted from:

Grind Size	Lower	Center	Upper	
6 mm	-7.40	1.976	11.357	(-----*-----)
Mixer	-14.15	-4.767	4.614	(-----*-----)

-----+-----+-----+-----+
-10 0 10 20

Grind Size = 6 mm subtracted from:

Grind Size	Lower	Center	Upper	
Mixer	-16.12	-6.742	2.638	(-----*-----)

-----+-----+-----+-----+
-10 0 10 20

Grouping Information Using Tukey Method and 95.0% Confidence

Gum	N	Mean	Grouping
Gum	120	0.6	A
No Gum	120	-0.6	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Adhesiveness Residuals
 All Pairwise Comparisons among Levels of Gum
 Gum = Gum subtracted from:

Gum	Lower	Center	Upper	
No Gum	-6.337	-1.283	3.770	(-----*-----)

-6.0 -3.0 0.0 3.0

Grouping Information Using Tukey Method and 95.0% Confidence

Grind Size	Gum	N	Mean	Grouping
6 mm	No Gum	30	4.5	A
6 mm	Gum	30	4.3	A
4:1 mm	No Gum	30	2.9	A
4:1 mm	Gum	30	1.9	A
Mixer	Gum	30	-0.7	A
3 mm	Gum	30	-2.9	A
Mixer	No Gum	30	-4.0	A
3 mm	No Gum	30	-6.0	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Adhesiveness Residuals
 All Pairwise Comparisons among Levels of Grind Size*Gum
 Grind Size = 3 mm
 Gum = Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
3 mm	No Gum	-18.81	-3.113	12.58
4:1 mm	Gum	-10.86	4.838	20.53
4:1 mm	No Gum	-9.89	5.803	21.50
6 mm	Gum	-8.53	7.163	22.86
6 mm	No Gum	-8.26	7.430	23.12
Mixer	Gum	-13.51	2.180	17.87
Mixer	No Gum	-16.77	-1.072	14.62

Grind Size	Gum	-----+-----+-----+-----+
3 mm	No Gum	(-----*-----)
4:1 mm	Gum	(-----*-----)
4:1 mm	No Gum	(-----*-----)
6 mm	Gum	(-----*-----)
6 mm	No Gum	(-----*-----)
Mixer	Gum	(-----*-----)
Mixer	No Gum	(-----*-----)

-15 0 15 30

Grind Size = 3 mm

Gum = No Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
4:1 mm	Gum	-7.74	7.952	23.65
4:1 mm	No Gum	-6.78	8.917	24.61
6 mm	Gum	-5.42	10.277	25.97
6 mm	No Gum	-5.15	10.543	26.24
Mixer	Gum	-10.40	5.293	20.99
Mixer	No Gum	-13.65	2.042	17.74

Grind Size = 4:1 mm

Gum = Gum subtracted from:

Grind Size	Gum	Lower	Center	Upper
4:1 mm	No Gum	-14.73	0.965	16.660
6 mm	Gum	-13.37	2.325	18.020
6 mm	No Gum	-13.10	2.592	18.286
Mixer	Gum	-18.35	-2.658	13.036
Mixer	No Gum	-21.60	-5.910	9.785

Grind Size = 4:1 mm

Gum = No Gum subtracted from:

Grind Size = 6 mm

Gum = Gum subtracted from:

Grind Size = 6 mm

Gum = No Gum subtracted from:

Grind Size = Mixer

Gum = Gum subtracted from:

14.3.3. Analyses of Variance of the Texture Ratings: Degrees of Freedom, F-ratios, and Error Mean Squares Minitab Output

General Linear Model: Hardness versus Panelists, Day, GrindxGum_1

Factor	Type	Levels	Values
Panelists	random	8	Dan Zhao, Haibin Guo, Jenifer Tharani, Mariella Poveda, Matt Arnold, Megan Cleveland, Taki Chrysovergis, Xiomara Elias
Day	random	3	1, 2, 3
GrindxGum_1	fixed	8	3 mmGum, 3 mmNo Gum, 4:1 mmGum, 4:1 mmNo Gum, 6 mmGum, 6 mmNo Gum, MixerGum, MixerNo Gum

Analysis of Variance for Hardness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Panelists	7	6149.60	6149.60	878.51	1.64	0.155 x
Day	2	949.40	949.40	474.70	1.46	0.262 x
GrindxGum_1	7	10681.05	10681.05	1525.86	4.46	0.001 x
Panelists*Day	14	4019.88	4019.88	287.13	5.27	0.000
Panelists*GrindxGum_1	49	14871.16	14871.16	303.49	5.57	0.000
Day*GrindxGum_1	14	1304.60	1304.60	93.19	1.71	0.066
Error	98	5340.78	5340.78	54.50		
Total	191	43316.48				

x Not an exact F-test.

S = 7.38226 R-Sq = 87.67% R-Sq(adj) = 75.97%

Unusual Observations for Hardness

Obs	Hardness	Fit	SE Fit	Residual	St Resid
59	71.6000	58.0724	5.1654	13.5276	2.56 R
76	35.2500	50.8784	5.1654	-15.6284	-2.96 R
84	60.0000	47.4995	5.1654	12.5005	2.37 R
103	16.1000	26.7430	5.1654	-10.6430	-2.02 R
108	51.7500	66.7911	5.1654	-15.0411	-2.85 R
112	50.2500	36.5411	5.1654	13.7089	2.60 R
116	74.2500	63.2638	5.1654	10.9862	2.08 R
120	13.9000	29.3013	5.1654	-15.4013	-2.92 R
184	35.2500	49.8120	5.1654	-14.5620	-2.76 R

R denotes an observation with a large standardized residual.

General Linear Model: Cohesiveness versus Panelists, Day, GrindxGum_1

Factor	Type	Levels	Values
Panelists	random	8	Dan Zhao, Haibin Guo, Jenifer Tharani, Mariella Poveda, Matt Arnold, Megan Cleveland, Taki Chrysovergis, Xiomara Elias
Day	random	3	1, 2, 3
GrindxGum_1	fixed	8	3 mmGum, 3 mmNo Gum, 4:1 mmGum, 4:1 mmNo Gum, 6 mmGum, 6 mmNo Gum, MixerGum, MixerNo Gum

Analysis of Variance for Cohesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Panelists	7	9045.72	9045.72	1292.25	4.76	0.001 x
Day	2	710.99	710.99	355.50	2.80	0.118 x
GrindxGum_1	7	44754.11	44754.11	6393.44	19.16	0.000 x
Panelists*Day	14	1109.49	1109.49	79.25	0.85	0.618
Panelists*GrindxGum_1	49	14011.64	14011.64	285.95	3.05	0.000
Day*GrindxGum_1	14	1978.75	1978.75	141.34	1.51	0.122
Error	98	9181.56	9181.56	93.69		
Total	191	80792.28				

x Not an exact F-test.

