UTILIZATION OF PSYLLIUM HUSK (*PLANTAGO OVATE*) POWDER AS A FUNCTIONAL INGREDIENT IN A PROCESSED TURKEY PRODUCT

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UTILIZATION OF PSYLLIUM HUSK (*PLANTAGO OVATE*) POWDER AS A FUNCTIONAL INGREDIENT IN A PROCESSED TURKEY PRODUCT

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ABSTRACT

The high demand for convenient and flavorful products has kept the processed meat industry thriving, but the shift for developing more functional products is on the rise. Meat has a high potential to be an excellent matrix for functional ingredients, but a large portion of the previous research involves using nonmeat ingredients as binders, fat replacers, or as a cost reduction. Currently, there is limited published research that tries to develop a functional meat product that contains dietary fiber.

Therefore, the primary objective of this first study was to determine if 0, 0.6, 1.0, and 1.5% psyllium husk powder had an effect on the functional properties of a restructured ground turkey product. Results showed that as the fiber percentage increased the cooking yield, moisture content, and water holding capacity of the product also increased. The psyllium husk powder had minimal effects on the water activity value, but results did show a significant ($P < 0.05$) decrease in pH and binding strength as the fiber percentage increased. However, these differences may be statistically different but there is no basis to determine if they are different at a consumer level. Thus, it was determined that a subsequent study is required to upscale the product and fiber levels and to also include a consumer taste panel.

The second phase of this study involved using the Genesis R&D Food Formulation and Labeling Software to model a ground turkey product that would contain either 0, 1, 2, or 3 g of dietary fiber per 55 g serving. From there, the psyllium husk powder (PHP) percentages (0, 1.6, 6.4, and 12.8%) were incorporated into a 24-pound meat block that would be subjected to functionality testing and sensory evaluation. The 6.4 and 12.8% PHP treatments resulted in the highest significant ($P < 0.05$) cook yield values, 90.0 and 90.6%, respectively. Additionally, the 1.6 and 6.4% PHP treatments observed the highest percentages for moisture, 70.1 and 69.4%, respectively. As the fiber percentage increased within the meat block, the parameters for texture profile analysis (hardness, springiness, cohesiveness, gumminess, chewiness, and resilience) and water holding capacity also increased. Fortunately, there were no significant ($P > 0.05$) differences observed for pH and water activity.

During the sensory evaluation there were two significant ($P < 0.05$) differences observed. As the percentage of fiber increased the consumers' "degree of liking" for flavor and appearance decreased. There was no significant ($P > 0.05$) difference calculated for texture. Overall, consumers were less willing (only 5%) to purchase the product that contained the 3 g of dietary fiber, but the 1.6% PHP or product with 1 g of dietary fiber was not statistically different from the control sample in all categories. So, in summary, it can be stated that using psyllium husk powder can benefit the functional properties of a processed turkey product and be used at levels adequate enough to produce a meat product that contains 1 g of dietary fiber.

CHAPTER 1: INTRODUCTION

The global demand for protein is continually growing throughout the years (Sikes 2017). Animal and plant meat are the main sources of protein, B-complex vitamins, iron, and zinc (Arihara 2006). Meat intake does vary globally, but within the United States animal protein composes more than 15% daily energy, 40% daily protein, and 20% daily fat intake (Hiza and others 2008). Likewise, the United States has the most affordable and safe food supply (Sikes 2017). Consumers are constantly changing and demanding more fresh, healthy, sustainable, and convenient products (Sikes 2017). New food trends include natural ingredients, clean labels, food waste reduction, nutrition, and meal kits (Wulf 2017).

Additionally, consumers are searching for products that contain a motivational, emotional, and personal aspect (Wolf 2017). These food values are causing shifts between Baby Boomers', Millennials', and Generation Zs' purchasing decisions. Today, 94% of Americans spend a portion of their day snacking (Wolf 2017). More than half of snacking involves consumers searching for a specific product to satisfy hunger (Wolf 2017). Fortunately, retail stores are observing an increase in sales for salty and meat-oriented snacks (Proper 2017). This dietary shift has created a pattern of increased meat consumption as well as cereals and other plant-based products (Krebs-Smith 1998; Terry and others 2001).

Sixty-one percent of consumers pursue products that are high in protein; however, fifty-seven percent also pursue products high in fiber (Proper 2017). Likewise, consumers ranked fiber among the top ten functional foods due to its associated health benefits (Niba 2012). Previous research has demonstrated fibers can function in meat products as fat substitutes, emulsifiers, texture improvers, and increasing cook yield (Huber and others 2016). Specific fibers that have already been tested in meat products include pea, wheat, bamboo, soy, apple, oat, and potato (Huber and others 2016; Besbes and other 2008). Fruit and vegetable fiber sources are discovered to contain better nutritional quality over cereal fiber due to its presence of bioactive compounds (Vergara-Valencia and others 2007). Additionally, processed by-products such as husks and peels are found to be rich in antioxidant agents and nutraceuticals (Chau and Huang 2003).

Psyllium is obtained from the seeds of the *Plantago* plant, and 85% of its production lies within the country of India (Raymundo and others 2014). The husk of psyllium is separated from the seeds through mechanical milling to form a white fibrous hydrophilic material and/or clear mucilaginous gel (Raymundo and others 2014). This solution contains roughly 80% soluble fiber and is an excellent source of both soluble and insoluble fractions (Raymundo and others 2014). The active psyllium gel is a natural polysaccharide used for treating high cholesterol, diabetes, obesity in children, constipation, diarrhea, bowel diseases, and ulcerative colitis (Singh 2007). The use of this ingredient has become widespread in the United States due to the approved FDA health claim for reducing the risk of coronary heart disease (FDA 2012) The application of psyllium husk powder has appeared in biscuit and pasta research formulations (Fradinho and others 2015). However, the use of this dietary fiber has not been studied in the application of a processed meat product. Therefore, the objectives of this study are

1.1 Objectives

1. Determine the functional effects of 0, 0.6, 1.0, and 1.5% psyllium husk powder in a restructured (calcium alginate) ground turkey product.

2. Determine the effect of different dietary fiber levels of psyllium husk powder (0, 1g, 2g, or 3g) on the functional properties of a processed ground turkey product.

3. Determine consumer preferences for a processed ground turkey product containing the dietary fiber additive.

CHAPTER 2: LITERATURE REVIEW

2.1 Meat

Low meat intake recommendations can overlook the fact that meat is an important source of protein, iron, selenium, vitamins A, B12, folic acid, and zinc. This reasoning is because meat is either the only source or has a higher bioavailability of these essential micronutrients (Biesalski 2005). Vitamins A and B12 cannot be compensated by plant derived provitamins, because provitamin B12 does not exist and the provitamin A requires a high dosage due to a poor conversion rate (1:12). Similarly, iron and folic acid have a higher bioavailability when derived from meat (Biesalski 2005).

The vitamin B12, riboflavin, and selenium intake of vegans and vegetarians can become easily inadequate, and the use of supplements often do not meet the recommend daily allowance (RDA). One hundred grams of low-fat pork meat or pig liver contains 1.8 mg iron, 2.6 mg zinc or 360 mg magnesium, 20 mg iron, and 60 μg selenium, respectively (Anderson and others 1986; Boelsma and others 2001). These two animal-based sources can cover up to 50% of the RDA for iron, zinc, selenium, and vitamins B1, B2, and B6 (Anderson and others 1986; Boelsma and others 2001). Overall, consuming meat along with a balanced diet can benefit human health and development through micronutrient and amino acid delivery and energy metabolism (Biesalski 2005).

2.2 Micronutrients

2.2.1 Iron

Iron is one of most abundant elements on Earth, but it is also one of the most common nutritional disorders present (DeMaeyer and Adiels-Tegman 1985). Within the human body, iron supports oxidative metabolism, gas exchange at the tissue and cellular level, energy metabolism, and host-defense responses (Beard and others 1996; Griffiths 1996). Iron deficiencies are a result of various reasons; however, the composition of an individual's diet can vary the iron bioavailability by a 5- to 10-fold (World Health Organization 1992) factor. According to Biesalski (2005), "the different bioavailability depends on the presence or absence of different ligands which can form complexes with iron and zinc and block their absorption". Studies have shown that a diet primarily composed of vegetables, rice, beans, and corn is associated with poor iron bioavailability (Biesalski 2005).

2.2.2 Selenium

In the United States, selenium is derived from various cereals, breads, meats, and meat products. According to van der Torre and others (1991), "Beef alone is estimated to contribute approximately 17% of the total selenium in the American diet." This antioxidant functions as a cellular protector against free radical oxidative damage and properly maintaining the immune system (Clark and others 1996; Thane and Bates 2001). Geographical areas with low soil selenium content (Europe) are recommended to consume sources that contain high amounts of selenium with good bioavailability (Rayman 1997, 2000). Xia and others (1992), concluded that "the bioavailability of selenium from beef is higher than, or at least equal to, that of selenite and slightly lower than that of L-selenomethionine"; thus, concluding that meat is an important source of bioavailable selenium.

2.2.3 Vitamin A and B12

Vitamin A is essential for the growth and development of cells and tissues especially within the respiratory epithelium and lungs (Kurokowa and others 1994). In addition, vitamin A is responsible for cell and tissue formation during embryonic lung development. Consequently, a moderate vitamin A-deficiency can cause an increase occurrence of lung infections and diseases (Pinnock and others 1986; Sommer 1993; West and others 1991). Fortunately, meat and liver sources (100 g/day) can cover 100% of the vitamin A recommended daily allowance and 50% vitamin B12 (Anderson and others 1986; Boelsma and others 2001). Vitamin B12 is only found in animal products and is required to properly maintain function and development of the brain, nerves, and blood cells (WebMD 2018).

2.2.4 Folate (Folic Acid)

Folate is a water-soluble B-vitamin that is naturally found in vegetables, fruits, nuts, beans, dairy products, meat, eggs, seafood, and grains (NIH 2016). This vitamin functions as a methyl donor in the synthesis of nucleic acids and metabolism of amino acids and aids in proper cell division (Bailey and Gregory 2006; IM 1998; Carmel 2005). Though fruits and vegetables are key sources of folate, the bioavailability of folate from meat and liver sources is higher (Biesalski 2005).

2.2.5 Zinc

Red meat and poultry provide the most zinc intake within the American diet; however, other key sources include oysters, dairy products, grains, legumes, and vegetables (Groff and Grooper 2000; IM 2001; USDA 2011). This mineral is a key factor in cell growth and replication, osteogenesis, immunity, and DNA synthesis (Groff and Grooper 2000; IMFNB 2001; Prasad 1995). The bioavailability of zinc is higher for meat and poultry sources rather than legumes and grains, because meat does not contain phytates which can inhibit the absorption of zinc (Hunt 2003; ADA 2003).

2.3 Processed Meat Products

Processed meats are a variety of products that have been cured, salted, or smoked to enhance the flavor or extend the shelf life for daily or occasional consumption (Bouvard and others 2015). Since processed meats derive from fresh meat sources, they do still contain naturally beneficial proteins, vitamins, and minerals (Decker and Park 2010). The demand for convenience and good taste has allowed processed meats to remain a stable product within the market and consumers' diets (Grunert 2006).

2.4 Functional Meat Products

Menrad (2003) and Roberfriod (2000) agreed that "today, foods are not intended to only satisfy hunger and to provide necessary nutrients for humans, but to also prevent nutrition-related diseases and improve physical and mental well-being of the consumers."

According to the European Commission (2010), “A food can be regarded as functional if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease. It is consumed as part of a normal food pattern. It is not a pill, a capsule or any form of dietary supplement.” Unfortunately, the meat industry is one of the least trusted food sectors today; thus, why the industry has an opportunity to develop healthier processed meat products (European Commission 2012). Meat has the potential to be an excellent matrix for functional foods because it appeals to a wide range of consumers, is very versatile, and contains high quality nutrients (Grasso and others 2014).

Generally, consumer acceptance of functional foods can vary depending on social, economic, geographical, political, cultural, and ethnic backgrounds (Jimenez-Colmenero and others 2001). Japan was the first country to develop the idea of functional foods, and as of 2013, thirteen “Foods for Specified Health Use” (FOSHU) meat products were approved into the market (Hardy 2000; Kwak and Jukes 2001; Anonymous 2013). These functional foods within Japan are considered a distinct product category, and the health benefiting functions supersedes product taste (Siro and others 2008). The United States has an estimated market share of more than 50% for the total functional foods market. The European functional foods market has been steadily increasing with consumers in central and northern countries favoring functional food products (Menrad 2003). The United States and Europe perceive functionality as adding into an existing product category rather than creating a separate group (Siro and others 2008). Traditional methods to help create healthier meat products include reducing fat, cholesterol, sodium, and nitrite/nitrate content and modifying fatty acid profiles (Grasso and others 2014). Recently, new innovative techniques to create healthier meat products include using starches, cereal flours, hydrocolloids, collagen derivatives, blood, milk, and plant proteins, and fibers (Petracci and others 2013).

2.5 Poultry Products

Over the past few decades the consumption of poultry meat has been increasing. Poultry meat has become very favorable due to high-protein content, low-fat content, omega-3/6 fatty acids, low cholesterol, neutral flavor, consistent texture, light color, lower pricing when compared to red meat, and no cultural/religious effects (Cavani and others 2009). Processed poultry products can be divided into four main categories: whole muscle ("intact muscle cells with water entrapped in cellular and extracellular spaces"); formed/restructured ("chunks or pieces of meat that are bonded or glued together"); course ground ("ground meat with still recognizable meat fibrous structure"); and emulsified ("meat batters with solubilized muscle proteins, muscle fibers, fragmented myofibrils, fat cells, and droplets") (Petracci and others 2013). Each product category functions to achieve various goals such as brine retention, increase cook yield, optimal texture, meat binding, water retention, and stability during processing (Givens and others 2011).

2.6 Restructured Meat

Within the meat industry, the term "restructuring" can be defined by Pearson and Gillett (1999): "a group of procedures that partially or completely disassemble meat and then bind together the meat pieces to form a cohesive mass that resembles an intact muscle." Since this definition encompasses a variety of meats, restructured meat products can be classified according to the degree of comminution and the preparation process (Pearson and Gillett 1999). According to Secrist (1987), the advantages for restructuring meat products include: ease of slicing, accurate portion control and yield, decrease cook loss, color, texture, and fat uniformity, reduce carcass/product waste, and additional nutritive value. Since the early 1970's, the need for restructured products has been increasing because of lifestyle changes, smaller family sizes, the need for leaner and less fat products, and convenience (Mandigo 1988; Sun 2009). The process of restructuring meats can be utilized using either a hot- or cold-set binding system.

2.7 Cold-Set Binding

2.7.1 Calcium Alginate Gelation

Typically, the main sources of gelatin used within a variety of industries has been pigskin and cattle bones and hides. Recently though, gelatin replacements have been a major issue within the vegetarian, halal, and kosher markets (Karim and Bhat 2008). Ideally, gelatin alternatives should possess six main characteristics: "melt-in-the-mouth" property, thermally reversible gel, surface activity, multi-functional, tailor-made application, and easy to use (Karim and Bhat 2008).

Hydrocolloids are derived from plant or marine sources that function as a hydrophilic polymer forming either a gel or viscous solution. The most common hydrocolloids used within poultry meat products are carrageenans and alginates (Petracci and others 2013). Alginate is the salt of alginic acid and a polysaccharide derived from the brown algae of the class Phaeophyceae (Clarke and others 1988; Al-Joher and Clarke 1993; Schaake and others 1993; Boles and Shand 1998; Feiner 2006a). Structurally, sodium alginate is made from β-D-mannuronic acid and α-L-guluronic acid. These acids are represented as homopolymeric regions named M- or G-alginate or copolymeric region (MG). The ratio of 0.5 (G-alginate): 2 (M-alginate) appears to provide the strongest gelling properties and will remain stable in a pH range between 5.0 and 9.5 (Feiner 2006; Borgogna and others 2013).