S = 9.67933 R-Sq = 88.64% R-Sq(adj) = 77.85%

Unusual Observations for Cohesiveness

Obs	Cohesiveness	Fit	SE Fit	Residual	St Resid
62	111.000	86.232	6.773	24.768	3.58 R
64	17.600	32.142	6.773	-14.542	-2.10 R
68	72.000	89.365	6.773	-17.365	-2.51 R
70	49.850	72.544	6.773	-22.694	-3.28 R
72	49.850	29.630	6.773	20.220	2.92 R
97	13.850	35.941	6.773	-22.091	-3.19 R
98	40.500	24.082	6.773	16.418	2.37 R
112	63.000	42.736	6.773	20.264	2.93 R
113	64.150	43.580	6.773	20.570	2.97 R
120	16.850	40.030	6.773	-23.180	-3.35 R
149	54.000	69.053	6.773	-15.053	-2.18 R

R denotes an observation with a large standardized residual.

General Linear Model: Chewiness versus Panelists, Day, GrindxGum_1

Factor	Type	Levels	Values
Panelists	random	8	Dan Zhao, Haibin Guo, Jenifer Tharani, Mariella Poveda, Matt Arnold, Megan Cleveland, Taki Chrysovergis, Xiomara Elias
Day	random	3	1, 2, 3
GrindxGum_1	fixed	8	3 mmGum, 3 mmNo Gum, 4:1 mmGum, 4:1 mmNo Gum, 6 mmGum, 6 mmNo Gum, MixerGum, MixerNo Gum

Analysis of Variance for Chewiness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Panelists	7	24322.7	24322.7	3474.7	2.94	0.020 x
Day	2	1378.1	1378.1	689.1	0.89	0.435 x
GrindxGum_1	7	31804.3	31804.3	4543.5	7.71	0.000 x
Panelists*Day	14	11023.4	11023.4	787.4	3.81	0.000
Panelists*GrindxGum_1	49	29501.6	29501.6	602.1	2.91	0.000
Day*GrindxGum_1	14	2719.7	2719.7	194.3	0.94	0.520
Error	98	20266.8	20266.8	206.8		
Total	191	121016.6				

x Not an exact F-test.

S = 14.3807 R-Sq = 83.25% R-Sq(adj) = 67.36%

Unusual Observations for Chewiness

Obs	Chewiness	Fit	SE Fit	Residual	St Resid
28	34.150	61.277	10.062	-27.127	-2.64 R
52	114.000	90.631	10.062	23.369	2.27 R
57	37.900	58.512	10.062	-20.612	-2.01 R
59	98.300	66.862	10.062	31.438	3.06 R
65	102.700	80.805	10.062	21.895	2.13 R
67	45.700	71.467	10.062	-25.767	-2.51 R
69	115.850	88.722	10.062	27.128	2.64 R
91	48.000	27.076	10.062	20.924	2.04 R
104	82.850	61.577	10.062	21.273	2.07 R
120	23.600	46.024	10.062	-22.424	-2.18 R
146	10.100	41.475	10.062	-31.375	-3.05 R
148	106.900	81.258	10.062	25.642	2.50 R
150	123.750	91.068	10.062	32.682	3.18 R
151	18.750	41.852	10.062	-23.102	-2.25 R
158	29.650	52.447	10.062	-22.797	-2.22 R

R denotes an observation with a large standardized residual.

General Linear Model: Adhesiveness versus Panelists, Day, GrindxGum_1

Factor	Type	Levels	Values
Panelists	random	8	Dan Zhao, Haibin Guo, Jenifer Tharani, Mariella Poveda, Matt Arnold, Megan Cleveland, Taki Chrysovergis, Xiomara Elias
Day	random	3	1, 2, 3
GrindxGum_1	fixed	8	3 mmGum, 3 mmNo Gum, 4:1 mmGum, 4:1 mmNo Gum, 6 mmGum, 6 mmNo Gum, MixerGum, MixerNo Gum

Analysis of Variance for Adhesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Panelists	7	3974.3	3974.3	567.8	0.26	0.964 x
Day	2	2103.3	2103.3	1051.7	0.61	0.555 x
GrindxGum_1	7	4862.9	4862.9	694.7	0.96	0.470 x
Panelists*Day	14	23339.4	23339.4	1667.1	11.53	0.000
Panelists*GrindxGum_1	49	33062.0	33062.0	674.7	4.67	0.000
Day*GrindxGum_1	14	2683.7	2683.7	191.7	1.33	0.206
Error	98	14170.1	14170.1	144.6		
Total	191	84195.8				

x Not an exact F-test.

S = 12.0247 R-Sq = 83.17% R-Sq(adj) = 67.20%

Unusual Observations for Adhesiveness

Obs	Adhesiveness	Fit	SE Fit	Residual	St Resid
52	85.100	63.263	8.414	21.837	2.54 R
61	99.000	81.360	8.414	17.640	2.05 R
68	53.650	72.696	8.414	-19.046	-2.22 R
72	79.850	57.552	8.414	22.298	2.60 R
88	35.200	16.012	8.414	19.188	2.23 R
92	91.500	69.375	8.414	22.125	2.58 R
96	22.500	43.598	8.414	-21.098	-2.46 R
111	83.250	60.056	8.414	23.194	2.70 R
112	12.750	46.647	8.414	-33.897	-3.95 R
119	45.000	63.923	8.414	-18.923	-2.20 R
120	87.000	66.740	8.414	20.260	2.36 R
149	42.750	70.265	8.414	-27.515	-3.20 R
165	31.500	13.329	8.414	18.171	2.12 R

R denotes an observation with a large standardized residual.

14.4 ACCEPTABILITY TEST MINITAB OUTPUT

14.4.1 Acceptability Test Overall Means Output

General Linear Model: Overall, how much do you LIKE o versus Samp-Desc

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson

Analysis of Variance for Overall, how much do you LIKE o, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	207.547	207.547	51.887	12.35	0.000
Error	185	777.105	777.105	4.201		
Total	189	984.653				

S = 2.04953 R-Sq = 21.08% R-Sq(adj) = 19.37%

Unusual Observations for Overall, how much do you LIKE o

Obs	Overall, how much do you LIKE o	Fit	SE Fit	Residual	St Resid
5	9.00000	4.68421	0.33248	4.31579	2.13 R
46	2.00000	6.13158	0.33248	-4.13158	-2.04 R
71	2.00000	6.13158	0.33248	-4.13158	-2.04 R
73	1.00000	6.13158	0.33248	-5.13158	-2.54 R
81	8.00000	3.52632	0.33248	4.47368	2.21 R
137	1.00000	5.76316	0.33248	-4.76316	-2.36 R
152	1.00000	5.76316	0.33248	-4.76316	-2.36 R
159	2.00000	6.31579	0.33248	-4.31579	-2.13 R
160	2.00000	6.31579	0.33248	-4.31579	-2.13 R
187	2.00000	6.31579	0.33248	-4.31579	-2.13 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
Tyson	38	6.3	A
McDonald's	38	6.1	A
Quron	38	5.8	A B
Boca	38	4.7	B C
Moofu	38	3.5	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Overall, how much do you LIKE o
 All Pairwise Comparisons among Levels of Samp-Desc
 Samp-Desc = Boca subtracted from:

Samp-Desc = McDonald's subtracted from:

Samp-Desc = Moofu subtracted from:

Samp-Desc = Quron subtracted from:

Main Effects Plot for Overall, how much do you LIKE o

General Linear Model: How much do you LIKE or DISLIKE versus Samp-Desc

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson

Analysis of Variance for How much do you LIKE or DISLIKE, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	286.947	286.947	71.737	24.86	0.000
Error	185	533.895	533.895	2.886		
Total	189	820.842				

S = 1.69880 R-Sq = 34.96% R-Sq(adj) = 33.55%

Unusual Observations for How much do you LIKE or DISLIKE

Obs	How much do you LIKE or DISLIKE	Fit	SE Fit	Residual	St Resid
16	2.00000	5.81579	0.27558	-3.81579	-2.28 R
39	3.00000	6.39474	0.27558	-3.39474	-2.03 R
49	3.00000	6.39474	0.27558	-3.39474	-2.03 R
71	2.00000	6.39474	0.27558	-4.39474	-2.62 R
73	1.00000	6.39474	0.27558	-5.39474	-3.22 R
97	8.00000	3.34211	0.27558	4.65789	2.78 R
106	7.00000	3.34211	0.27558	3.65789	2.18 R
111	7.00000	3.34211	0.27558	3.65789	2.18 R
153	3.00000	6.52632	0.27558	-3.52632	-2.10 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
Quron	38	6.6	A
Tyson	38	6.5	A
McDonald's	38	6.4	A
Boca	38	5.8	A
Moofu	38	3.3	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable How much do you LIKE or DISLIKE

All Pairwise Comparisons among Levels of Samp-Desc

Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	-0.496	0.579	1.654	(---*---)
Moofu	-3.548	-2.474	-1.399	(---*---)
Quron	-0.285	0.789	1.864	(---*---)
Tyson	-0.364	0.711	1.785	(---*---)

-2.5 0.0 2.5

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-4.127	-3.053	-1.978	(---*---)
Quron	-0.864	0.211	1.285	(---*---)
Tyson	-0.943	0.132	1.206	(---*---)

-2.5 0.0 2.5

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper	
Quron	2.188	3.263	4.338	(---*---)
Tyson	2.109	3.184	4.259	(---*---)

-2.5 0.0 2.5

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper	
Tyson	-1.154	-0.07895	0.9958	(---*---)

-2.5 0.0 2.5

Main Effects Plot for How much do you LIKE or DISLIKE

General Linear Model: Overall, how much do you LIKE_1 versus Samp-Desc

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson

Analysis of Variance for Overall, how much do you LIKE_1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	192.263	192.263	48.066	11.18	0.000
Error	185	795.447	795.447	4.300		
Total	189	987.711				

S = 2.07358 R-Sq = 19.47% R-Sq(adj) = 17.72%

Unusual Observations for Overall, how much do you LIKE_1

Obs	Overall, how much do you LIKE_1	Fit	SE Fit	Residual	St Resid
5	9.00000	4.52632	0.33638	4.47368	2.19 R
73	1.00000	5.81579	0.33638	-4.81579	-2.35 R
77	8.00000	3.44737	0.33638	4.55263	2.23 R
142	1.00000	5.71053	0.33638	-4.71053	-2.30 R
148	1.00000	5.71053	0.33638	-4.71053	-2.30 R
160	2.00000	6.15789	0.33638	-4.15789	-2.03 R
179	2.00000	6.15789	0.33638	-4.15789	-2.03 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
Tyson	38	6.2	A
McDonald's	38	5.8	A B
Quron	38	5.7	A B
Boca	38	4.5	B C
Moofu	38	3.4	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Overall, how much do you LIKE_1

All Pairwise Comparisons among Levels of Samp-Desc

Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	-0.022	1.289	2.6013	(----*----)
Moofu	-2.391	-1.079	0.2329	(-----*-----)
Quron	-0.128	1.184	2.4961	(-----*-----)
Tyson	0.320	1.632	2.9435	(-----*-----)

-2.5 0.0 2.5 5.0

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-3.680	-2.368	-1.057	(-----*-----)
Quron	-1.417	-0.105	1.207	(-----*-----)
Tyson	-0.970	0.342	1.654	(-----*-----)

-2.5 0.0 2.5 5.0

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper	
Quron	0.9513	2.263	3.575	(----*----)
Tyson	1.3987	2.711	4.022	(----*----)

-2.5 0.0 2.5 5.0

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper	
Tyson	-0.8645	0.4474	1.759	(----*----)

-2.5 0.0 2.5 5.0

Main Effects Plot for Overall, how much do you LIKE_1

General Linear Model: Is the CHICKEN FLAVOR in the nu versus Samp-Desc

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson

Analysis of Variance for Is the CHICKEN FLAVOR in the nu, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	24.0842	24.0842	6.0211	6.45	0.000
Error	185	172.6316	172.6316	0.9331		
Total	189	196.7158				

S = 0.965994 R-Sq = 12.24% R-Sq(adj) = 10.35%

Unusual Observations for Is the CHICKEN FLAVOR in the nu

Obs	Is the CHICKEN FLAVOR in the nu	Fit	SE Fit	Residual	St Resid
16	1.00000	3.78947	0.15670	-2.78947	-2.93 R
46	1.00000	3.47368	0.15670	-2.47368	-2.60 R
79	1.00000	3.68421	0.15670	-2.68421	-2.82 R
86	1.00000	3.68421	0.15670	-2.68421	-2.82 R
92	1.00000	3.68421	0.15670	-2.68421	-2.82 R
101	1.00000	3.68421	0.15670	-2.68421	-2.82 R
152	1.00000	3.10526	0.15670	-2.10526	-2.21 R
157	5.00000	2.84211	0.15670	2.15789	2.26 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
Boca	38	3.8	A
Moofu	38	3.7	A B
McDonald's	38	3.5	A B
Quron	38	3.1	B C
Tyson	38	2.8	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Is the CHICKEN FLAVOR in the nu
 All Pairwise Comparisons among Levels of Samp-Desc
 Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	-0.927	-0.3158	0.2954	(-----*-----)
Moofu	-0.716	-0.1053	0.5059	(-----*-----)
Quron	-1.295	-0.6842	-0.0731	(-----*-----)
Tyson	-1.559	-0.9474	-0.3362	(-----*-----)

-1.40 -0.70 0.00 0.70

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-0.401	0.2105	0.82168	(-----*-----)
Quron	-0.980	-0.3684	0.24273	(-----*-----)
Tyson	-1.243	-0.6316	-0.02043	(-----*-----)

-1.40 -0.70 0.00 0.70

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper	
Quron	-1.190	-0.5789	0.0322	(-----*-----)
Tyson	-1.453	-0.8421	-0.2310	(-----*-----)

-1.40 -0.70 0.00 0.70

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper	
Tyson	-0.8743	-0.2632	0.3480	(-----*-----)

-1.40 -0.70 0.00 0.70

Main Effects Plot for Is the CHICKEN FLAVOR in the nu

General Linear Model: Is the MOISTNESS of the nugget. versus Samp-Desc

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson

Analysis of Variance for Is the MOISTNESS of the nugget., using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	22.0842	22.0842	5.5211	9.69	0.000
Error	185	105.3684	105.3684	0.5696		
Total	189	127.4526				

S = 0.754691 R-Sq = 17.33% R-Sq(adj) = 15.54%

Unusual Observations for Is the MOISTNESS of the nugget.

Obs	Is the MOISTNESS of the nugget.	Fit	SE Fit	Residual	St Resid
16	5.00000	2.92105	0.12243	2.07895	2.79 R
32	1.00000	2.92105	0.12243	-1.92105	-2.58 R
36	1.00000	2.92105	0.12243	-1.92105	-2.58 R
45	5.00000	3.50000	0.12243	1.50000	2.01 R
46	2.00000	3.50000	0.12243	-1.50000	-2.01 R
52	1.00000	3.50000	0.12243	-2.50000	-3.36 R
55	5.00000	3.50000	0.12243	1.50000	2.01 R
73	5.00000	3.50000	0.12243	1.50000	2.01 R
86	2.00000	3.55263	0.12243	-1.55263	-2.08 R
90	2.00000	3.55263	0.12243	-1.55263	-2.08 R
104	1.00000	3.55263	0.12243	-2.55263	-3.43 R
108	2.00000	3.55263	0.12243	-1.55263	-2.08 R
115	1.00000	2.86842	0.12243	-1.86842	-2.51 R
157	1.00000	2.73684	0.12243	-1.73684	-2.33 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
Moofu	38	3.6	A
McDonald's	38	3.5	A
Boca	38	2.9	B
Quron	38	2.9	B
Tyson	38	2.7	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Is the MOISTNESS of the nugget.
All Pairwise Comparisons among Levels of Samp-Desc
Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	0.1015	0.5789	1.0564	(-----*-----)
Moofu	0.1541	0.6316	1.1090	(-----*-----)
Quron	-0.5301	-0.0526	0.4248	(-----*-----)
Tyson	-0.6617	-0.1842	0.2933	(-----*-----)

-----+-----+-----+-----
-0.70 0.00 0.70

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-0.425	0.0526	0.5301	(-----*-----)
Quron	-1.109	-0.6316	-0.1541	(-----*-----)
Tyson	-1.241	-0.7632	-0.2857	(-----*-----)

-----+-----+-----+-----
-0.70 0.00 0.70

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper	
Quron	-1.162	-0.6842	-0.2067	(-----*-----)
Tyson	-1.293	-0.8158	-0.3383	(-----*-----)
				-----+-----+-----+-----
				-0.70 0.00 0.70

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper	
Tyson	-0.6090	-0.1316	0.3459	(-----*-----)
				-----+-----+-----+-----
				-0.70 0.00 0.70

Main Effects Plot for Is the MOISTNESS of the nugget.

General Linear Model: Overall, how much do you LIKE_2 versus Samp-Desc

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson

Analysis of Variance for Overall, how much do you LIKE_2, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	121.737	121.737	30.434	8.87	0.000
Error	185	634.579	634.579	3.430		
Total	189	756.316				