The process of using the alginate binding system was first patented by researchers at Colorado State University in 1986 (Lamkey JW 2011). This thermo-irreversible gel is formed when sodium alginate, a calcium source, and an acidifier are thoroughly mixed within the raw meat pieces (FMC Biopolymer 2001; Farouk 2010). During mixing, the meat batter begins to slowly gel, and the meat mixture can be molded or encased without disturbing the binding system (Means and others 1987). This type of gelation is time and temperature sensitive. Commonly, 6 to 24 hours at 0-4ºC is needed to allow the calcium to become fully solubilized and chemically induce the alginate gelation (Farouk 2010).

To prevent pre-gelation, the calcium source must have slow releasing properties and be the last ingredient incorporated (Farouk 2010; Boles 2011). Typically, calcium carbonate is used because it is inexpensive and has slow releasing properties which require an acidifier to help initiate solubilization (Boles 2011). Glucuronic acid has a high affinity for divalent cations; thus, the alginate can react with the available calcium ions during solubilization and form an “egg-box” structure (Means and Schmidt 1987; Boles 2011). This gel is then able to interact with the myofibrillar proteins through electrostatic interactions of the alginate anionic groups and the protein cationic groups (Shand and others 1993; Montero and others 2000).

Originally, glucono-delta-lactone (GDL) was the acidifier used within this system at Colorado State University, but the use of encapsulated lactic acid has also shown to perform the same binding strength when compared to other acidifier sources (Esguerra 1994). Therefore, meat processors are recommended to use 0.6% sodium alginate, 0.6% organic acid, and 0.2% calcium carbonate to ensure maximum binding strength within the meat matrix and no off-flavor development (Esguerra 1994; Boles and Shand 1998, 1999).

2.8 Dietary Fiber

According to The American Association of Cereal Chemists (2018), “Dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine.” Sources of dietary fiber range between polysaccharides, lignin, inulin, and resistant starches (Jones and others 2006). Past research has shown that dietary fiber reduces the risk of coronary heart disease, stroke, hypertension, diabetes, obesity, and certain gastrointestinal disorders (Liu and others 1999; Steffen and others 2003; Whelton and others 2005; Montonen and others 2003; Lairon and others 2005; Petruzziello and others 2006; Eastwood 1992). The current recommendations for dietary fiber intake are relevant to an individual’s age, gender, and energy intake. Generally, women consuming 2000 kcal/day are recommended to intake 28 g of dietary fiber per day, and men consuming 2600 kcal/day are recommended to intake 36 g of dietary fiber per day (USDA 2005). Regrettably, most Americans consume less than half of the dietary fiber recommended daily intakes; hence, why fortification of meat products could have potential health benefits (Park and others 2005; Decker and Park 2010. Likewise, previous research conducted at the University of Missouri has utilized citrus fiber as a functional ingredient in meatballs (Gedikoglu 2015). The results and conclusions of that study have interested the investigators to continue research in developing fiber fortified meat products. Fiber from oat, sugar beet, soy, apple, and pea have been formulated within various meat patties and sausages (Cofrades and others 2000; Keeton 1994; Troutt and others 1992); however, there has been little to no research done with incorporating psyllium husk powder into a meat product.

2.9 Psyllium Husk (*Plantago ovate*) Powder

Psyllium husk (isabgol or ispaghula) is derived from the *Plantago* species and is commercially dominated within the Indian market (Raymundo and others 2014; Bijkerk and others 2004). Recent years have shown an increase consumption of psyllium within the European and American market (Fradinho and others 2015) due to, the approved FDA (2012) claim that psyllium soluble fiber is associated with reducing the risk of coronary heart disease. Psyllium contains roughly 80% soluble fiber, 23% arabinose, 75% xylose, a small amount of sugars, and 35% non-reducing terminal residues. This polysaccharide is highly branched containing both (1-4) and β-(1-3) glycosidic linkages in the xylan backbone (Fischer and others 2004).

A white fibrous mucilage is obtained through mechanical milling of the psyllium seed coat. This mucilage or dried powder has extremely strong water uptake and gelling capacities (Bijkerk and others 2004) and can remain stable over a variety of pH values and temperatures (Ibuki 1989). According to Kristensen and Jensen (2011), “1 gram of psyllium is able to retain about 10 grams of water.” Products that contain at least 1.7 grams of psyllium soluble fiber per reference amount usually consumed are eligible for the FDA (2012) approved reduced risk of coronary heart disease health claim. Fortunately, this is an important marketing advantage with products enriched with psyllium; however, formulations with adequate levels for the health claim can become challenging (Cheng and others 2009).

2.10 Functionality Properties

2.10.1 Cook Yield

The cooking yield of a product describes the change in raw to cooked weight due to moisture loss, water absorption, or fat lose during preparation (Showell and others 2012; Roseland and others 2014). This percentage is valuable information because it can indicate whether certain cooking methods, types of meat, and/or ingredients affect the overall yield of one’s product. Likewise, this data can also be used for developing nutrient estimates and food plans/preparations (Showell and others 2012; Roseland and others 2014). According to the USDA’s Table of Cooking Yield for Meat and Poultry

(2014), turkey, retail parts (breast, drumstick, thigh, or wing meat and skin), enhanced and non-enhanced averaged a cook yield of 68 and 73.8%, respectively. Therefore, these results indicate that turkey retail parts do have potential to be further processed with additional ingredients to create higher cooking yields.

2.10.2 Moisture Content

All meat and poultry are composed of natural water, proteins, connective tissue, fat, and bone. The naturally occurring water may differ within meat and poultry because of the types of muscle and meat, fiber structure, pH, and yearly season (USDA 2013). Leaner cuts, such as poultry, will have a slightly higher average water content on a per weight basis from the increase of protein content and decrease in fat. On average, cooked poultry products will have a moisture content value ranging between 60 and 70% (USDA 2013). In general, there seems to be a negative correlation between degree of doneness and moisture loss. The greater degree of doneness causes more moisture loss within the product; however, the loss is also dependent on water-holding capacity, lipid translocation, and subcutaneous fat (USDA 2013; Aberle and others 2012a). Determining moisture can be accomplished using a drying oven, vacuum oven, moisture balance, or azeotropic distillation (Clarke 2004).

2.10.3 pH

Potentia hydrogeni or pH refers to the negative logarithm to the base 10 of the hydrogen-ion concentration. Feiner (2006b) explains: “a change of 1 pH unit indicates a tenfold change in the hydrogen-ion concentration”; thus, why pH is an important value regarding color, shelf-life, taste, microbiological stability, yield, and texture. Generally, the pH of a processed meat product will range between 4.6 and 6.4, depending on product category. Unfortunately, any product pH near the value of 6.4 or higher is more susceptible to spoilage, off-odors, and discoloration (Feiner 2006b).

2.10.3.1 Dark. Firm, and Dry (DFD) Meat

The meat quality condition called dark, firm, and dry (DFD) can occur in a small percentage of beef, lamb, and pork products due to long term (>24hrs) exposure to stress. During glycolysis, a large portion of the glycogen and ATP levels are already used up, so there will not be enough substrate present to start postmortem at a normal rate (Aberle and others 2012b). Products experiencing this type of abnormal condition have a higher (above 5.6) ultimate pH value, darker color, and tighter muscle structure. This pH difference can cause these products to have a higher water-holding capacity, higher growth of microorganisms, normal tenderness values, higher juiciness, and an intense/salty flavor (Aberle and others 2012b).

2.10.3.2 Pale, Soft, and Exudative (PSE) Meat

Pale, soft, and exudative (PSE) meat commonly occurs within the pork industry but can also occur within poultry. This condition occurs when animals are exposed to short term (<24hrs) stress before slaughtering. The speed of glycolysis increases within the live animal and causes the ultimate pH to decrease below the normal value (5.6)

(Aberle and others 2012b). Fortunately, this condition does not have an adverse effect on microbial growth, but will cause lower water-holding capacity, lighter color, loose/grainy muscle structure, and a dry/bland product (Aberle and others 2012b).

2.10.4 Water Activity

Water activity is an important value within the meat industry because it can cause severe changes within appearance, physical behavior, and shelf-life. Water activity can be calculated by dividing the vapor pressure of the food (at a certain temperature, ºC) by the vapor pressure of pure water at the same temperature (Feiner 2006c). An important factor to note is that water activity is only evaluating how much unbound or free water is within the food matrix. Fresh meat and many cooked sausages have a water activity value around 0.98 or 0.97. The reduction of water activity can be achieved through removing water, binding water through ions, reducing how much water is added into the product, or immobilizing water (Feiner 2006c).

2.10.5 Water Holding Capacity

The authors of *Principles of Meat Science* (Aberle and others 2012c) state that water-holding capacity is “the ability of meat to retain naturally occurring or added moisture during the application of any external force.” The strong or weak ability to hold water within a meat matrix can affect other properties such as color, tenderness, and juiciness (Aberle and others 2012c). Water present within a meat matrix adheres to one of three forms: bound, immobilized, or free. Bound water is tightly associated with the meat proteins and does not become lost during mechanical or physical action. Immobilized water refers to the water that is not readily available but will become lost during the cooking process and when pressure is applied. Lastly, free water contains weak surface forces and will become lost during the aging, fabrication, and rigor mortis process (Aberle and others 2012c).

Researchers have developed three theories that can explain the loss or gain of water. The **net charge effect** occurs when the H^+ concentration exceeds the muscle cell's buffering capacity during postmortem metabolism. The increase in H^+ concentration causes the pH to drop and reduces the net charge across all muscle cell proteins (Aberle and others 2012c). The change in protein charge can affect the amount of protein solubility, degradation, and its interactions with water. Unfortunately, if the pH drop is close to the isoelectric point (5.2-5.0) the positive and negative charges within the protein structure will attract and be less capable of binding water. As a result, meat that has experienced normal postmortem metabolism will loss one-third of its water-holding capacity due to this net charge effect (Aberle and others 2012c).

The physical changes, **steric effect**, that occur within myofibrils are caused by little net charging proteins. This lack of charge prevents repulsive forces from separating the proteins, and from binding water within the matrix. The proteins can become tightly packed during the permanent formation of actin and myosin cross-bridges, or when divalent cations (Ca^{2+} or Mg^{2+}) attach and neutralize the reactive protein groups (Aberle and others 2012c). Fortunately, after the completion of rigor mortis meat can improve water retention.

During postmortem proteolysis, the myofibril structure is disrupted and swells. The swelling decreases membrane integrity and forces a redistribution of ions where some divalent ions can be replaced by monovalent ions (Na^+). Over time, as one divalent cation is replaced, one protein reactive group is freed to bind water. This phenomenon is referred to as the **exchange of ions** theory (Aberle and others 2012c). Common methods for determining water-holding capacity are free drip and bag drip (no force), centrifugation and filter paper press method (mechanical force) and cook loss (thermal force) (Aberle and others 2012c).

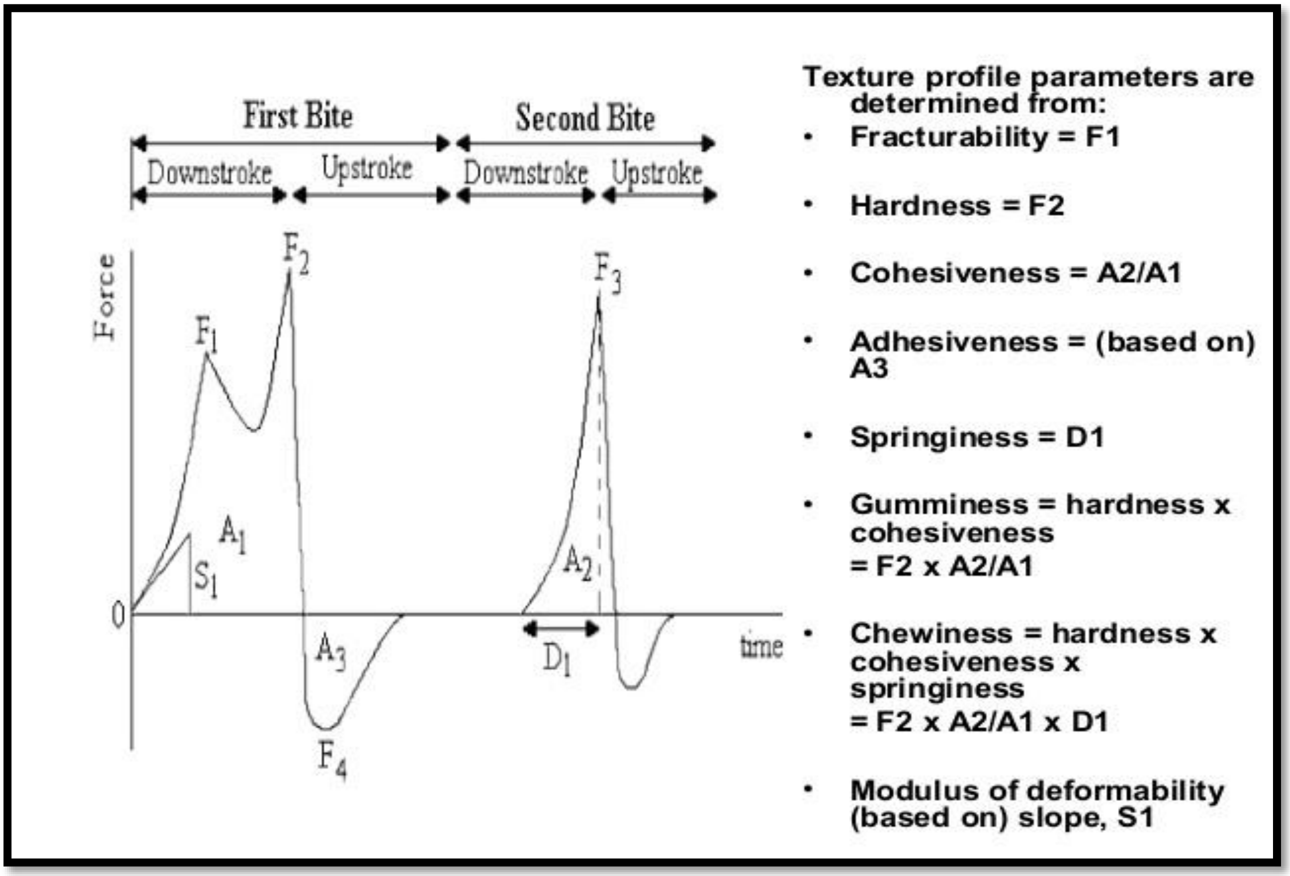
2.10.6 Texture Profile Analysis

Unfortunately, analyzing texture is one of the least well-described organoleptic food attributes. Most previous work regarding food texture only dealt with specific characteristics within a specific food product (Szczesniak 1962). Even the definition of the word “texture” can have multiple meanings: “the disposition or manner of union or the particles of a body or substance” (Merriam-Webster 2018); “how hard or how soft the food mass” (Hall and Fryer 1953); “the rigidity of solid units of food” (Smith 1947); or “the attribute of a substance resulting from a combination of physical properties and perceived by the touch, sight, and hearing senses” (Jowitt 1974). To find an appropriate definition for grading meat quality, Ball and others (1957) constructed the “sight” and “feel” organoleptic properties of raw and cooked meat. The “sight” definition refers to the “the microscopic appearance of muscle tissue from the smoothness or fineness of grain.” The “feel” definition refers to the “feel of smoothness or fineness of the muscle tissue in the mouth” (Ball and others 1957).

These definitions conclude that texture is mainly resulting from the geometrical and mechanical characteristics, but also other characteristics such as moisture and fat content (Ball and others 1957). Mechanical characteristics can be determined by the reaction of food to stress through the pressure exerted during chewing by the teeth, tongue, and roof of mouth. Geometrical characteristics are mainly sensed visually but can refer to the size and shape of the particles and their orientation. Lastly, the moisture and fat content can reflect the perceived amount, rate, and manner of liquid released in the mouth (Szczesniak 1962). Adversely, many of the perceived problems regarding restructured meat texture are excessive/insufficient binding, pocket formation, excessive connective tissue, and inconsistent uniformity (Berry 1987).