S = 1.85207 R-Sq = 16.10% R-Sq(adj) = 14.28%

Unusual Observations for Overall, how much do you LIKE_2

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Overall,
how much
do you
Obs    LIKE_2    Fit    SE Fit    Residual    St Resid
22    1.00000    5.39474    0.30045    -4.39474      -2.40 R
39    2.00000    5.73684    0.30045    -3.73684      -2.04 R
73    2.00000    5.73684    0.30045    -3.73684      -2.04 R
97    8.00000    3.89474    0.30045     4.10526       2.25 R
112   8.00000    3.89474    0.30045     4.10526       2.25 R
115   2.00000    5.97368    0.30045    -3.97368      -2.17 R
157   2.00000    6.10526    0.30045    -4.10526      -2.25 R
187   2.00000    6.10526    0.30045    -4.10526      -2.25 R

```

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
Tyson	38	6.1	A
Quron	38	6.0	A
McDonald's	38	5.7	A
Boca	38	5.4	A
Moofu	38	3.9	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Overall, how much do you LIKE_2

All Pairwise Comparisons among Levels of Samp-Desc

Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	-0.830	0.342	1.5138	(-----*-----)
Moofu	-2.672	-1.500	-0.3283	(-----*-----)
Quron	-0.593	0.579	1.7507	(-----*-----)
Tyson	-0.461	0.711	1.8823	(-----*-----)

-2.0 0.0 2.0 4.0

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-3.014	-1.842	-0.6704	(-----*-----)
Quron	-0.935	0.237	1.4086	(-----*-----)
Tyson	-0.803	0.368	1.5402	(-----*-----)

-2.0 0.0 2.0 4.0

S = 0.873345 R-Sq = 6.66% R-Sq(adj) = 4.65%

Unusual Observations for Is the TEXTURE of the nugget...

Obs	Is the TEXTURE of the nugget...	Fit	SE Fit	Residual	St Resid
7	5.00000	2.63158	0.14168	2.36842	2.75 R
39	5.00000	3.26316	0.14168	1.73684	2.02 R
45	5.00000	3.26316	0.14168	1.73684	2.02 R
52	1.00000	3.26316	0.14168	-2.26316	-2.63 R
81	5.00000	2.71053	0.14168	2.28947	2.66 R
94	5.00000	2.71053	0.14168	2.28947	2.66 R
110	5.00000	2.71053	0.14168	2.28947	2.66 R
149	1.00000	2.76316	0.14168	-1.76316	-2.05 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
McDonald's	38	3.3	A
Quron	38	2.8	A B
Moofu	38	2.7	B
Tyson	38	2.7	B
Boca	38	2.6	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Is the TEXTURE of the nugget...

All Pairwise Comparisons among Levels of Samp-Desc

Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	0.0790	0.63158	1.1841	(-----*-----)
Moofu	-0.4736	0.07895	0.6315	(-----*-----)
Quron	-0.4210	0.13158	0.6841	(-----*-----)
Tyson	-0.4999	0.05263	0.6052	(-----*-----)

-----+-----+-----+-----+
-0.70 0.00 0.70 1.40

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-1.105	-0.5526	-0.00010	(-----*-----)
Quron	-1.053	-0.5000	0.05253	(-----*-----)
Tyson	-1.131	-0.5789	-0.02641	(-----*-----)

-----+-----+-----+-----+
-0.70 0.00 0.70 1.40

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper	-----+-----+-----+-----+
Quron	-0.4999	0.05263	0.6052	(-----*-----)
Tyson	-0.5788	-0.02632	0.5262	(-----*-----)
				-----+-----+-----+-----+
				-0.70 0.00 0.70 1.40

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper	-----+-----+-----+-----+
Tyson	-0.6315	-0.07895	0.4736	(-----*-----)
				-----+-----+-----+-----+
				-0.70 0.00 0.70 1.40

Main Effects Plot for Is the TEXTURE of the nugget...

General Linear Model: Is the CHEWINESS of the nugget. versus Samp-Desc

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson

Analysis of Variance for Is the CHEWINESS of the nugget., using Adjusted SS for Tests

S = 0.875460 R-Sq = 3.36% R-Sq(adj) = 1.27%

Obs	Is the CHEWINESS of the nugget.	Fit	SE Fit	Residual	St Resid	
16	1.00000	2.84211	0.14202	-1.84211	-2.13	R
22	1.00000	2.84211	0.14202	-1.84211	-2.13	R
24	5.00000	2.84211	0.14202	2.15789	2.50	R
25	1.00000	2.84211	0.14202	-1.84211	-2.13	R
26	5.00000	2.84211	0.14202	2.15789	2.50	R
29	1.00000	2.84211	0.14202	-1.84211	-2.13	R
52	5.00000	2.47368	0.14202	2.52632	2.92	R
90	5.00000	2.94737	0.14202	2.05263	2.38	R
92	1.00000	2.94737	0.14202	-1.94737	-2.25	R
93	1.00000	2.94737	0.14202	-1.94737	-2.25	R
96	5.00000	2.94737	0.14202	2.05263	2.38	R
98	1.00000	2.94737	0.14202	-1.94737	-2.25	R
104	5.00000	2.94737	0.14202	2.05263	2.38	R
148	1.00000	2.84211	0.14202	-1.84211	-2.13	R
157	5.00000	2.78947	0.14202	2.21053	2.56	R
177	1.00000	2.78947	0.14202	-1.78947	-2.07	R
187	1.00000	2.78947	0.14202	-1.78947	-2.07	R

Grouping Information Using Tukey Method and 95.0% Confidence

Means that do not share a letter are significantly different.

Samp-Desc	Lower	Center	Upper	
McDonald's	-0.9223	-0.3684	0.1855	(-----*-----)
Moofu	-0.4486	0.1053	0.6591	(-----*-----)
Quron	-0.5539	-0.0000	0.5539	(-----*-----)
Tyson	-0.6065	-0.0526	0.5012	(-----*-----)

-0.60 0.00 0.60 1.20

Samp-Desc	Lower	Center	Upper
Moofu	-0.0802	0.4737	1.0276
Quron	-0.1855	0.3684	0.9223
Tyson	-0.2381	0.3158	0.8697

Samp-Desc	Lower	Center	Upper
Quron	-0.6591	-0.1053	0.4486
Tyson	-0.7118	-0.1579	0.3960

-----+-----+-----+-----+

(-----*-----)

(-----*-----)

-----+-----+-----+-----+

-0.60 0.00 0.60 1.20

Samp-Desc	Lower	Center	Upper	-----+-----+-----+-----+
Tyson	-0.6065	-0.05263	0.5012	(-----*-----)
				-----+-----+-----+-----+
				-0.60 0.00 0.60 1.20

Main Effects Plot for Is the CHEWINESS of the nugget.
Fitted Means

Mean

Samp-Desc

Samp-Desc	Mean
Boca	2.84
McDonald's	2.47
Moofu	2.95
Quron	2.84
Tyson	2.79

14.4.2. Acceptability Test Target Versus Non-Target Minitab Output

General Linear Model: OverallTXT versus Samp-Desc, Target

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson
Target	fixed	2	1, 2

Analysis of Variance for OverallTXT, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	109.102	76.365	19.091	5.39	0.000
Target	1	0.208	0.208	0.208	0.06	0.809
Samp-Desc*Target	4	6.414	6.414	1.603	0.45	0.771
Error	195	691.281	691.281	3.545		
Total	204	807.005				

S = 1.88282 R-Sq = 14.34% R-Sq(adj) = 10.39%

Unusual Observations for OverallTXT

Obs	OverallTXT	Fit	SE Fit	Residual	St Resid
5	9.00000	5.12903	0.33817	3.87097	2.09 R
9	9.00000	5.12903	0.33817	3.87097	2.09 R
22	1.00000	5.12903	0.33817	-4.12903	-2.23 R
76	2.00000	5.77419	0.33817	-3.77419	-2.04 R
80	2.00000	5.77419	0.33817	-3.77419	-2.04 R