The equipment first used to measure food texture was with the General Foods Texturometer (Friedman and others 1963). This device was designed to imitate the motion of the human jaw during the first bites of a food product using a small cylindrical disk and a two-cycle compression test (Bourne 2002). Today, the results obtained from this two-cycle compression test can be classified as the texture profile analysis (TPA) and can determine individual parameters such as hardness, springiness, cohesiveness, gumminess, chewiness, and resilience (Figure 2.1).

Hardness refers to the force required to obtain a given deformation and will be the highest peak during the first bite compression test (Lormond 1976; Banjare and others 2015; Szczesniak 1962). The term springiness refers to the height of the sample during the force relaxation time between the first and second bite compression tests (Patel and others 2006). Cohesiveness is explained by how well a food product can stay together after deformation and is calculated by dividing the area under the first peak by the area under the second peak (Lormond 1976; Banjare and others 2015). Gumminess is “the energy required to disintegrate a semisolid food product into a state ready for swallowing” (Szczesniak 1962; Lormond 1976) and can be calculated by multiplying the values of hardness and cohesiveness. Chewiness is defined as “the energy required to masticate a solid food product into a state ready for swallowing” (Szczesniak 1962) and is calculated by multiplying the hardness, cohesiveness, and springiness values (Patel and others 2006). Lastly, resilience is a “measurement of how a sample will recover from deformation in relation to the speed and force used” (Baker pedia 2018).



Texture profile parameters are determined from:

- **Fracturability = F1**
- **Hardness = F2**
- **Cohesiveness = A2/A1**
- **Adhesiveness = (based on) A3**
- **Springiness = D1**
- **Gumminess = hardness x cohesiveness = F2 x A2/A1**
- **Chewiness = hardness x cohesiveness x springiness = F2 x A2/A1 x D1**
- **Modulus of deformability (based on) slope, S1**

Figure 2.1 Simulation of TPA Curve with Texture Parameters (Puranik and Mishra 2013).

2.11 Sensory Evaluation

Since the 1960's, sensory evaluation has become a useful tool for accurately measuring human responses and sensory properties of food without creating biasing environments (Lawless and Heymann 2010). The three main testing methods used within sensory evaluation are discrimination, descriptive, and affective. The affective class attempts to quantify the degree of liking or disliking consumers may have with certain products. Usually individuals are offered a choice among different alternative products and a clear preference is determined by majority rule (Lawless and Heymann 2010). During the 1940's, the U.S. Army Food and Container Institute developed the classic 9-point hedonic scale that is commonly used today during affective sensory evaluation: *9- "Like Extremely"; 8- "Live Very Much"; 7- "Like Moderately"; 6- "Like Slightly"; 5- "Neither Like nor Dislike": 4- "Dislike Slightly"; 3- "Dislike Moderately"; 2- "Dislike Very Much"; and 1- "Dislike Extremely"* (Lawless and Heymann 2010).

2.12 Consumer Insight

Developing new products within the meat industry can fall into either the processing or differentiation dimension (Grunert and others 2011). The success of any new product will highly depend on consumer acceptance and the intended product user (Moskowitz 1985). Five big factors that influence the demand for meat and meat products in the U.S. today are increased health concerns, demographics, convenience, distribution change, and price (USDA/ERS 2002). Over the past few years, the meat industry has been striving to reformulate or introduce innovative products that have improving nutritional and health properties (Toldra and Reig 2011)

According to Van Kleef and others (2005), producers should explore what diseases/health concerns consumers most fear and try to develop products that prevent or reduce those risks. Many surveys conducted by (Drbohlav and others 2007; Hilliam 1998; Keller 2006; Korzen-Bohr and O'doherty Jensen 2006; Van Kleef and others 2002, 2005) concluded that consumers are primarily concerned with cardiovascular disease, stress, high blood pressure, digestive diseases, arthritis, and obesity. Therefore, adding functional ingredients that have had a longer awareness (fiber, vitamins, or minerals) can achieve higher consumer acceptance rates when compared to those functional ingredients with shorter time line (flavonoids, carotenoids, or omega-3 fatty acids) (Bech-Larsen and Grunert 2003; Bech-Larsen and Scholderer 2007; Krygier 2007; Urala and Lähteenmäki 2007). Generally, consumers found enrichment of "non-healthy" foods to be more justified when compared to food that were already perceived as healthy; thus, opens a market for the meat industry to begin designing healthier processed meat products (Jonas and Beckmann 1998; Poulsen 1999; Bech-Larsen and Grunert 2003).

CHAPTER 3: EFFECTS OF PSYLLIUM HUSK (*PLANTAGO OVATE*) POWDER ON A COLD-SET RESTRUCTURED GROUND TURKEY PRODUCT

3.1 ABSTRACT

The objectives of this study were to determine the effects of 0, 0.6, 1.0, and 1.5% of psyllium husk powder in a restructured turkey product. It was observed that as the concentration of fiber increased the binding strength and pH of the cooked samples significantly ($P < 0.05$) decreased. However, cooked treatments with the psyllium husk powder did have a significantly ($P < 0.05$) higher water holding capacity than the control. Both cook yield and moisture content observed the same statistical difference pattern. The 1.0 and 1.5% psyllium husk powder treatments had significantly ($P < 0.05$) higher cooking yield and moisture percentages, 80.0%, 70.2%, 81.2%, and 70.6%, respectively, compared to the control. Finally, adding the fiber did have a variable effect on water activity, the cooked 0.6% PHP treatment had a significantly ($P < 0.05$) lower value, 0.987. Overall, the use of psyllium husk powder had beneficial characteristics in the restructured product. The differences in texture are reasoning to include sensory evaluation in this next study. The appearance, texture, and flavor of the product are important for development and the consumers. Another step to include is calculating different fiber percentages for proper serving levels; however, this can become a limitation and a challenge within the next project.

3.2 INTRODUCTION

Incorporating various meat products within a balanced diet can provide essential nutrients and energy. The demand for convenient and great tasting products have evolved the processing meat industry (Grunert 2006). Fortunately, consumers are demanding more functional food products that not only satisfy hunger but also assist in preventing/reducing health-related diseases (Menrad 2003; Roberfroid 2000). Known sources of dietary fiber have been shown to reduce the risk of coronary heart disease, stroke, hypertension, diabetes, obesity, and certain gastrointestinal disorders (Liu and others 1999; Steffen and others 2003; Whelton and others 2005; Montonen and others 2003; Lairon and others 2005; Petruzziello and others 2006; Eastwood 1992). Over recent years, the FDA (2012) has approved that the consumption of psyllium husk (at least 1.7 g soluble fiber per reference amount usually consumed) will reduce the risk of coronary heart disease.

Previous research has shown beneficial outcomes of using various vegetable, fruit, and cereal fibers within a processed meat product as fat replacers, emulsifiers, texture improvers, or to increase overall cook yield (Arihara 2006; Fradinho and others 2015; Jimenez-Colmenero and others 2001; Huber and others 2016). Unfortunately, at this moment, there has been no current research utilizing psyllium husk within a processed meat product. Therefore, the objective of this study was to determine how various levels (0, 0.6, 1.0, and 1.5%) of psyllium husk powder effect the functional properties of a restructured, ground turkey product.

3.3 MATERIALS AND METHODS

3.3.1 Materials

Honeysuckle White 85% lean/15% fat ground turkey (Cargill Meat Solutions Corp.) was obtained from a local grocery store in Columbia, Missouri. The GRINDSTED® Alginate FD 155 ingredient was obtained from DuPont Nutrition & Health (DANISCO) (New Century, Kansas). PrimeCAP® Lactic Acid 50-135 was supplied from Innovative Food Processors (Hayfield, MN). The MICRO-WHITE® 50/CODEX, calcium carbonate, was obtained through the E.C.C. America Inc. (Sylacauga, AL). Finally, the organic psyllium husk powder was obtained at another local grocery store in Columbia, Missouri.

3.3.2 Sample Preparation

Ground turkey was bought at the local grocery store prior to starting the project and was kept in a freezer (at least -10 ºC) until needed. Each trial required the ground turkey to be thawed before treatment formulation began. Meat, dry ingredients, and water were weighed out for the four different treatments labeled as Control (C), 0.6% psyllium husk powder (PHP), 1.0% PHP, and 1.5% PHP. Table 3.1 below provides in detail the formulation for each treatment. Water was added at constant level of (5%) to each treatment batch rather than using the USDA added water constant (Eilert and others 1993). The USDA added water constant would have required varying levels of water added into each batch, but the aim of this project was to isolate the effects of only the psyllium husk powder (Eilert and others 1993). Likewise, the ingredients used for the calcium alginate system were kept at constant levels during the entire experimental design.

Table 3.1 Treatment Formulation for Adding Psyllium Husk Powder into a Cold-Set Restructured Ground Turkey Product.

Treatment	Ground Turkey	Sodium Alginate	Encapsulated Lactic Acid	Calcium Carbonate	Distilled Water	Psyllium Husk Powder
Control	93.5%	0.6%	0.6%	0.3%	5.0%	________
0.6% PHP	92.9%	0.6%	0.6%	0.3%	5.0%	0.6%
1.0% PHP	92.5%	0.6%	0.6%	0.3%	5.0%	1.0%
1.5% PHP	92.0%	0.6%	0.6%	0.3%	5.0%	1.5%

Each treatment was mixed using a Kitchen Aid® mixer (St. Joseph, MI) for two minutes at a level 2 speed. After mixing, the meat batter was transferred into a LED Products, INC. Original Jerky Cannon. This device allowed each treatment to be appropriately stuffed into eight separate 50 mL polypropylene tubes. Picture 3.1 below illustrates the filled tubes of the uncooked samples for each treatment prior to cooking.

Picture 3.1 Stuffed Tubes Containing each Treatment before being Cooked via Water Bath.

After each mixing and stuffing, the equipment used was properly cleaned before preparing the next treatment. Once the tubes were filled for each treatment, the entire batch was kept in a refrigerator (4 ºC) for 24 hours to set the binding system. The remaining raw material left for each treatment was set aside and used later for functionality testing. Samples were then cooked to an internal temperature of 72 ºC via a Fisher Scientific (Model Isotemp 210, Dubuque, IA) Water Bath. The water bath temperature was programmed at 80 ºC. After cooking, each treatment was analyzed for cook yield, moisture percentage, pH, water activity, water holding capacity, and binding strength. The entire experiment was repeated four times and within each replicate every treatment (0, 0.6, 1.0, 1.5%) was prepared at the same time.

3.3.3 Cooking Yield

The cooking yield of the restructured ground turkey links were calculated using the formula shown below (Bishop and others 1993). Eight tubes were stuffed per treatment, thus the raw weight values were measured for each tube prior to cooking. A temperature probe was placed into one of the tubes during each replicate for tracking cooking temperature. The temperature probe was set to 72 ºC (≈ 162 ºF). On average each replicate took 30 minutes to reach the desired internal temperature. Once the temperature reached 72 ºC, the samples were taken out of the water bath and allowed time to cool. Samples were taken out of each tube, lightly plotted to remove any excess surface fat, and reweighed. Each treatment per replicate resulted in eight viable links used to calculate cooking yield (%).

$$Cooking\ Yield = \left(\frac{Cooked\ Weight\ of\ the\ Links}{Uncooked\ Weight\ of\ the\ Links}\right) * 100$$

3.3.4 Moisture Percentage

Moisture percentage was conducted in duplicates for the raw and cooked samples for each treatment. A 5 g sample was weighed onto 42 mL Fisher Aluminum dishes. Sixteen samples were placed into a National Appliance Company (Model 3640 VO, Portland, OR) Vacuum Oven for 24hrs at a constant temperature of 80 ºC (Picture 3.2).

Picture 3.2 Duplicate Samples of each Treatment being Placed Inside the Vacuum Oven.

After the 24hrs, samples were removed from the vacuum oven and placed within a desiccator until reaching room temperature. Samples were reweighed to calculate "final weight" values. Moisture percentage was calculated using the equation below.

$$Moisture\ \% = \left(\frac{Initial\ Weight - Final\ Weight}{Initial\ Weight}\right) * 100$$

3.3.5 pH

A 10 g sample was homogenized in a blender with 90 mL of distilled water. The pH of each sample was determined using a Mettler Toledo Five Easy FE20 pH Meter (Schwerzenbach, Switzerland). 4.0 and 7.0 buffer solutions were used to calibrate the pH meter prior to use. The pH measurements of both the raw and cooked samples of the four replicates were determined in duplicates.

3.3.6 Water Activity

Water activity was measured using a Decagon Devices Inc. Aqua Lab CX-2 Water Activity Meter (Pullman, WA). Accuracy of the equipment was determined by using a distilled water and sodium chloride solution prior to each testing. The water activity values of both the raw and cooked samples of the four replicates were determined in duplicates.

3.3.7 Water Holding Capacity

The water holding capacity of both the raw and cooked samples were determined according to the methods described by (Wierbicki 1958). Roughly 0.50 ± 0.02 g of each treatment was placed in the center of a Whatman® No. 1 filter paper. The paper containing each meat sample was placed between two Plexiglas® plates. The plates were pressurized at 5000 psi for five minutes using a Carver® Press (Laboratory Press Model C, Carver® Inc, Wabash, IN). After the five minutes, the meat and water areas were calculated using 10 dots per square inch plastic grid (Iowa State University, Extension; Ames, IA). The formula used to calculate the water holding capacity (WHC) is shown below (Price and Schweigert 1987); WHC was determined in duplicate for each treatment.

$$WHC = \left(\frac{Area\ of\ Free\ Water}{Area\ of\ Meat}\right)$$

3.3.8 Binding Strength

Binding strength is referred to the force required to separate two pieces of meat (Turner and others 1979). This force was determined using a Stevens-LFRA Texture Analyzer (Scarsdale, NY). Eight 1 cm thick discs of raw and cooked samples from each treatment were used. The equipment was programmed to travel 20 mm at a speed of 2.0 mm/sec for each puncture test. The highest value (in grams) was recorded. These values were then averaged to give a final binding strength measurement per treatment.

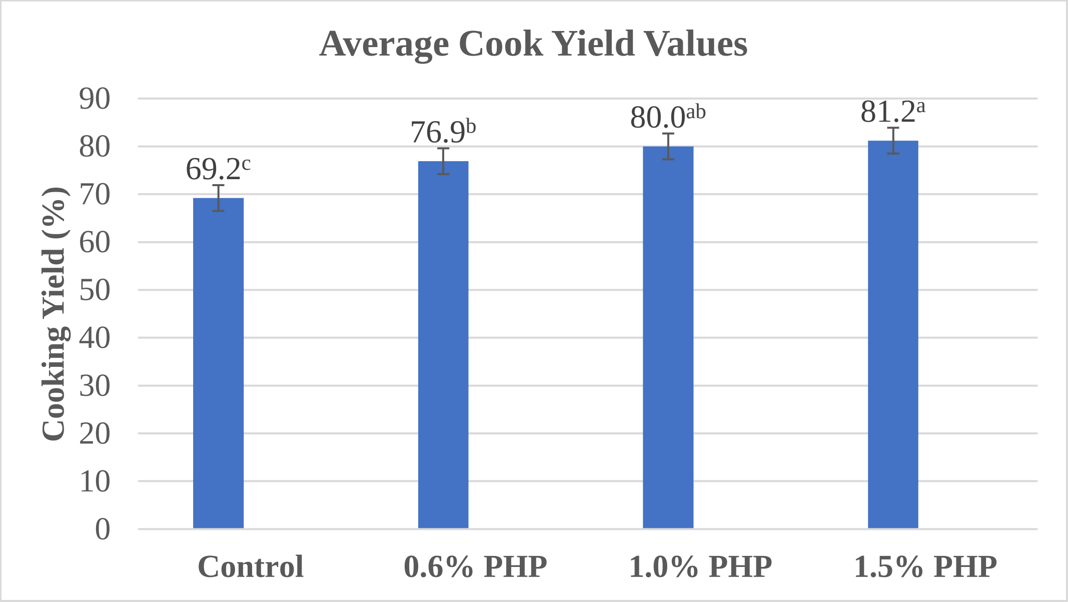
3.3.9 Statistical Analysis

Four replications of restructured ground turkey products were evaluated for cook yield, moisture percentage, pH, water activity, water holding capacity, and binding strength. Data was analyzed using a Randomized Complete Block Design in which there were 4 blocks and 4 treatments (9.4 SAS System Software). Block*treatment was used as the denominator for F-value for testing treatment. Differences of means were separated using the Fisher Protected Least Significant Difference (LSD).

3.4 RESULTS AND DISCUSSION

3.4.1 Cooking Yield

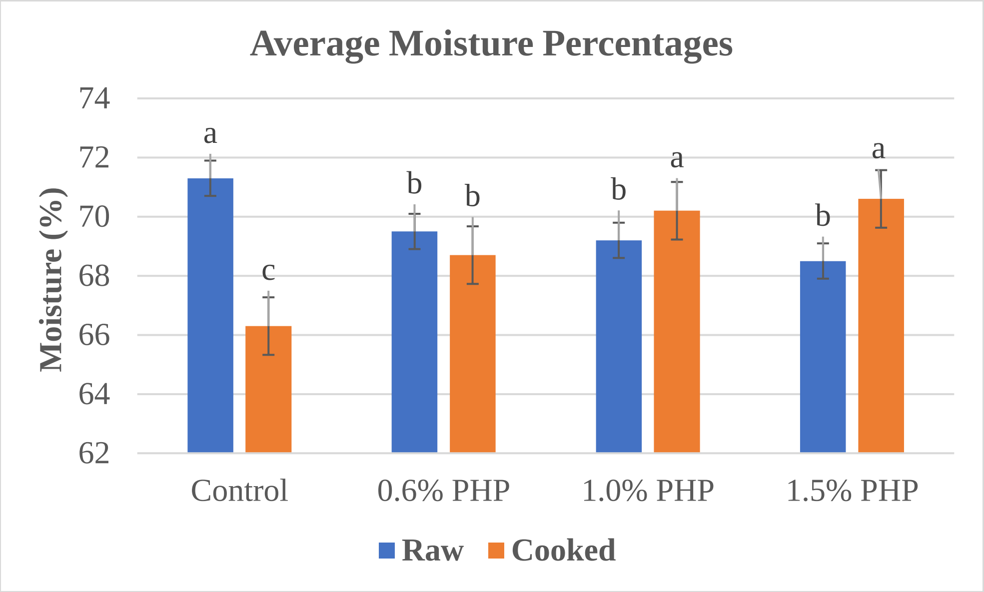
Figure 3.1 below shows the average cooking yield for each restructured ground turkey product. Significant ($P < 0.05$) differences were observed for two out of the four treatments. The 1.5% PHP treatments had significantly ($P < 0.05$) the highest cooking yield values when compared to the 0.6% PHP and control treatments. Likewise, the 0.6% PHP treatment did have a significantly higher ($P < 0.05$) cook yield than the control. Previous studies have also shown that various fiber sources are successful at holding moisture, inducing gelation, and increasing the cook yield of the meat product (Besbes and others 2008; Pinero and others 2008; Soltanizadeh and Ghiasi-Esfahani 2015; Mansour and Khalil 1999; Aleson-Carbonell and others 2005).



[ab] Means that do not share a letter are significantly ($P > 0.05$) different.

Figure 3.1 Cook Yield for Control, 0.6% PHP, 1.0% PHP, and 1.5% PHP Treatments.

3.4.2 Moisture Percentage



^{abc} Means in the same colored column that do not share a letter are significantly ($P < 0.05$) different.

Figure 3.2. Moisture Percentage Values for Control, 0.6% PHP, 1.0% PHP, and 1.5% PHP Treatments.

The results obtained for moisture percentage are located above in Figure 3.2. When comparing all averages for both the raw and cooked samples, it appears that the control raw and control cooked sample had significantly ($P < 0.05$) the highest and lowest moisture percentage values, respectively. For the raw samples, as the psyllium husk powder percentage increased the moisture percentage decreased. This could be attributed to the fiber's strong ability to retain water and reduce the amount of free water within the system that can be available for testing (Bijkerk and others 2004; Aberle and others 2012c). Adversely, the cooked sample moisture percentages increased as the psyllium husk powder percentage increased. This observation could be a direct relation to the fiber's strong water holding capacity (Bijkerk and others 2004). The retention of water during formulation prevents the samples fortified with the fiber to loss the same amount of moisture during cooking when compared to the control samples. No other distinct trends were observed for moisture percentage values.

3.4.3 pH

There was only one significant ($P < 0.05$) difference observed for the raw treatment samples (Table 3.2). The 1.5% PHP treatment had the lowest pH value for the raw samples at 6.45. No significant ($P > 0.05$) differences were observed for the cooked samples but slight differences were noticed. Though the difference is small, it could be contributed to the fiber's ability to reduce product residue during formulation and allow the calcium alginate binding system to become completely incorporated. Ultimately, all values recorded below are well within the typical pH range for cooked meat products (Feiner 2006b).

Table 3.2 pH Values for Both Raw and Cooked Samples.

Treatment	**Raw**	**Cooked**
Control	6.48 ± 0.007^a	6.31 ± 0.026^a
0.6% PHP	6.49 ± 0.007^a	6.30 ± 0.026^a
1.0% PHP	6.49 ± 0.007^a	6.26 ± 0.026^a
1.5% PHP	6.45 ± 0.007^b	6.26 ± 0.026^b

Results are expressed as Means ± Standard Error.

[ab] Means that do not share a letter within the same column are significantly ($P < 0.05$) different.

3.4.4 Water Activity

Numerically the 1.0 and 1.5% PHP raw treatments showed a lower water activity value than the 0.6% PHP and control treatments (Table 3.3). This could be due to the fiber's ability to bind more free water within the meat matrix and create a less desirable microbial environment (Feiner 2006c). Also, when visually observing the raw treatment samples it was evident that the meat matrix structure became more dough-like and rubbery as the fiber percentage increased. Likewise, there was a slight difference observed within the cooked samples. The 0.6% PHP water activity was lower when compared to the control and 1.5% PHP treatments. A possible explanation for this outcome could be an inconsistent incorporation of the ingredients into the meat block during the four replicates which might induce varying results. Overall, no statistically significant ($P > 0.05$) differences were observed for this data set.

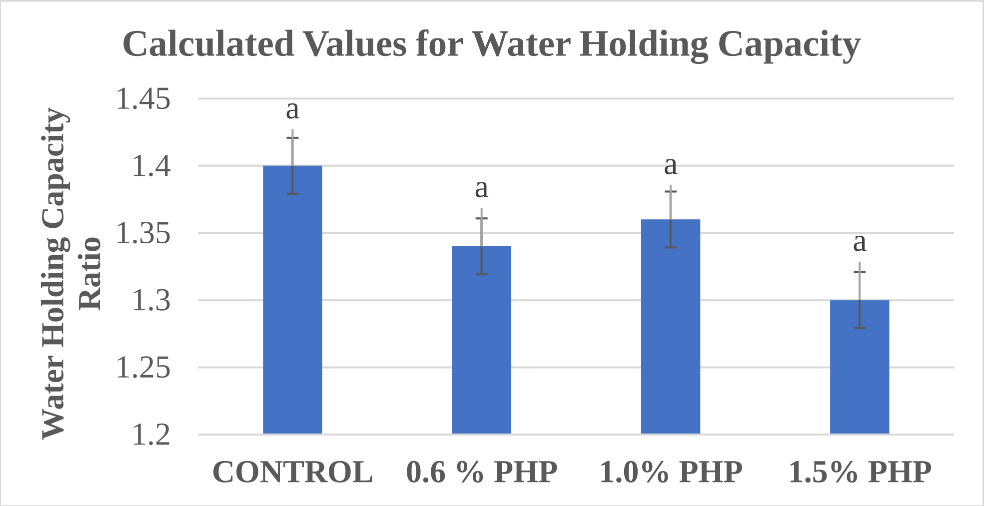
Table 3.3 Water Activity Values for Raw and Cooked Samples.

Treatment	**Raw**	**Cooked**
Control	0.994 ± 0.002^{a}	0.994 ± 0.004^{a}
0.6% PHP	0.995 ± 0.002^{a}	0.987 ± 0.004^{a}
1.0% PHP	0.989 ± 0.002^{a}	0.992 ± 0.004^{a}
1.5% PHP	0.988± 0.002^{a}	0.999 ± 0.004^{a}

Results are expressed as Means ± Standard Error.
[a] Means that do not share a letter within the same column are significantly ($P < 0.05$) different.

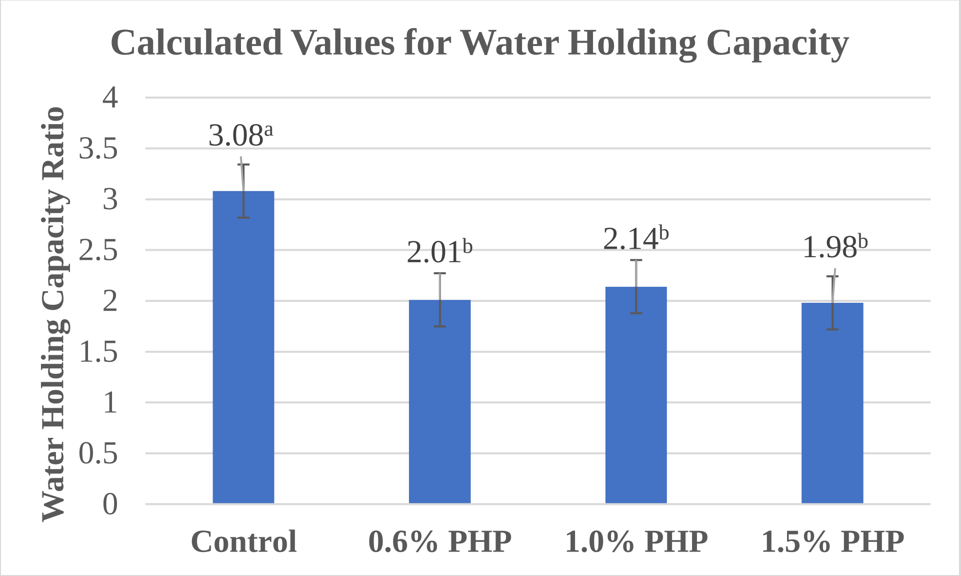
3.4.5 Water Holding Capacity

No significant ($P > 0.05$) differences were observed for the raw treatment samples (Figure 3.3). Average water holding capacity values for the raw samples ranged between 1.30 and 1.39. These low ratios indicate that regardless of treatment the raw meat matrix can adequately hold water. However, the cooked sample mean differences did indicate a significant difference (Figure 3.4). As mentioned earlier, to calculate water holding capacity the area of free water is divided by the area of meat; so, if there is a smaller area of free water then the calculated value will be lower. However, having a lower area of free water in the calculation would result in a product that has a higher water holding capacity (Price and Schweigert 1987). The treatments with the psyllium husk powder did have a significantly ($P < 0.05$) higher water holding capacity than the control. This should be to no surprise because literature has stated that just 1 gram of psyllium fiber can hold up to 10 grams of water; so, the water holding capacity of the samples with the fiber should be higher (Kristensen and Jensen 2011).



[a] Means that do not share a letter are significantly ($P < 0.05$) different.

Figure 3.3 Difference of Means for Raw Treatment Sample Water Holding Capacity.

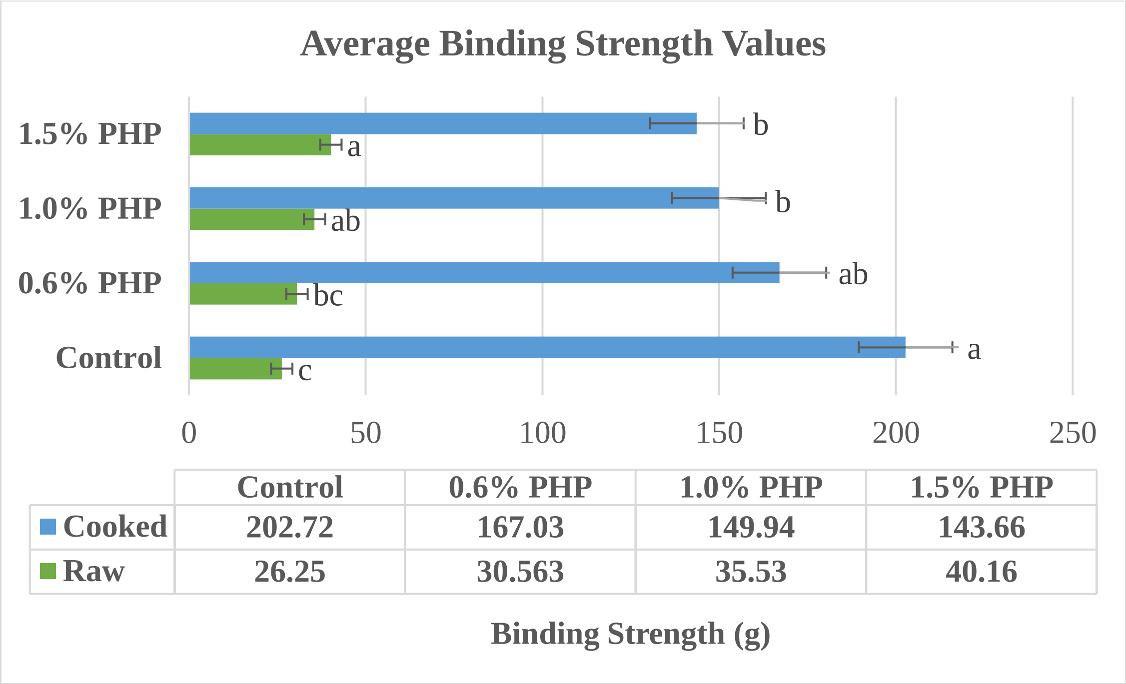


[ab] Means that do not share a letter are significantly ($P < 0.05$) different.

Figure 3.4 Water Holding Capacity Values for Cooked Treatment Samples.

3.4.6 Binding Strength

Two significant ($P < 0.05$) trends were observed within the raw and cooked samples (Figure 3.5). The raw samples concluded that as the fiber percentage increased the binding strength also significantly ($P < 0.05$) increased from 26.25 g (control) to 40.16 g (1.5% PHP). However, in the cooked samples the binding strength significantly ($P < 0.05$) decreased as the fiber percentage increased. The cooked 1.0 and 1.5% PHP samples resulted in the significantly ($P < 0.05$) lowest binding strength values at 149.94 g and 143.66 g, respectively. This result could be a direct connection to the increase in moisture percentage and water holding capacity as the fiber percentage increased. The extra held water within the meat system allows for a juicier and more tender product when compared to those that have lower moisture percentages and water holding capacities (Aberle and others 2012c).



	Control	0.6% PHP	1.0% PHP	1.5% PHP
🟦 Cooked	202.72	167.03	149.94	143.66
🟩 Raw	26.25	30.563	35.53	40.16

Binding Strength (g)

^{abc} Means that do not share a letter within the same colored bar are significantly ($P < 0.05$) different.

Figure 3.5 Average Binding Strength (g) for Raw and Cooked Samples.

3.5 CONCLUSION

Results from this study show that even small percentages of psyllium husk powder can have beneficial affects on a meat product's functionality. As the fiber percentage increased the cook yield, moisture content, and water holding capacity values also increased. The binding strength, pH, and water activity values were only minimally affected by the fiber's presence. However, further research is still needed to determine if the addition of psyllium husk powder at levels for nutritional benefits effect functionality and more importantly sensory evaluation. Therefore, this project was a positive step in the development of processed meat products with added fiber and an upscaled project is to be studied to better understand this new, innovative idea.