83	8.00000	4.00000	0.33817	4.00000	2.16 R
103	8.00000	4.00000	0.33817	4.00000	2.16 R
118	8.00000	4.10000	0.59540	3.90000	2.18 R
122	8.00000	4.00000	0.33817	4.00000	2.16 R
165	2.00000	6.12903	0.33817	-4.12903	-2.23 R
203	2.00000	6.12903	0.33817	-4.12903	-2.23 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
McDonald's	41	6.0	A
Tyson	41	5.8	A
Quron	41	5.7	A
Boca	41	5.1	A B
Moofu	41	4.0	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable OverallTXT

All Pairwise Comparisons among Levels of Samp-Desc

Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper
McDonald's	-0.409	0.923	2.2544
Moofu	-2.396	-1.065	0.2673
Quron	-0.727	0.605	1.9366
Tyson	-0.682	0.650	1.9818

-----+-----+-----+-----
 (-----*-----)
 (-----*-----)
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----
 -2.0 0.0 2.0

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper
Moofu	-3.319	-1.987	-0.6553
Quron	-1.650	-0.318	1.0141
Tyson	-1.604	-0.273	1.0592

-----+-----+-----+-----
 (-----*-----)
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----
 -2.0 0.0 2.0

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper
Quron	0.3376	1.669	3.001
Tyson	0.3827	1.715	3.046

-----+-----+-----+-----
 (-----*-----)
 (-----*-----)
 -----+-----+-----+-----
 -2.0 0.0 2.0

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper
Tyson	-1.287	0.04516	1.377

-----+-----+-----+-----
 (-----*-----)
 -----+-----+-----+-----
 -2.0 0.0 2.0

Grouping Information Using Tukey Method and 95.0% Confidence

Target	N	Mean	Grouping
2	155	5.4	A
1	50	5.3	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable OverallTXT
 All Pairwise Comparisons among Levels of Target
 Target = 1 subtracted from:

Target	Lower	Center	Upper
2	-0.5297	0.07419	0.6781

-----+-----+-----+-----+-----+-----+
 (-----*-----)
 -----+-----+-----+-----+-----+-----+
 -0.35 0.00 0.35 0.70

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	Target	N	Mean	Grouping
McDonald's	1	10	6.3	A
Tyson	2	31	6.1	A
Quron	2	31	5.8	A
McDonald's	2	31	5.8	A
Quron	1	10	5.6	A B
Tyson	1	10	5.4	A B
Boca	2	31	5.1	A B
Boca	1	10	5.1	A B
Moofu	1	10	4.1	A B
Moofu	2	31	4.0	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable OverallTXT

All Pairwise Comparisons among Levels of Samp-Desc*Target

Samp-Desc = Boca

Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Boca	2	-2.164	0.029	2.222
McDonald's	1	-1.497	1.200	3.897
McDonald's	2	-1.519	0.674	2.868
Moofu	1	-3.697	-1.000	1.697
Moofu	2	-3.293	-1.100	1.093
Quron	1	-2.197	0.500	3.197
Quron	2	-1.455	0.739	2.932
Tyson	1	-2.397	0.300	2.997
Tyson	2	-1.164	1.029	3.222

Samp-Desc = Boca

Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
McDonald's	1	-1.022	1.171	3.3643
McDonald's	2	-0.887	0.645	2.1771
Moofu	1	-3.222	-1.029	1.1643
Moofu	2	-2.661	-1.129	0.4029
Quron	1	-1.722	0.471	2.6643
Quron	2	-0.822	0.710	2.2416
Tyson	1	-1.922	0.271	2.4643
Tyson	2	-0.532	1.000	2.5319

Samp-Desc = McDonald's
Target = 1 subtracted from:

Samp-Desc = McDonald's
Target = 2 subtracted from:

Samp-Desc = Moofu

Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Moofu	2	-2.293	-0.1000	2.093
Quron	1	-1.197	1.5000	4.197
Quron	2	-0.455	1.7387	3.932
Tyson	1	-1.397	1.3000	3.997
Tyson	2	-0.164	2.0290	4.222

Samp-Desc	Target	
Moofu	2	(-----*-----)
Quron	1	(-----*-----)
Quron	2	(-----*-----)
Tyson	1	(-----*-----)
Tyson	2	(-----*-----)

+-----+-----+-----+-----
-5.0 -2.5 0.0 2.5

Samp-Desc = Moofu

Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Quron	1	-0.5933	1.600	3.793
Quron	2	0.3068	1.839	3.371
Tyson	1	-0.7933	1.400	3.593
Tyson	2	0.5971	2.129	3.661

Samp-Desc	Target	
Quron	1	(-----*-----)
Quron	2	(-----*-----)
Tyson	1	(-----*-----)
Tyson	2	(-----*-----)

+-----+-----+-----+-----
-5.0 -2.5 0.0 2.5

Samp-Desc = Quron

Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Quron	2	-1.955	0.2387	2.432
Tyson	1	-2.897	-0.2000	2.497
Tyson	2	-1.664	0.5290	2.722

Samp-Desc	Target	
Quron	2	(-----*-----)
Tyson	1	(-----*-----)
Tyson	2	(-----*-----)

+-----+-----+-----+-----
-5.0 -2.5 0.0 2.5

Samp-Desc = Quron

Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Tyson	1	-2.632	-0.4387	1.755
Tyson	2	-1.242	0.2903	1.822

Samp-Desc = Tyson
Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Tyson	2	-1.464	0.7290	2.922

Interaction Plot for OverallTXT

General Linear Model: Appearance versus Samp-Desc, Target

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson
Target	fixed	2	1, 2

Analysis of Variance for Appearance, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	289.785	218.048	54.512	19.98	0.000
Target	1	1.819	1.819	1.819	0.67	0.415
Samp-Desc*Target	4	13.073	13.073	3.268	1.20	0.313
Error	195	532.084	532.084	2.729		
Total	204	836.761				

S = 1.65186 R-Sq = 36.41% R-Sq(adj) = 33.48%

Unusual Observations for Appearance

Obs	Appearance	Fit	SE Fit	Residual	St Resid
16	2.00000	5.20000	0.52236	-3.20000	-2.04 R
52	3.00000	6.25806	0.29668	-3.25806	-2.00 R
74	2.00000	6.25806	0.29668	-4.25806	-2.62 R
76	1.00000	6.25806	0.29668	-5.25806	-3.24 R
80	1.00000	6.25806	0.29668	-5.25806	-3.24 R
103	8.00000	3.51613	0.29668	4.48387	2.76 R
112	7.00000	3.51613	0.29668	3.48387	2.14 R
117	7.00000	3.51613	0.29668	3.48387	2.14 R
121	7.00000	3.51613	0.29668	3.48387	2.14 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
Tyson	41	6.8	A
McDonald's	41	6.6	A B
Quron	41	6.2	A B
Boca	41	5.5	B
Moofu	41	3.5	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Appearance

All Pairwise Comparisons among Levels of Samp-Desc

Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	-0.125	1.044	2.2120	(---*---)
Moofu	-3.246	-2.077	-0.9090	(----*---)
Quron	-0.483	0.685	1.8539	(----*---)
Tyson	0.051	1.219	2.3878	(----*---)

-----+-----+-----+-----
-2.5 0.0 2.5

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-4.289	-3.121	-1.953	(----*---)
Quron	-1.526	-0.358	0.810	(----*---)
Tyson	-0.993	0.176	1.344	(----*---)

-----+-----+-----+-----
-2.5 0.0 2.5

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper	-----+-----+-----+-----
Quron	1.594	2.763	3.931	(----*----)
Tyson	2.128	3.297	4.465	(---*----)
				-----+-----+-----+-----