CHAPTER 4: UTILIZATION OF PSYLLIUM HUSK (*PLANTAGO OVATE*) POWDER AS A DIETARY FIBER SOURCE FOR IMPROVING THE QUALITY OF A PROCESSED TURKEY PRODUCT

4.1 ABSTRACT

The objectives of this study were based on the previous chapter's research outcomes to determine the effects of different dietary fiber levels (0, 1, 2, or 3 g per serving) of psyllium husk powder on the functional properties of a processed ground turkey product and consumer preferences. The cook yield values concluded that the 6.4 and 12.8% PHP treatments had significantly ($P < 0.05$) higher percentages, 90.0 and 90.6%, respectively. There were no significant ($P > 0.05$) differences observed for the raw and cook pH, cooked water activity, and raw water holding capacity values. The 1.6 and 6.4% PHP cooked treatments showed the highest values ($P < 0.05$) for moisture content at 70.1 and 69.4%, respectively. The 12.8% PHP had the highest significant ($P < 0.05$) values for cooked water holding capacity, hardness, springiness, cohesiveness, gumminess, chewiness, and resilience when compared to the other three treatments. As the fiber percentage increased, the consumers' degree of liking for flavor and appearance significantly ($P < 0.05$) decreased; however, no significant ($P > 0.05$) difference was observed for the texture category. Overall, this study indicated that adding dietary fiber into a processed meat product can benefit functionality properties such as cook yield, water holding capacity, and texture but at certain levels can have a negative impact on sensory evaluation.

4.2 INTRODUCTION

Results and observations from the previous chapter have paved a path for furthering the research with psyllium husk powder and processed meats. Like mentioned before, the demand for convenient and great tasting products have evolved the processing meat industry (Grunert 2006). Fortunately, consumers are demanding more functional food products that not only satisfy hunger but also assist in preventing/reducing health-related diseases (Menrad 2003; Roberfroid 2000). Developing products that are fortified with psyllium husk powder not only open a new marketing angle but can allow the addition of beneficial claims such as “reduce the risk of coronary heart disease” (FDA 2012).

A major challenge in this next step is to accurately formulate a product that will contain enough of the ingredient to suffice the dietary fiber claim on the nutrition label. Likewise, the functionality properties will also need to be studied to determine if these new fiber levels will have varying effects from the previous study, and a consumer taste panel will be incorporated as well to ultimately determine if this new innovative idea is desirable. Therefore, the objectives of this study were to determine the effect of different dietary fiber levels of psyllium husk powder (0, 1g, 2g, or 3g) on the functional properties of a processed ground turkey product and determine consumer preferences for a processed ground turkey product containing 0, 1.6, 6.4, and 12.8% psyllium husk powder.

4.3 MATERIALS AND METHODS

4.3.1 Materials

Honeysuckle White 85% lean/15% fat ground turkey (Cargill Meat Solutions Corp.) was obtained from a local grocery store in Columbia, Missouri. The GRINDSTED® Alginate FD 155 ingredient was obtained from DuPont Nutrition & Health (DANISCO) (New Century, Kansas). PrimeCAP® Lactic Acid 50-135 was supplied from Innovative Food Processors (Hayfield, MN). The MICRO-WHITE® 50/CODEX, calcium carbonate, was obtained through the E.C.C. America Inc. (Sylacauga, Alabama). Finally, the Kosher certified and organic psyllium husk powder was obtained through Monterey Bay Spice Company (Watsonville, California).

4.3.2 Sample Preparation

Ground turkey was bought at the local grocery store prior to starting the project and was kept in a freezer (at least -10 ºC) until needed. Each trial required the ground turkey to be thawed before treatment formulation began. The Genesis R&D Food Formulation and Labeling Software (2017 ESHA Research, Version: 11.4.500) was used to determine the appropriate psyllium husk powder (PHP) percentages to create a 55 g serving size with 0, 1, 2, or 3 g of dietary fiber (DF). Meat, dry ingredients, and water were weighed out for the four different treatments labeled as Control (C), 1.6% (1 g DF) PHP, 6.4% (2 g DF) PHP, and 12.8% (3 g DF) PHP. Table 4.1 below provides in detail the formulation for each treatment. Similarly, to the previous project, water was added at constant level of (5%) to each treatment batch rather than using the USDA added water constant (Eilert and others 1993). The USDA added water constant would have required varying levels of water added into each batch, but the aim of this project was to isolate the effects of only the psyllium husk powder (Eilert and others 1993). Likewise, the ingredients used for the calcium alginate system were kept at constant levels during the entire experimental design.

Table 4.1 Treatment Formulation for Enriching a Processed Turkey Product with Psyllium Husk Powder.

Treatment	Ground Turkey	Sodium Alginate	Encapsulated Lactic Acid	Calcium Carbonate	Distilled Water	Psyllium Husk Powder
Control	93.5%	0.6%	0.6%	0.3%	5.0%	________
1.6% PHP	91.9%	0.6%	0.6%	0.3%	5.0%	1.6%
6.4% PHP	87.1%	0.6%	0.6%	0.3%	5.0%	6.4%
12.8% PHP	80.7%	0.6%	0.6%	0.3%	5.0%	12.8%

Each treatment was mixed using a Leland Food “Double Mixer Action” (Model: L-100DA, Detroit, Michigan) Mixer until all ingredients were fully incorporated into the meat block. Next, each treatment was transferred into a Biro (Model: AFMG-52, Marblehead, Ohio) Stuffer and formed into Walton’s (Wichita, Kansas) 2.9” X 20” fibrous mahogany casings. Each treatment per replicate was stuffed into ten casings. A Tipper Clipper Inc. (Model: C437L, North Carolina) Stapler was used to properly seal each treatment casing. During each replicate, raw products were randomly placed on racks and wheeled inside an Enviro-Pak Microprocessor (Series MP 1000, Clackamas, Oregon) Smokehouse (Picture 4.1). A step cooking method (1 hour at 135 ºF/50% relative humidity; 30 minutes at 160 ºF/50% relative humidity; 190 ºF/50% relative humidity until the desired internal temperature) was used until an internal temperature of 165 ºF or three hours of cooking was reached. After cooking, samples were immediately moved into a commercial cooler at 34 ºC.

Picture 4.1 Products for Each Treatment Being Placed Inside the Smokehouse.

During each replicate, four casings per treatment were initially used for functionality testing, two casings per treatment were vacuum-sealed and stored at 4 ºC for 1 week for a secondary texture profile analysis, and the remaining four casings per treatment were vacuum-sealed and stored at -10 ºC for sensory evaluation. The entire experiment was repeated three times and within each replicate every treatment (0, 1.6, 6.4, 12.8%) was prepared at the same time.

4.3.3 Cooking Yield

The cooking yield of the processed turkey products were calculated using the formula shown below (Bishop and others 1993). The ten stuffed casings per treatment were weighed before and after cooking. The casing and staple weights were subtracted from the total weight to obtain only the raw and cooked product weight.

$$Cooking\ Yield = \left(\frac{Cooked\ Weight}{Uncooked\ Weight}\right) * 100$$

4.3.4 Moisture Percentage

Moisture percentage was conducted in triplicate for the raw and cooked samples for each treatment. A 5 g sample was weighed onto 42 mL Fisher Aluminum dishes. Twenty-four samples were placed into a National Appliance Company (Model 3640 VO, Portland, Oregon) Vacuum Oven for 24hrs at a constant temperature of 80 ºC (Picture 3.2). After the 24hrs, samples were removed from the vacuum oven and placed within a desiccator until reaching room temperature. Samples were reweighed to calculate “final weight” values. Moisture percentage was calculated using the equation below.

$$Moisture\ \% = \left(\frac{Initial\ Weight - Final\ Weight}{Initial\ Weight}\right) * 100$$

4.3.5 pH

A 10 g sample was homogenized in a blender with 90 mL of distilled water. The pH of each sample was determined using a Mettler Toledo Five Easy FE20 pH Meter (Schwerzenbach, Switzerland). 4.0 and 7.0 buffer solutions were used to calibrate the pH meter prior to use. The pH measurements of both the raw and cooked samples were determined in duplicate.

4.3.6 Water Activity

Water activity was measured using a Decagon Devices Inc. Aqua Lab CX-2 Water Activity Meter (Pullman, Washington). Accuracy of the equipment was determined by using a distilled water and sodium chloride solution prior to each testing. The water activity values of the cooked samples were determined in duplicate.

4.3.7 Water Holding Capacity

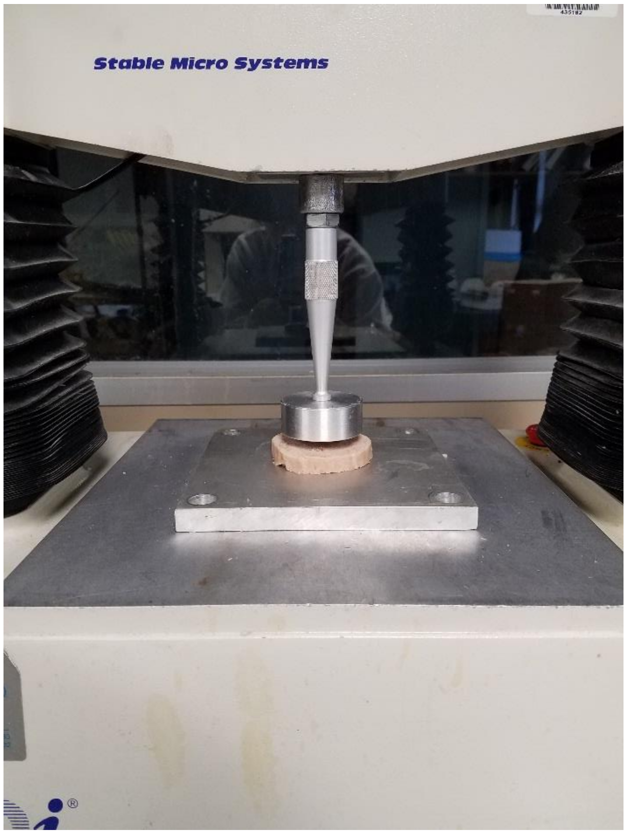
The water holding capacity of both the raw and cooked samples were determined according to the methods described by (Wierbicki 1958). Roughly 0.50 ± 0.02 g of each treatment was placed in the center of a Whatman® No. 1 filter paper. The paper containing each meat sample was placed between two Plexiglas® plates. The plates were pressurized at 5000 psi for five minutes using a Carver® Press (Laboratory Press Model C, Carver® Inc, Wabash, Indiana). After the five minutes, the meat and water areas were calculated using 10 dots per square inch plastic grid (Iowa State University, Extension;

Ames, IA). The formula used to calculate the water holding capacity (WHC) is shown below (Price and Schweigert 1987); WHC was determined in triplicate for each treatment.

$$WHC = \left(\frac{Area\ of\ Free\ Water}{Area\ of\ Meat}\right)$$

4.3.8 Texture Profile Analysis

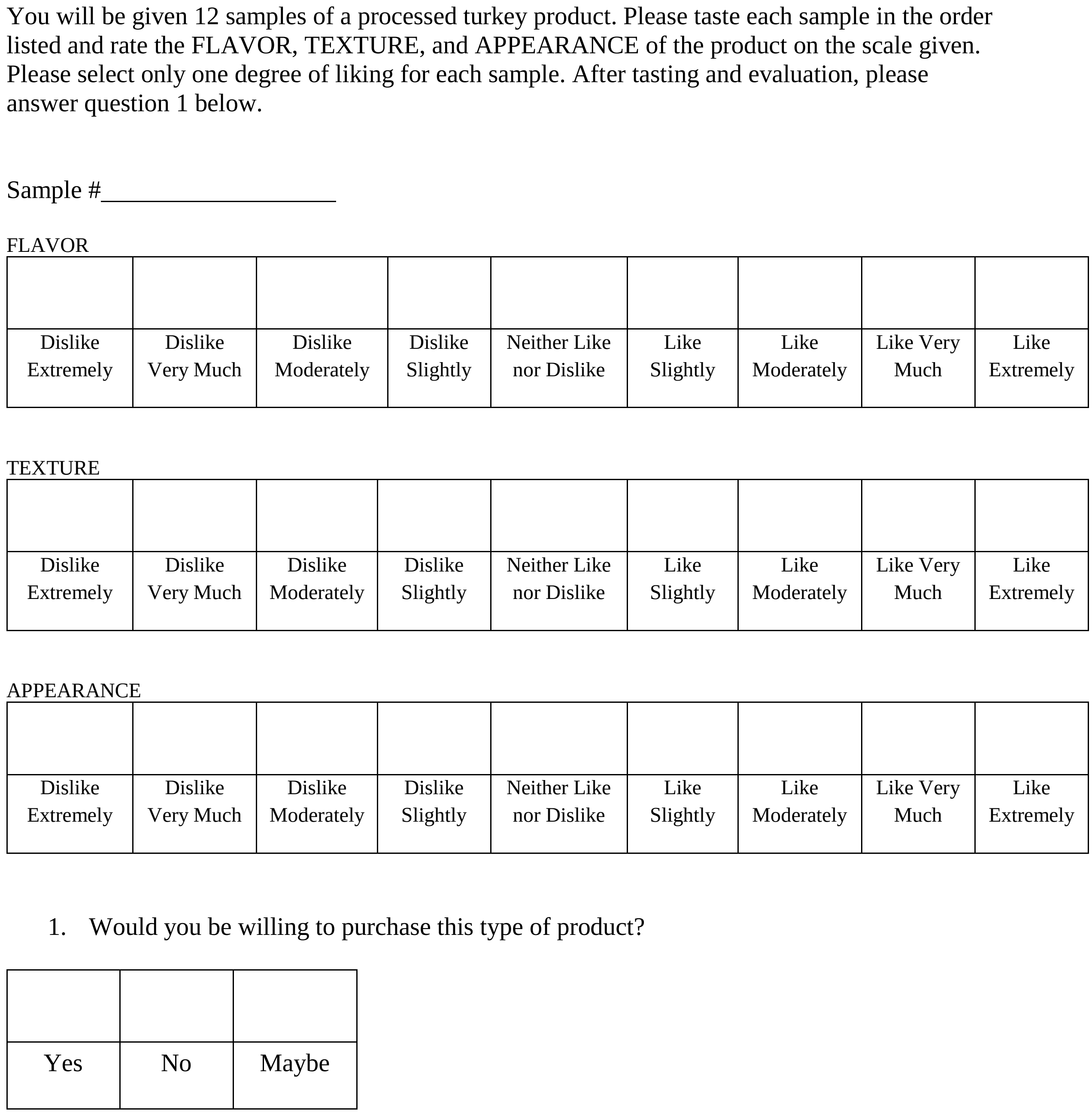
After the products were cooked, cooled, and weights recorded, twelve 1 cm width discs per treatment were sliced for texture profile analysis. Each disc was compressed to 50 percent of its original height in two consecutive cycles at a 1.00 mm/sec test speed using a TA-HDi Texture Analyzer (Stables Micro Systems, Surrey, UK). A 50 mm diameter probe was used, as described by (Bourne 1978), to evaluate characteristics such as hardness, springiness, cohesiveness, gumminess, chewiness, and resilience (Picture 4.2). Two casings per treatment were vacuum-sealed and stored in a cooler (4 ºC) for 1 week to determine if the fiber had any effect on product texture stability. Once the seven days passed, twelve 1 cm discs per treatment were re-evaluated using the same methods.



Picture 4.2 Placing Sample for Texture Profile Analysis.

4.3.9 Sensory Evaluation

A consumer taste panel was conducted on March 13th, 2018 at the University of Missouri's Sensory Science Laboratory. Panelists (20 men and 39 women) were asked to consume 12 research product samples and complete a 9-point hedonic scale (1- Dislike Extremely to 9-Like Extremely) (Picture 4.3). To determine if there were any differences between batch number (replicate number), panelists were given a sample from each treatment of batch 1, 2 and 3 (Picture 4.4). Each sample was given a score for flavor, appearance, and texture, plus panelists were asked to answer one additional question: "Would you be willing to purchase this type of product?". Panelists were given unsalted crackers and room temperature water to cleanse the palate between samples. Hedonic scale results were converted to numerical scores for statistical analysis.



You will be given 12 samples of a processed turkey product. Please taste each sample in the order listed and rate the FLAVOR, TEXTURE, and APPEARANCE of the product on the scale given. Please select only one degree of liking for each sample. After tasting and evaluation, please answer question 1 below.

Sample #___________________

FLAVOR

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

TEXTURE

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

APPEARANCE

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

1. Would you be willing to purchase this type of product?

Yes	No	Maybe

Picture 4.3 Sensory Evaluation Sheets Given to Each Panelist.

Picture 4.4 Sensory Evaluation Samples.

4.3.10 Statistical Analysis

Data was analyzed using a Randomized Complete Block Design in which there were 3 blocks and 4 treatments (9.4 SAS System Software). Block*treatment was used as the denominator for F-value for testing treatment. Differences of means were separated using the Fisher Protected Least Significant Difference (LSD). Texture Profile Analysis was also analyzed using Split Plot in Time RCBD where Block*treatment was used as the denominator of for testing treatment and block within (Treatment*week) was the denominator for F-value for testing Week and Treatment*week. Analysis described is similar to the work completed by Lettell and others (1998).

4.4 RESULTS AND DISCUSSION

4.4.1 Cooking Yield

Table 4.2 below summarizes the average calculated cook yields for each treatment. It was observed that as the fiber percentage increased the cook yield values also increased. This trend is also consistent with previous studies that used pea + wheat fiber (Besbes and others 2008), oat fiber (Pinero and others 2008), *Aloe vera* (Soltanizadeh and Ghiasi-Esfahani 2015), wheat fibers (Mansour and Khalil 1999), and lemon albedo (Aleson-Carbonell and others 2005) within a meat product. The 6.4 and 12.8% PHP treatments had significantly ($P < 0.05$) higher percentages, 90.0 and 90.6%, respectively. These results support claims made by Bijkerk and others (2004) that psyllium husk powder has strong water holding and gelling capacities that can enable a higher yield.

Table 4.2 Cook Yield Values for Control, 1.6, 6.4, & 12.8% PHP Treatments.

Treatment	**Cook Yield (%)**
Control	69.3 ± 1.59^{c}
1.6% PHP	83.3 ± 1.59^{b}
6.4% PHP	90.0 ± 1.62^{a}
12.8% PHP	90.6 ± 1.59^{a}

Results are expressed as Mean ± Standard Error.
[d] Means that do not share a letter are significantly ($P < 0.05$) different.

Likewise, an increase in cook yield was also observed visually (Pictures 4.5-4.8). Here, as the percentage of fiber increased the diameter thickness of the processed turkey product also increased. This response is also consistent with results found within a beef burger formulated with pea and wheat fibers. Besbes and others (2008) concluded that "this could be attributed to the binding and stabilizing properties of the fibers which reduce distortion of the product during cooking".

Picture 4.5 Control Treatment.

Picture 4.6 1.6% PHP Treatment.

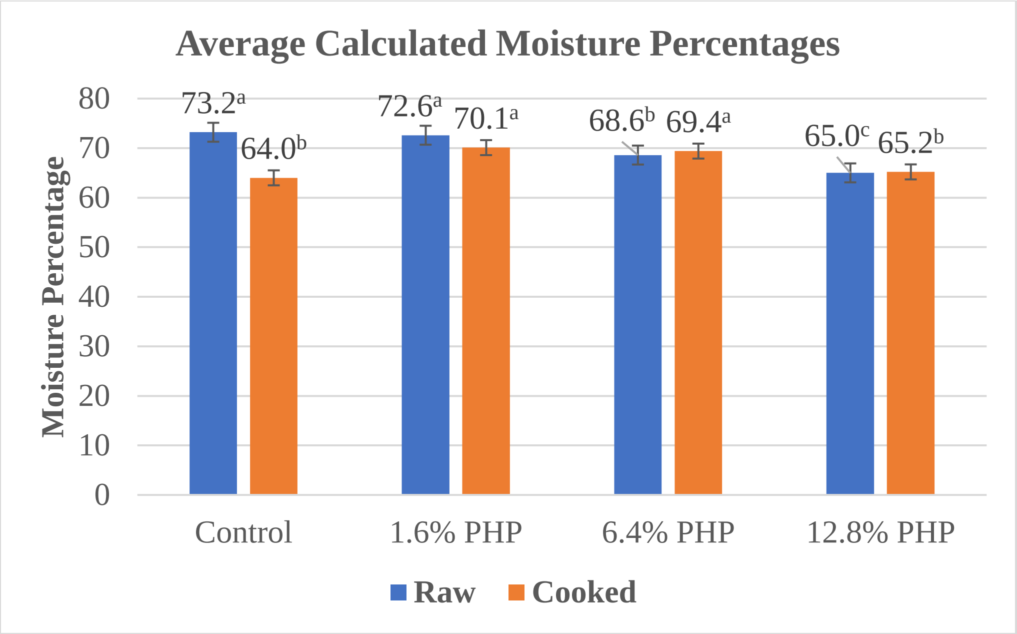
Picture 4.7 6.4% PHP Treatment.

Picture 4.8 12.8% PHP Treatment.

4.4.2 Moisture Percentage

Within the raw samples, as the fiber percentage increased the moisture content significantly ($P < 0.05$) decreased (Figure 4.1). The 1.6 and 6.4% PHP cooked treatments showed the highest values ($P < 0.05$) for moisture content at 70.1 and 69.4%, respectively. Addition of other fibers (lemon albedo, oat fiber, *Aloe vera*) have shown that as their percentage increases within the meat matrix, their ability to retain moisture also steadily increases (Aleson-Carbonell and others 2005; Pinero and others 2008; Soltanizadeh and Ghiasi-Esfahani 2015). Unfortunately, the strong water holding, and binding capacity of the psyllium husk powder has proven that using large amounts of the fiber can have an adverse effect on moisture content within the cooked product.

Throughout the experimental design, it was visually observed that as the fiber percentage increased the raw meat texture became more “rubbery” and less sticky. This observation was another method to confirm that the fiber was affecting the moisture content and water holding capacity. However, it was also visually observed that increasing the addition of psyllium husk powder reduced the amount of product residue left within the mixer (Pictures 4.9-4.16). Thus, this conclusion has the potential to suggest that psyllium husk powder can beneficially contribute to fully incorporating the calcium alginate binding system and reduce product waste.

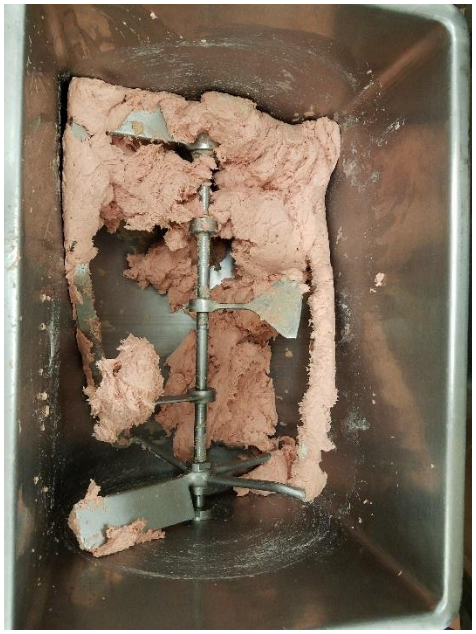


^{abc} Means of the same color that do not share a letter are significantly ($P < 0.05$) different.

Figure 4.1 Raw and Cooked Moisture Percentage Values for Each Treatment.

Picture 4.9 Control Treatment in Mixer.

Picture 4.10 Control Treatment Residue.



Picture 4.11 1.6% PHP in Mixer.

Picture 4.12 1.6% PHP Residue.

Picture 4.13 6.4% PHP in Mixer.

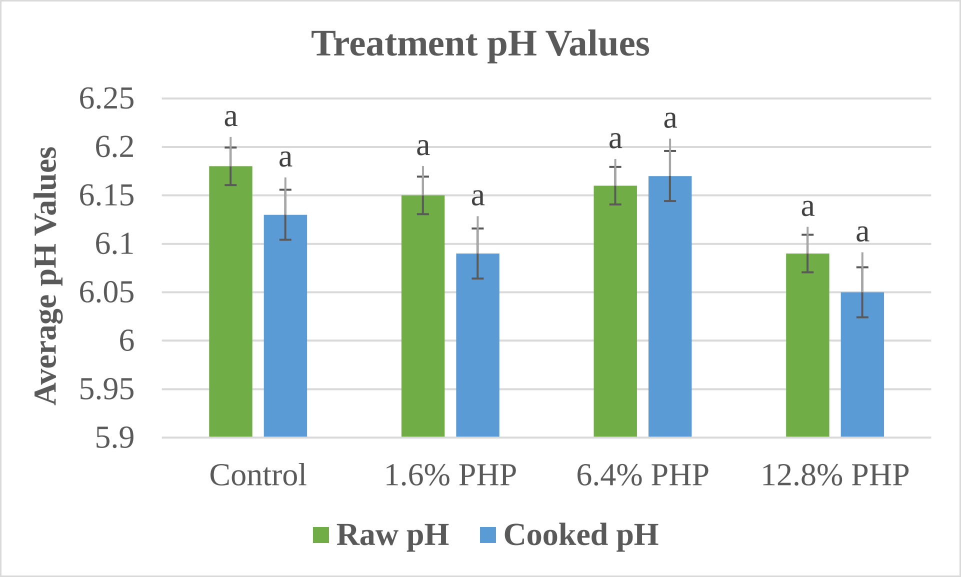
Picture 4.14 6.4% PHP Residue.

Picture 4.15 12.8% PHP in Mixer.

Picture 4.16 12.8% PHP Residue.

4.4.3 pH

No statistically ($P > 0.05$) significant values were observed for the raw and cooked pH samples for all four treatments (Figure 4.2). There were slight differences observed as the psyllium husk powder was introduced. The 12.8% PHP treatment showed the lowest raw and cooked values, 6.09 and 6.05, respectively. Fortunately, the pH value ranges are from 6.05 to 6.17 which still fall within the normal pH range for processed meat products and are below the 6.4 mark where spoilage, off-flavors, and discoloration are most susceptible (Feiner 2006b).

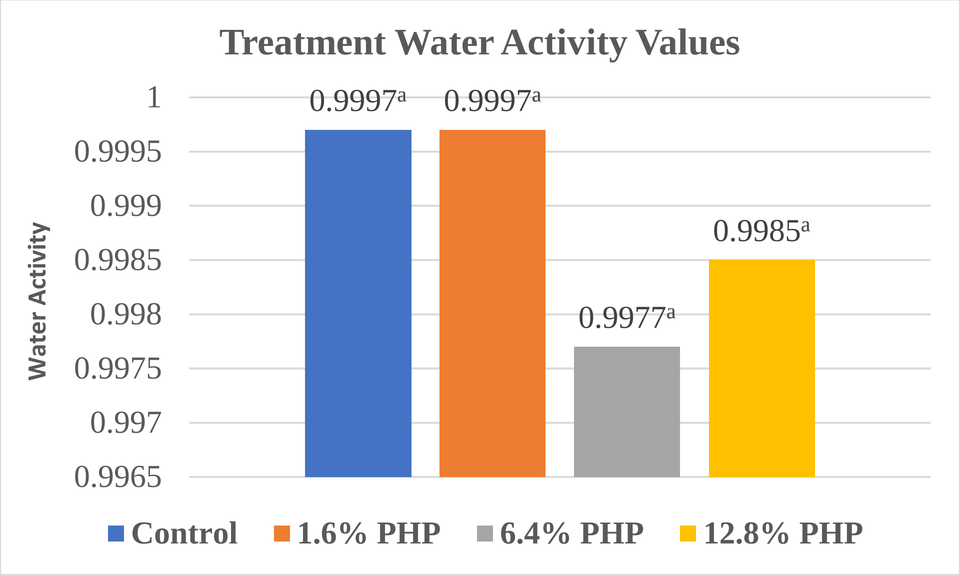


[a] Means of the same color that do not share a letter are significantly ($P < 0.05$) different.

Figure 4.2 Raw and Cooked pH Values for Each Treatment.

4.4.4 Water Activity

Figure 4.3 below illustrates that there were no significant ($P > 0.05$) differences observed among the four cooked treatments. These values are consistent with the typical water activity values of cooked sausage, 0.97 to 0.98, described by Feiner (2006c). A small observation that can be noted is that as the fiber percentage increased the water activity value slightly decreased. This small reduction could result from the calcium alginate system's ability to ionically bind the water and the fiber's ability to immobilize it (Feiner 2006c). Bhise and Kaur (2015) also concluded that muffins formulated with psyllium fiber had a lower water activity value than the control and oat fiber muffins.



[a] Means that do not share a letter are significantly ($P < 0.05$) different.

Figure 4.3 Water Activity Values for Cooked Treatment Samples.

4.4.5 Water Holding Capacity

No significant ($P > 0.05$) differences were observed for the raw samples among the four treatments; however, there were largely significant ($P < 0.05$) differences observed among the cooked samples (Table 4.3). As mentioned earlier, to calculate water holding capacity the area of free water is divided by the area of meat; so, if there is a smaller area of free water then the calculated value will be lower. However, having a lower area of free water in the calculation would result in a product that has a higher water holding capacity (Price and Schweigert 1987).

Thus, as the percentage of psyllium husk fiber increased within the product the water holding capacity of the sample also increased. Beef burgers formulated with *Aloe vera* also had an increase in water holding capacity as the functional ingredient increased from 0-5% (Soltanizadeh and Ghiasi-Esfahani 2015). Likewise, formulating a low-fat beef patty with oat fiber or lemon albedo increased the moisture retention from 43.57 to 48.41% (Pinero and others 2008) and 35.71 to 48.37%, respectively (Aleson-Carbonell and others 2005). Additionally, like mentioned earlier, 1 gram of psyllium husk fiber has the ability to retain roughly 10 grams of water. This mechanism could be explained by the 80% soluble fiber composition and its highly branched (1-4) and β-(1-3) glycosidic linkages in the xylan backbone (Kristensen and Jensen 2011; Fischer and others 2004). Hence, there is no surprise that the psyllium husk fiber decreased the amount of free water after pressurization and resulted in a much higher water holding capacity value.

Table 4.3 Raw and Cooked Water Holding Capacity Values.

TREATMENT	RAW WHC	COOKED WHC
CONTROL	1.58 ± 0.11^{a}	2.08 ± 0.06^{c}
1.6 % PHP	1.40 ± 0.11^{a}	1.70 ± 0.06^{b}
6.4% PHP	1.47 ± 0.11^{a}	1.64 ± 0.06^{ab}
12.8% PHP	1.34 ± 0.11^{a}	1.46 ± 0.06^{a}

Results are expressed as Means ± Standard Error.
^{abc} Means within the same column that do not share a letter are significantly ($P < 0.05$) different.

4.4.6 Texture Profile Analysis

Table 4.4 below illustrates that there were significant ($P < 0.05$) differences observed among the four treatments, but there was not any significant ($P > 0.05$) differences observed between week 0 and 1 and the interaction between week and treatment. These findings can continue to confirm that psyllium husk powder can remain stable over a variety of temperatures while still having a strong gelling capacity (Ibuki 1989), and the methodology and sample preparation of the project was consistent during the three replicates.

Table 4.4 ANOVA Analysis of Texture Parameters.

Effect	[a]DF	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
[b]Tr	3	*	*	*	*	*	*
[c]Wk	1	NS	NS	NS	NS	NS	NS
Tr*Wk	3	NS	NS	NS	NS	NS	NS

[a] Degrees of Freedom; [b]Tr: Treatment (Control, 1.6, 6.4, 12.8% PHP); [c]Wk: Week (0 and 1);
* Significantly ($P < 0.05$) different.; NS: Not significant ($P > 0.05$).

Many significant ($P < 0.05$) differences were observed throughout the texture profile analysis. The 12.8% PHP treatment showed the highest significant ($P < 0.05$) values for hardness (186.55), springiness (1.27), cohesiveness (0.630), gumminess (116.94), chewiness (147.07), and resilience (0.135). In general, there was a slight trend where when the fiber percentage increased the texture profile analysis values for each parameter also increased. Bhat and others (2017) also noted that the hardness, gumminess, cohesiveness, and springiness values of yogurt fortified with psyllium husk increased as the fiber percentage increased. These findings help to support the already known literature that psyllium husk powder has a wide range of applications in various temperatures and pH values because it can alter product structure due to the strong water retaining and gelling capacity (Ibuki 1989; Bijkerk and others 2004).