				-2.5 0.0 2.5

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper	-----+-----+-----+-----
Tyson	-0.6346	0.5339	1.702	(----*----)
				-----+-----+-----+-----
				-2.5 0.0 2.5

Grouping Information Using Tukey Method and 95.0% Confidence

Target	N	Mean	Grouping
2	155	5.8	A
1	50	5.6	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Appearance
 All Pairwise Comparisons among Levels of Target
 Target = 1 subtracted from:

Target	Lower	Center	Upper	+-----+-----+-----+-----
2	-0.3105	0.2194	0.7492	(-----*-----)
				+-----+-----+-----+-----
				-0.30 0.00 0.30 0.60

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	Target	N	Mean	Grouping
McDonald's	1	10	6.9	A
Tyson	1	10	6.8	A
Quron	2	31	6.7	A
Tyson	2	31	6.7	A
McDonald's	2	31	6.3	A
Boca	2	31	5.9	A
Quron	1	10	5.7	A B
Boca	1	10	5.2	A B C
Moofu	2	31	3.5	C
Moofu	1	10	3.4	B C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable Appearance
 All Pairwise Comparisons among Levels of Samp-Desc*Target
 Samp-Desc = Boca
 Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Boca	2	-1.253	0.671	2.5952
McDonald's	1	-0.666	1.700	4.0663
McDonald's	2	-0.866	1.058	2.9823
Moofu	1	-4.166	-1.800	0.5663
Moofu	2	-3.608	-1.684	0.2404
Quron	1	-1.866	0.500	2.8663
Quron	2	-0.382	1.542	3.4662
Tyson	1	-0.766	1.600	3.9663
Tyson	2	-0.415	1.510	3.4340

Samp-Desc = Boca
Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
McDonald's	1	-0.895	1.029	2.953
McDonald's	2	-0.957	0.387	1.731
Moofu	1	-4.395	-2.471	-0.547
Moofu	2	-3.699	-2.355	-1.011
Quron	1	-2.095	-0.171	1.753
Quron	2	-0.473	0.871	2.215
Tyson	1	-0.995	0.929	2.853
Tyson	2	-0.505	0.839	2.183

Samp-Desc = McDonald's
Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
McDonald's	2	-2.566	-0.642	1.282
Moofu	1	-5.866	-3.500	-1.134
Moofu	2	-5.308	-3.384	-1.460
Quron	1	-3.566	-1.200	1.166
Quron	2	-2.082	-0.158	1.766
Tyson	1	-2.466	-0.100	2.266
Tyson	2	-2.115	-0.190	1.734

Samp-Desc = McDonald's
Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Moofu	1	-4.782	-2.858	-0.934
Moofu	2	-4.086	-2.742	-1.398
Quron	1	-2.482	-0.558	1.366
Quron	2	-0.860	0.484	1.828
Tyson	1	-1.382	0.542	2.466
Tyson	2	-0.892	0.452	1.796

Samp-Desc = Moofu
Target = 1 subtracted from:

Samp-Desc = Moofu
Target = 2 subtracted from:

Target = 1 subtracted from:

Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Tyson	1	-1.866	0.05806	1.982
Tyson	2	-1.376	-0.03226	1.312

Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Tyson	2	-2.015	-0.09032	1.834

Interaction Plot for Appearance

General Linear Model: OverallFlavor versus Samp-Desc, Target

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson
Target	fixed	2	1, 2

Analysis of Variance for OverallFlavor, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	196.907	188.014	47.003	11.08	0.000
Target	1	4.288	4.288	4.288	1.01	0.316
Samp-Desc*Target	4	12.697	12.697	3.174	0.75	0.560
Error	195	827.065	827.065	4.241		
Total	204	1040.956				

S = 2.05946 R-Sq = 20.55% R-Sq(adj) = 16.88%

Unusual Observations for OverallFlavor

Obs	OverallFlavor	Fit	SE Fit	Residual	St Resid
5	9.00000	4.38710	0.36989	4.61290	2.28 R
76	1.00000	5.83871	0.36989	-4.83871	-2.39 R
80	1.00000	5.83871	0.36989	-4.83871	-2.39 R
151	1.00000	5.45161	0.36989	-4.45161	-2.20 R
157	1.00000	5.45161	0.36989	-4.45161	-2.20 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
Tyson	41	6.1	A
McDonald's	41	6.1	A
Quron	41	5.1	A B
Boca	41	4.1	B C
Moofu	41	3.3	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable OverallFlavor
All Pairwise Comparisons among Levels of Samp-Desc
Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	0.519	1.9758	3.4325	(-----*-----)
Moofu	-2.297	-0.8403	0.6164	(-----*-----)
Quron	-0.424	1.0323	2.4890	(-----*-----)
Tyson	0.550	2.0065	3.4632	(-----*-----)

-2.5 0.0 2.5

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-4.273	-2.816	-1.359	(-----*-----)
Quron	-2.400	-0.944	0.513	(-----*-----)
Tyson	-1.426	0.031	1.487	(-----*-----)

-2.5 0.0 2.5

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper	
Quron	0.4158	1.873	3.329	(-----*-----)
Tyson	1.3900	2.847	4.304	(-----*-----)

-2.5 0.0 2.5

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper	
Tyson	-0.4825	0.9742	2.431	(-----*-----)

-2.5 0.0 2.5

Grouping Information Using Tukey Method and 95.0% Confidence

Target	N	Mean	Grouping
2	155	5.1	A
1	50	4.8	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable OverallFlavor
 All Pairwise Comparisons among Levels of Target
 Target = 1 subtracted from:

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	Target	N	Mean	Grouping
McDonald's	1	10	6.3	A
Tyson	1	10	6.2	A B
Tyson	2	31	6.0	A B
McDonald's	2	31	5.8	A B
Quron	2	31	5.5	A B
Quron	1	10	4.8	A B C
Boca	2	31	4.4	A B C
Moofu	2	31	3.8	B C
Boca	1	10	3.8	A B C
Moofu	1	10	2.7	C

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
 Response Variable OverallFlavor
 All Pairwise Comparisons among Levels of Samp-Desc*Target
 Samp-Desc = Boca
 Target = 1 subtracted from:

Samp-Desc = Boca

Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
McDonald's	1	-0.486	1.913	4.3120
McDonald's	2	-0.224	1.452	3.1272
Moofu	1	-4.086	-1.687	0.7120
Moofu	2	-2.256	-0.581	1.0950
Quron	1	-1.986	0.413	2.8120
Quron	2	-0.611	1.065	2.7401
Tyson	1	-0.586	1.813	4.2120
Tyson	2	-0.063	1.613	3.2885

Samp-Desc = McDonald's

Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
McDonald's	2	-2.860	-0.461	1.9378
Moofu	1	-6.550	-3.600	-0.6498
Moofu	2	-4.893	-2.494	-0.0945
Quron	1	-4.450	-1.500	1.4502
Quron	2	-3.247	-0.848	1.5507
Tyson	1	-3.050	-0.100	2.8502
Tyson	2	-2.699	-0.300	2.0991

Samp-Desc = McDonald's

Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Moofu	1	-5.538	-3.139	-0.7396
Moofu	2	-3.708	-2.032	-0.3567
Quron	1	-3.438	-1.039	1.3604
Quron	2	-2.063	-0.387	1.2885
Tyson	1	-2.038	0.361	2.7604
Tyson	2	-1.514	0.161	1.8369

Samp-Desc = Moofu

Target = 1 subtracted from:

Samp-Desc = Moofu

Target = 2 subtracted from:

Samp-Desc = Quron

Target = 1 subtracted from:

Samp-Desc = Quron

Target = 2 subtracted from:

Samp-Desc = Tyson

Target = 1 subtracted from:

```

Samp-Desc  Target  -----+-----+-----+-----+
Tyson      2      (----*-----)
              -4.0      0.0      4.0      8.0

```

Interaction Plot for OverallFlavor

General Linear Model: OverallTXT versus Samp-Desc, Target

Factor	Type	Levels	Values
Samp-Desc	fixed	5	Boca, McDonald's, Moofu, Quron, Tyson
Target	fixed	2	1, 2

Analysis of Variance for OverallTXT, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Samp-Desc	4	109.102	76.365	19.091	5.39	0.000
Target	1	0.208	0.208	0.208	0.06	0.809
Samp-Desc*Target	4	6.414	6.414	1.603	0.45	0.771
Error	195	691.281	691.281	3.545		
Total	204	807.005				

S = 1.88282 R-Sq = 14.34% R-Sq(adj) = 10.39%

Unusual Observations for OverallTXT

Obs	OverallTXT	Fit	SE Fit	Residual	St Resid
5	9.00000	5.12903	0.33817	3.87097	2.09 R
9	9.00000	5.12903	0.33817	3.87097	2.09 R
22	1.00000	5.12903	0.33817	-4.12903	-2.23 R
76	2.00000	5.77419	0.33817	-3.77419	-2.04 R
80	2.00000	5.77419	0.33817	-3.77419	-2.04 R
83	8.00000	4.00000	0.33817	4.00000	2.16 R
103	8.00000	4.00000	0.33817	4.00000	2.16 R
118	8.00000	4.10000	0.59540	3.90000	2.18 R
122	8.00000	4.00000	0.33817	4.00000	2.16 R
165	2.00000	6.12903	0.33817	-4.12903	-2.23 R
203	2.00000	6.12903	0.33817	-4.12903	-2.23 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	N	Mean	Grouping
McDonald's	41	6.0	A
Tyson	41	5.8	A
Quron	41	5.7	A
Boca	41	5.1	A B
Moofu	41	4.0	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable OverallTXT

All Pairwise Comparisons among Levels of Samp-Desc

Samp-Desc = Boca subtracted from:

Samp-Desc	Lower	Center	Upper	
McDonald's	-0.409	0.923	2.2544	(-----*-----)
Moofu	-2.396	-1.065	0.2673	(-----*-----)
Quron	-0.727	0.605	1.9366	(-----*-----)
Tyson	-0.682	0.650	1.9818	(-----*-----)

-2.0 0.0 2.0

Samp-Desc = McDonald's subtracted from:

Samp-Desc	Lower	Center	Upper	
Moofu	-3.319	-1.987	-0.6553	(-----*-----)
Quron	-1.650	-0.318	1.0141	(-----*-----)
Tyson	-1.604	-0.273	1.0592	(-----*-----)

-2.0 0.0 2.0

Samp-Desc = Moofu subtracted from:

Samp-Desc	Lower	Center	Upper	
Quron	0.3376	1.669	3.001	(-----*-----)
Tyson	0.3827	1.715	3.046	(-----*-----)

-2.0 0.0 2.0

Samp-Desc = Quron subtracted from:

Samp-Desc	Lower	Center	Upper	-----+-----+-----+-----
Tyson	-1.287	0.04516	1.377	(-----*-----)
				-----+-----+-----+-----
				-2.0 0.0 2.0

Grouping Information Using Tukey Method and 95.0% Confidence

Target	N	Mean	Grouping
2	155	5.4	A
1	50	5.3	A

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable OverallTXT
All Pairwise Comparisons among Levels of Target
Target = 1 subtracted from:

Target	Lower	Center	Upper	-----+-----+-----+-----+-----
2	-0.5297	0.07419	0.6781	(-----*-----)
				-----+-----+-----+-----+-----
				-0.35 0.00 0.35 0.70

Grouping Information Using Tukey Method and 95.0% Confidence

Samp-Desc	Target	N	Mean	Grouping
McDonald's	1	10	6.3	A
Tyson	2	31	6.1	A
Quron	2	31	5.8	A
McDonald's	2	31	5.8	A
Quron	1	10	5.6	A B
Tyson	1	10	5.4	A B
Boca	2	31	5.1	A B
Boca	1	10	5.1	A B
Moofu	1	10	4.1	A B
Moofu	2	31	4.0	B

Means that do not share a letter are significantly different.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable OverallTXT
All Pairwise Comparisons among Levels of Samp-Desc*Target
Samp-Desc = Boca
Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Boca	2	-2.164	0.029	2.222
McDonald's	1	-1.497	1.200	3.897
McDonald's	2	-1.519	0.674	2.868
Moofu	1	-3.697	-1.000	1.697
Moofu	2	-3.293	-1.100	1.093
Quron	1	-2.197	0.500	3.197
Quron	2	-1.455	0.739	2.932
Tyson	1	-2.397	0.300	2.997
Tyson	2	-1.164	1.029	3.222

Samp-Desc = Boca
Target = 2 subtracted from:

Samp-Desc = McDonald's
Target = 1 subtracted from:

Samp-Desc = McDonald's
 Target = 2 subtracted from:

Samp-Desc = Moofu
 Target = 1 subtracted from:

Samp-Desc = Moofu
 Target = 2 subtracted from:

Samp-Desc = Quron

Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Quron	2	-1.955	0.2387	2.432
Tyson	1	-2.897	-0.2000	2.497
Tyson	2	-1.664	0.5290	2.722

Samp-Desc	Target	
Quron	2	(-----*-----)
Tyson	1	(-----*-----)
Tyson	2	(-----*-----)

+-----+-----+-----+-----

-5.0 -2.5 0.0 2.5

Samp-Desc = Quron

Target = 2 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Tyson	1	-2.632	-0.4387	1.755
Tyson	2	-1.242	0.2903	1.822

Samp-Desc	Target	
Tyson	1	(-----*-----)
Tyson	2	(-----*-----)

+-----+-----+-----+-----

-5.0 -2.5 0.0 2.5

Samp-Desc = Tyson

Target = 1 subtracted from:

Samp-Desc	Target	Lower	Center	Upper
Tyson	2	-1.464	0.7290	2.922

Samp-Desc	Target	
Tyson	2	(-----*-----)

+-----+-----+-----+-----

-5.0 -2.5 0.0 2.5

Interaction Plot for OverallTXT