Other researchers have shown significant and nonsignificant differences between various fiber sources and their concentrations within dry fermented sausages, chicken patties, hot dogs and beef patties (García and others 2002; Steenblock and others 2001;

Huber and others 2016; Aleson-Carbonell and others 2005; Soltanizadeh and Ghiasi-Esfahani 2015). Those differences could be due to the origin of the fiber, emulsion properties, hydrophilic and lipophilic properties, concentration, shape/size of the particles, and product category; thus, why it appears difficult to compare results and observations. Unfortunately, the 1.6% PHP had significantly ($P < 0.05$) lower values for hardness and gumminess when compared to the control, 6.4, and 12.8% PHP treatments. This outcome could be related to the dilution effect of nonmeat ingredients within a meat protein system that could have resulted in the softer texture (Comer and Dempster 1981; Tsai and others 1998). Since these treatments were not formulated into a specific product category, it is not appropriate to state that these texture results are above, below, or meet the already known and accepted textural properties by consumers within the meat industry.

Table 4.5 Average Texture Measurements (1).

Treatment	Hardness (N/cm^2)	Springiness (cm)	Cohesiveness ratio
Control	126.07 ± 16.1^{b}	0.84 ± 0.12^{b}	0.395 ± 0.02^{b}
1.6% PHP	71.38 ± 16.1^{c}	0.87 ± 0.12^{b}	0.363 ± 0.02^{b}
6.4% PHP	122.70 ± 16.1^{b}	1.07 ± 0.12^{ab}	0.560 ± 0.02^{a}
12.8% PHP	186.55 ± 16.1^{a}	1.27 ± 0.12^{a}	0.630 ± 0.02^{a}

Results are expressed as Means ± Standard Error.

^{abc} Means that do not share a letter within the same column are significantly ($P < 0.05$) different.

Table 4.6 Average Texture Measurements (2).

Treatment	Gumminess (N/cm^2)	Chewiness (N/cm^2)	Resilience (Pa)
Control	51.06 ± 8.60^{b}	43.68 ± 9.17^{bc}	0.076 ± 0.015^{b}
1.6% PHP	25.86 ± 8.60^{c}	22.90 ± 9.17^{c}	0.046 ± 0.015^{b}
6.4% PHP	68.50 ± 8.56^{b}	72.82 ± 9.19^{b}	0.093 ± 0.015^{ab}
12.8% PHP	116.94 ± 8.60^{a}	147.07 ± 9.17^{a}	0.135 ± 0.015^{a}

Results are expressed as Means ± Standard Error.

^{abc} Means that do not share a letter within the same column are significantly ($P < 0.05$) different.

4.4.7 Sensory Evaluation

Table 4.7 below indicates that there were no significant (P > 0.05) differences observed due the trial/batch number. This is a good indicator that the experimental design was completed consistently during the course of the project. The only significant differences observed between treatments are for flavor and appearance. The control and 1.6% PHP treatments had a significantly (P < 0.05) higher "degree of liking" for flavor, 5.78 and 5.63, respectively and appearance, 6.00 and 5.57, respectively when compared to the 6.4 and 12.8% PHP treatments (Figure 4.4).

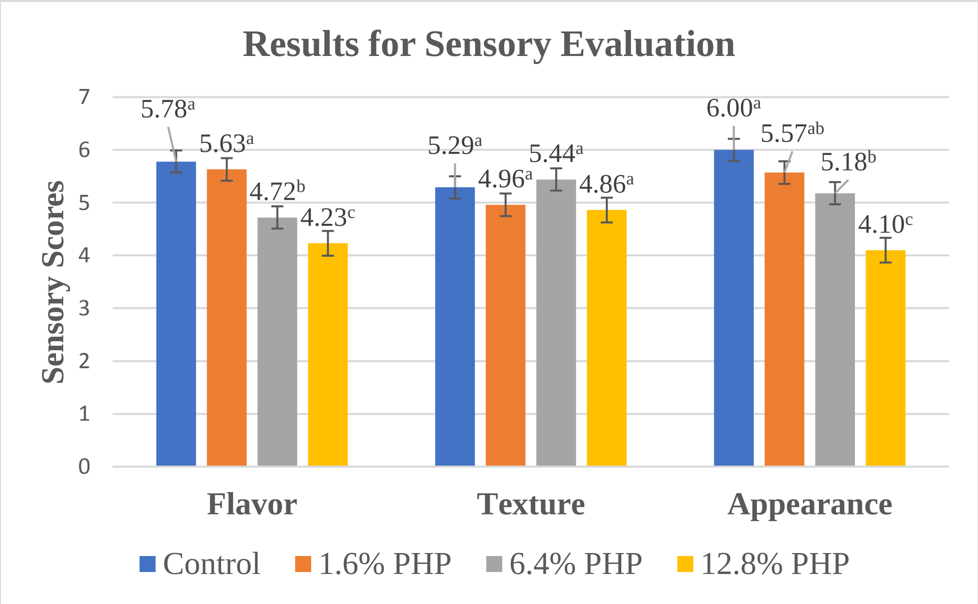
Previous research has also shown that the use of oat fiber in beef patties decreased the "degree of likeness" for color, appearance, and taste (Pinero and others 2008). Similarly, as the percentage of pea + wheat fiber increased within a beef burger the "degree of likeness" for flavor and texture decreased (Besbes and others 2008). Bhat and others (2017) observed that as the psyllium husk percentage increased from 0 to 0.5% in yogurt the "degree of liking" for flavor, texture, and overall acceptability also increased, but once the psyllium husk percentage reached 0.7% these sensory characteristics decreased. This observation could be related to psyllium husk's ability to absorb water and prevent the release of flavoring components within the yogurt matrix (Fernandez-Garcia and others 1998).

Surprisingly, there was no (P > 0.05) statistical significance observed for texture among the four treatments. As previously stated, there was a visual difference made between the four treatments, but the consumer taste panel must have had a diverse group of men and women with varying textural preferences. When asked "Would you be willing to purchase this type of product?" consumers' rating of a "Yes" decreased as the product contained more psyllium husk powder. 34% of panelists were willing to purchase the control sample, 26% for the 1.6% PHP, 7% for the 6.4% PHP, and only 5% for the 12.8% PHP. The dramatic decrease in purchasing intent is to no surprise since the "degree of liking" for flavor and appearance decrease significantly as the fiber percentage increased.

Table 4.7 ANOVA Analysis of Sensory Evaluation.

Effect	[a]DF	Flavor	Texture	Appearance
[b]Trial	2	NS	NS	NS
[c]Tr	3	*	NS	*

[a] Degrees of Freedom; [b]Trial: Replicate number (1, 2, & 3);
[c]Tr; Treatment (Control, 1.6, 6.4, 12.8% PHP);
* Significantly ($P < 0.05$) different.; NS: Not significant ($P > 0.05$).



[abc] Means that do not share a letter in each category are significantly ($P < 0.05$) different.

Figure 4.4 Average Scores for Sensory Evaluation.

4.5 CONCLUSION

Overall, the use of psyllium husk powder as a dietary fiber source does have some beneficial and adverse effects on a processed turkey product. Functionality characteristics such as cook yield, water holding capacity, and texture do increase as the percentage of fiber increases. Likewise, important safety aspects, pH and water activity, are not significantly affected by the addition of psyllium husk powder into the calcium alginate + ground turkey system. Unfortunately, consumers do not like the flavor and appearance of the samples that contained the 6.4 and 12.8% PHP. Ideally, though, there is a potential use for the 1.6% PHP or 1 gram of dietary fiber per 55 g serving size, in a processed meat product. This could open a new marketing angle without functionally or sensorially altering the product, but further research is still needed to promote and study this innovative idea.

CHAPTER 5: CONCLUSION

In this study, formulating ground turkey with psyllium husk powder at low percentages and percentages that provide 1, 2, or 3 g of dietary fiber have been implemented and determined if those levels of fiber affect functional properties and sensory evaluation.

The first part of the study (Chapter 3), focused on using levels of 0, 0.6, 1.0, and 1.5% of the psyllium husk powder into a ground turkey + calcium alginate binding system matrix. Functional properties that were tested were cook yield, moisture percentage, pH, water activity, water holding capacity, and binding strength. The 1.0 and 1.5% PHP treatments had the highest cooking yield values, 80.0 and 81.2%, respectively, when compared to the 0.6% PHP and control treatments. It appeared that as the fiber percentage increased the moisture percentage of the cooked samples also increased, but this trend was opposite within the raw samples. pH and water activity values of the cooked samples were slightly affected by the presence of the psyllium husk powder, but the range was fairly normal from 6.31 to 6.26 and 0.999 to 0.987, respectively. The 0.6, 1.0, and 1.5% PHP treatments had a significantly ($P < 0.05$) higher water holding capacity when compared to the control. Therefore, when testing binding strength, the 1.5% PHP had the lowest value, 143.66 g. Ultimately resulting from the increase in moisture within the meat system. Results obtained from this portion were deemed beneficial enough to further the research and formulate a product that contained enough psyllium husk powder for health benefits.

The second and last part of the study (Chapter 4), focused on determining the proper levels of psyllium husk powder that would provide a 55 g serving size with either 0, 1, 2, or 3 g of dietary fiber. The project design was upscaled from one-pound batches to 24-pound batches, but the same ground turkey and calcium alginate system was used. Functional properties that tested were cook yield, moisture percentage, pH, water activity, water holding capacity, and texture profile analysis (hardness, cohesiveness, chewiness, gumminess, springiness, and resilience). Also, sensory evaluation was performed were 49 panelists were asked to rate each sample on a 9-point hedonic scale for flavor, texture, and appearance, and asked to answer one question: “Would you be willing to purchase this type of product?”.

The 6.4 and 12.8% PHP treatments had significantly ($P < 0.05$) higher cooking yield values, 90.0 and 90.6% respectively, when compared to the 1.6 and control treatments. The 1.6 and 6.4% PHP cooked treatments showed the highest values ($P < 0.05$) for moisture content at 70.1 and 69.4%, respectively. The moisture percentage of the raw samples were decreasing as the fiber percentage increased, because more water was becoming immobilized and unavailable. Visual observations were noted for the “rubber” texture of the raw meat with fiber, and how there became a reduced amount of product residue within the mixer as the fiber percentage increased. There was no significant ($P > 0.05$) differences observed among the four treatments for pH and water activity. Similarly, to the first part, as the fiber percentage increased the product’s water holding capacity also increased.

During the texture profile analysis, there were significant ($P < 0.05$) differences observed among the four treatments, but there was not any significant ($P > 0.05$)

differences observed between week 0 and 1 and the interaction between week and treatment. The 12.8% PHP treatment showed the highest significant ($P < 0.05$) values for hardness (19,023.0), springiness (1.274), cohesiveness (0.630), gumminess (11,925.0), chewiness (14,997.0), and resilience (0.1347). Unfortunately, since these treatments were not formulated into a specific product category, it is not appropriate to state that these texture results are above, below, or meet the already known and accepted textural properties by consumers within the meat industry.

The only significant differences observed between treatments during sensory evaluation were for flavor and appearance. The control and 1.6% PHP treatments had a significantly ($P < 0.05$) higher "degree of liking" for flavor, 5.78 and 5.63, respectively and appearance, 6.00 and 5.57, respectively when compared to the 6.4 and 12.8% PHP treatments. When asked "Would you be willing to purchase this type of product?" consumers' rating of a "Yes" decreased as the product contained more psyllium husk powder. 34% of panelists were willing to purchase the control sample, 26% for the 1.6% PHP, 7% for the 6.4% PHP, and only 5% for the 12.8% PHP.

Overall, it does appear that using psyllium husk powder within a processed meat product can benefit the cooking yield, moisture percentage, water holding capacity, and texture of the product while only minimally or not at all affecting safety aspects such as pH and water activity. Unfortunately, consumers disliked the flavor and appearance of the product when higher percentages of fiber were used. This could be attributed to the dark color and lack of spices. The 1.6% PHP treatment does seem to have potential within the market because it provides 1 g of dietary fiber per serving, improved functionality, and was considered statistically similar to the more desirable control sample for flavor, appearance, and texture. Further research can still be done with this fiber at the same or lower levels to determine shelf-life, microbiological growth, and consumer acceptability if incorporated into a specific product category.

APPENDIX A: GLM PROCEDURE OUTPUT

PROJECT 1

Dependent Variable: Cooking Yield

Class Level Information

Class	**Levels**	**Values**
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	64

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	15	1894.594375	126.306292	53.45	<.0001
Error	48	113.420000	2.362917		
CT	63	2008.014375			

R-Square	**Coeff Var**	**Root MSE**	**Cooking Yield Mean**
0.943516	2.001290	1.537178	76.80938

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	3	269.068125	89.689375	37.96	<.0001
Trt	3	1396.456875	465.485625	197.00	<.0001
Batch*Trt	9	229.069375	25.452153	10.77	<.0001

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	3	269.068125	89.689375	37.96	<.0001
Trt	3	1396.456875	465.485625	197.00	<.0001
Batch*Trt	9	229.069375	25.452153	10.77	<.0001

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Trt	3	1396.456875	465.485625	18.29	0.0004

Dependent Variable: Moisture Percentage

RAW

Class Level Information

Class	Levels	Values
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	32

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	138.3271875	9.2218125	8.01	<.0001
Error	16	18.4150000	1.1509375		
CT	31	156.7421875			

R-Square	Coeff Var	Root MSE	Moisture Percentage Mean
0.882514	1.541059	1.072818	69.61563

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	3	86.80593750	28.93531250	25.14	<.0001
Trt	3	34.70343750	11.56781250	10.05	0.0006
Batch*Trt	9	16.81781250	1.86864583	1.62	0.1906

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	3	86.80593750	28.93531250	25.14	<.0001
Trt	3	34.70343750	11.56781250	10.05	0.0006
Batch*Trt	9	16.81781250	1.86864583	1.62	0.1906

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	34.70343750	11.56781250	6.19	0.0144

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Class Level Information

Class	Levels	Values
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	32

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	116.9021875	7.7934792	20.73	<.0001
Error	16	6.0150000	0.3759375		
CT	31	122.9171875			

R-Square	Coeff Var	Root MSE	Moisture Percentage Mean
0.951065	0.889128	0.613137	68.95938

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	3	11.99343750	3.99781250	10.63	0.0004
Trt	3	92.41093750	30.80364583	81.94	<.0001
Batch*Trt	9	12.49781250	1.38864583	3.69	0.0111

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	3	11.99343750	3.99781250	10.63	0.0004
Trt	3	92.41093750	30.80364583	81.94	<.0001
Batch*Trt	9	12.49781250	1.38864583	3.69	0.0111

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	92.41093750	30.80364583	22.18	0.0002

Dependent Variable: pH

RAW

Class Level Information

Class	**Levels**	**Values**
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	32

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	15	0.04129687	0.00275312	5.61	0.0007
Error	16	0.00785000	0.00049062		
CT	31	0.04914687			

R-Square	**Coeff Var**	**Root MSE**	**pH Mean**
0.840275	0.341937	0.022150	6.477813

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	3	0.02833437	0.00944479	19.25	<.0001
Trt	3	0.00948437	0.00316146	6.44	0.0046
Batch*Trt	9	0.00347812	0.00038646	0.79	0.6317

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	3	0.02833437	0.00944479	19.25	<.0001
Trt	3	0.00948437	0.00316146	6.44	0.0046
Batch*Trt	9	0.00347812	0.00038646	0.79	0.6317

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Trt	3	0.00948437	0.00316146	8.18	0.0061

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Class Level Information

Class	Levels	Values
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	32

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	0.11469687	0.00764646	8.13	<.0001
Error	16	0.01505000	0.00094063		
CT	31	0.12974687			

R-Square	Coeff Var	Root MSE	pH Mean
0.884005	0.488200	0.030670	6.282188

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	3	0.04805937	0.01601979	17.03	<.0001
Trt	3	0.01863437	0.00621146	6.60	0.0041
Batch*Trt	9	0.04800312	0.00533368	5.67	0.0013

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	3	0.04805937	0.01601979	17.03	<.0001
Trt	3	0.01863437	0.00621146	6.60	0.0041
Batch*Trt	9	0.04800312	0.00533368	5.67	0.0013

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	0.01863437	0.00621146	1.16	0.3758

Dependent Variable: Water Activity

RAW

Class Level Information

Class	**Levels**	**Values**
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	32

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	15	0.00073672	0.00004911	1.68	0.1557
Error	16	0.00046650	0.00002916		
CT	31	0.00120322			

R-Square	**Coeff Var**	**Root MSE**	**Water Activity Mean**
0.612290	0.544680	0.005400	0.991344

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	3	0.00009434	0.00003145	1.08	0.3862
Trt	3	0.00027409	0.00009136	3.13	0.0548
Batch*Trt	9	0.00036828	0.00004092	1.40	0.2654

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	3	0.00009434	0.00003145	1.08	0.3862
Trt	3	0.00027409	0.00009136	3.13	0.0548
Batch*Trt	9	0.00036828	0.00004092	1.40	0.2654

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Trt	3	0.00027409	0.00009136	2.23	0.1537

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Class Level Information

Class	Levels	Values
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	32

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	0.00225987	0.00015066	3.40	0.0101
Error	16	0.00070800	0.00004425		
CT	31	0.00296788			

R-Square	Coeff Var	Root MSE	Water Activity Mean
0.761445	0.669854	0.006652	0.993063

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	3	0.00049863	0.00016621	3.76	0.0324
Trt	3	0.00058937	0.00019646	4.44	0.0188
Batch*Trt	9	0.00117187	0.00013021	2.94	0.0288

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	3	0.00049863	0.00016621	3.76	0.0324
Trt	3	0.00058937	0.00019646	4.44	0.0188
Batch*Trt	9	0.00117187	0.00013021	2.94	0.0288

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	0.00058937	0.00019646	1.51	0.2776

Dependent Variable: Water Holding Capacity

RAW

Class Level Information

Class	**Levels**	**Values**
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	32

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	15	0.34437187	0.02295812	2.96	0.0193
Error	16	0.12415000	0.00775938		
CT	31	0.46852188			

R-Square	**Coeff Var**	**Root MSE**	**Water Holding Capacity Mean**
0.735018	6.493421	0.088087	1.356563

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	3	0.12130938	0.04043646	5.21	0.0106
Trt	3	0.01965938	0.00655313	0.84	0.4894
Batch*Trt	9	0.20340312	0.02260035	2.91	0.0299

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	3	0.12130938	0.04043646	5.21	0.0106
Trt	3	0.01965938	0.00655313	0.84	0.4894
Batch*Trt	9	0.20340312	0.02260035	2.91	0.0299

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Trt	3	0.01965938	0.00655313	0.29	0.8317

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Class Level Information

Class	Levels	Values
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	32

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	11.33919688	0.75594646	13.56	<.0001
Error	16	0.89215000	0.05575938		
CT	31	12.23134688			

R-Square	Coeff Var	Root MSE	Water Holding Capacity Mean
0.927060	10.25695	0.236134	2.302188

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	3	3.25315938	1.08438646	19.45	<.0001
Trt	3	6.56515938	2.18838646	39.25	<.0001
Batch*Trt	9	1.52087812	0.16898646	3.03	0.0256

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	3	3.25315938	1.08438646	19.45	<.0001
Trt	3	6.56515938	2.18838646	39.25	<.0001
Batch*Trt	9	1.52087812	0.16898646	3.03	0.0256

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	6.56515938	2.18838646	12.95	0.0013

Dependent Variable: Binding Strength

<u>RAW</u>

Class Level Information

Class	Levels	Values
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	128

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	8255.000000	550.333333	49.59	<.0001
Error	112	1243.000000	11.098214		
CT	127	9498.000000			

R-Square	Coeff Var	Root MSE	Binding Strength Mean
0.869130	10.05705	3.331398	33.12500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	3	4059.812500	1353.270833	121.94	<.0001
Trt	3	3489.937500	1163.312500	104.82	<.0001
Batch*Trt	9	705.250000	78.361111	7.06	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	3	4059.812500	1353.270833	121.94	<.0001
Trt	3	3489.937500	1163.312500	104.82	<.0001
Batch*Trt	9	705.250000	78.361111	7.06	<.0001

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	3489.937500	1163.312500	14.85	0.0008

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Class Level Information

Class	Levels	Values
Batch	4	1 2 3 4
Treatment	4	0.6 1.0 1.5 Control

Number of Observations

Number of Observations Read	128
Number of Observations Used	128

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	139536.4297	9302.4286	11.88	<.0001
Error	112	87713.1250	783.1529		
CT	127	227249.5547			

R-Square	Coeff Var	Root MSE	Binding Strength Mean
0.614023	16.87503	27.98487	165.8359

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	3	15336.77344	5112.25781	6.53	0.0004
Trt	3	67407.02344	22469.00781	28.69	<.0001
Batch*Trt	9	56792.63281	6310.29253	8.06	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	3	15336.77344	5112.25781	6.53	0.0004
Trt	3	67407.02344	22469.00781	28.69	<.0001
Batch*Trt	9	56792.63281	6310.29253	8.06	<.0001

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	67407.02344	22469.00781	3.56	0.0604

APPENDIX B: GLM PROCEDURE OUTPUT

PROJECT 2

Dependent Variable: Cook Yield

Class Level Information

Class	**Levels**	**Values**
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	153
Number of Observations Used	119

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	11	9298.448086	845.313462	186.88	<.0001
Error	107	483.988889	4.523261		
CT	118	9782.436975			

R-Square	**Coeff Var**	**Root MSE**	**Cook Yield Mean**
0.950525	2.554645	2.126796	83.25210

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	2	57.695308	28.847654	6.38	0.0024
Trt	3	8787.812792	2929.270931	647.60	<.0001
Batch*Trt	6	452.939985	75.489998	16.69	<.0001

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	2	49.207702	24.603851	5.44	0.0056
Trt	3	8806.114414	2935.371471	648.95	<.0001
Batch*Trt	6	452.939985	75.489998	16.69	<.0001

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Trt	3	8806.114414	2935.371471	38.88	0.0003

Dependent Variable: Raw Moisture Percentage

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	153
Number of Observations Used	36

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	486.3333333	44.2121212	227.38	<.0001
Error	24	4.6666667	0.1944444		
CT	35	491.00000			

R-Square	Coeff Var	Root MSE	Raw Moisture Percentage Mean
0.990496	0.631444	0.440959	69.83333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	2	45.500000	22.7500000	117.00	<.0001
Trt	3	395.00000	131.666667	677.14	<.0001
Batch*Trt	6	45.8333333	7.6388889	39.29	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	2	45.5000000	22.75000000	117.00	<.0001
Trt	3	395.00000	131.666667	677.14	<.0001
Batch*Trt	6	45.8333333	7.6388889	39.29	<.0001

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	395.0000000	131.666666	17.24	0.0024

Dependent Variable: Cooked Moisture Percentage

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	153
Number of Observations Used	36

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	292.9722222	26.6338384	95.88	<.0001
Error	24	6.6666667	0.2777778		
CT	35	299.6388889			

R-Square	Coeff Var	Root MSE	Cooked Moisture Percentage Mean
0.977751	0.784360	0.527046	67.19444

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	2	24.2222222	12.1111111	43.60	<.0001
Trt	3	248.972222	82.9907407	298.77	<.0001
Batch*Trt	6	19.7777778	3.2962963	11.87	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	2	24.2222222	12.1111111	43.60	<.0001
Trt	3	248.972222	82.9907407	298.77	<.0001
Batch*Trt	6	19.7777778	3.2962963	11.87	<.0001

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	248.9722222	82.9907407	25.18	0.0008

Dependent Variable: Raw pH

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	153
Number of Observations Used	24

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	0.26081250	0.02371023	21.64	<.0001
Error	12	0.01315000	0.00109583		
CT	23	0.27396250			

R-Square	Coeff Var	Root MSE	Raw pH Mean
0.952001	0.538814	0.033103	6.143750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	2	0.20312500	0.10156250	92.68	<.0001
Trt	3	0.02591250	0.00863750	7.88	0.0036
Batch*Trt	6	0.03177500	0.00529583	4.83	0.0099

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	2	0.20312500	0.10156250	92.68	<.0001
Trt	3	0.02591250	0.00863750	7.88	0.0036
Batch*Trt	6	0.03177500	0.00529583	4.83	0.0099

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	0.02591250	0.00863750	1.63	0.2790

Dependent Variable: Cooked pH

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	153
Number of Observations Used	24

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	0.46031250	0.04184659	87.33	<.0001
Error	12	0.00575000	0.00047917		
CT	23	0.46606250			

R-Square	Coeff Var	Root MSE	Cooked pH Mean
0.987663	0.358336	0.021890	6.108750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	2	0.33647500	0.16823750	351.10	<.0001
Trt	3	0.05181250	0.01727083	36.04	<.0001
Batch*Trt	6	0.07202500	0.01200417	25.05	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	2	0.33647500	0.16823750	351.10	<.0001
Trt	3	0.05181250	0.01727083	36.04	<.0001
Batch*Trt	6	0.07202500	0.01200417	25.05	<.0001

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	0.05181250	0.01727083	1.44	0.3216

Dependent Variable: Water Activity

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	153
Number of Observations Used	24

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	0.00050512	0.00004592	2.08	0.1127
Error	12	0.00026550	0.00002213		
CT	23	0.00077062			

R-Square	Coeff Var	Root MSE	Water Activity Mean
0.655474	0.470902	0.004704	0.998875

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	2	0.00040900	0.00020450	9.24	0.0037
Trt	3	0.00001712	0.00000571	0.26	0.8542
Batch*Trt	6	0.00007900	0.00001317	0.60	0.7292

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	2	0.00040900	0.00020450	9.24	0.0037
Trt	3	0.00001712	0.00000571	0.26	0.8542
Batch*Trt	6	0.00007900	0.00001317	0.60	0.7292

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	0.00001712	0.00000571	0.43	0.7369

Dependent Variable: Raw Water Holding Capacity

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	153
Number of Observations Used	36

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	0.91663056	0.08333005	9.74	<.0001
Error	24	0.20540000	0.00855833		
CT	35	1.12203056			

R-Square	Coeff Var	Root MSE	Raw WHC Mean
0.816939	6.396016	0.092511	1.446389

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Batch	2	0.00423889	0.00211944	0.25	0.7826
Trt	3	0.28416389	0.09472130	11.07	<.0001
Batch*Trt	6	0.62822778	0.10470463	12.23	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Batch	2	0.00423889	0.00211944	0.25	0.7826
Trt	3	0.28416389	0.09472130	11.07	<.0001
Batch*Trt	6	0.62822778	0.10470463	12.23	<.0001

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	3	0.28416389	0.09472130	0.90	0.4922

Dependent Variable: Cooked Water Holding Capacity

Class Level Information

Class	**Levels**	**Values**
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	153
Number of Observations Used	36

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	11	2.13370000	0.19397273	13.90	<.0001
Error	24	0.33500000	0.01395833		
CT	35	2.46870000			

R-Square	**Coeff Var**	**Root MSE**	**Cooked WHC Mean**
0.864301	6.875580	0.118145	1.718333

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	2	0.08911667	0.04455833	3.19	0.0590
Trt	3	1.82285556	0.60761852	43.53	<.0001
Batch*Trt	6	0.22172778	0.03695463	2.65	0.0409

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Batch	2	0.08911667	0.04455833	3.19	0.0590
Trt	3	1.82285556	0.60761852	43.53	<.0001
Batch*Trt	6	0.22172778	0.03695463	2.65	0.0409

Tests of Hypotheses Using the Type III MS for Batch*Trt as an Error Term

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Trt	3	1.82285556	0.60761852	16.44	0.0027

Dependent Variable: Hardness

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control
Week	2	0 1

Number of Observations

Number of Observations Read	306
Number of Observations Used	238

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error
Batch	4600991	5492514
Batch*Trt	2526554	2060555
Batch (Trt*Wk)	1737596	947786
Residual	1559741	150786

Type II Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Trt	3	6	19.93	0.0016
Week	1	8	1.52	0.2533
Trt*Week	3	8	0.52	0.6827

Trt Least Squares Means

Trt	Estimate	SE	DF	t Value	Pr > F
1.6	7278.77	1640.56	6	4.44	0.0044
12.8	19023	1640.56	6	11.60	<.0001
6.4	12511	1640.85	6	7.62	0.0003
Control	12856	1640.56	6	7.84	0.0002

Dependent Variable: Springiness

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control
Week	2	0 1

Number of Observations

Number of Observations Read	306
Number of Observations Used	238

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error
Batch	0.007545	0.01723
Batch*Trt	0.02050	0.02188
Batch (Trt*Wk)	0.02501	0.01510
Residual	0.05154	0.004983

Type II Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Trt	3	6	3.35	0.0967
Week	1	8	1.96	0.1995
Trt*Week	3	8	0.57	0.6509

Trt Least Squares Means

Trt	Estimate	SE	DF	t Value	Pr > F
1.6	0.8717	0.1199	6	7.27	0.0003
12.8	1.2738	0.1199	6	10.62	<.0001
6.4	1.0663	0.1200	6	8.88	0.0001
Control	0.8444	0.1199	6	7.04	0.0004

Dependent Variable: Cohesiveness

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control
Week	2	0 1

Number of Observations

Number of Observations Read	306
Number of Observations Used	238

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error
Batch	0	.
Batch*Trt	01.78E-22	.
Batch (Trt*Wk)	0.002098	0.000860
Residual	0.003277	0.000317

Type II Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Trt	3	6	40.73	0.0002
Week	1	8	2.64	0.1430
Trt*Week	3	8	0.71	0.5723

Trt Least Squares Means

Trt	Estimate	SE	DF	t Value	Pr > F
1.6	0.3631	0.02011	6	18.06	<.0001
12.8	0.6296	0.02011	6	31.32	<.0001
6.4	0.5601	0.02011	6	27.79	<.0001
Control	0.3954	0.02011	6	19.66	<.0001

Dependent Variable: Gumminess

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control
Week	2	0 1

Number of Observations

Number of Observations Read	306
Number of Observations Used	238

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error
Batch	1001217	1335167
Batch*Trt	994195	754850
Batch (Trt*Wk)	478051	289124
Residual	998526	96525

Type II Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Trt	3	6	35.94	0.0003
Week	1	8	3.57	0.0954
Trt*Week	3	8	0.71	0.5728

Trt Least Squares Means

Trt	Estimate	SE	DF	t Value	Pr > F
1.6	2637.01	872.61	6	3.02	0.0233
12.8	11925	872.61	6	13.67	<.0001
6.4	6985.12	872.61	6	8.00	0.0002
Control	5206.64	872.61	6	5.97	0.0010

Dependent Variable: Chewiness

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control
Week	2	0 1

Number of Observations

Number of Observations Read	306
Number of Observations Used	238

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error
Batch	173024	861580
Batch*Trt	1222335	1542082
Batch (Trt*Wk)	1874685	1229786
Residual	5804650	561107

Type II Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Trt	3	6	37.56	0.0003
Week	1	8	5.03	0.0552
Trt*Week	3	8	0.68	0.5859

Trt Least Squares Means

Trt	Estimate	SE	DF	t Value	Pr > F
1.6	2335.44	935.05	6	2.50	0.0467
12.8	14997	935.05	6	16.04	<.0001
6.4	7425.97	936.94	6	7.93	0.0002
Control	4454.33	935.05	6	4.76	0.0031

Dependent Variable: Resilience

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control
Week	2	0 1

Number of Observations

Number of Observations Read	306
Number of Observations Used	238

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error
Batch	0.000043	0.000227
Batch*Trt	0.000101	0.000464
Batch (Trt*Wk)	0.000731	0.000549
Residual	0.003634	0.000351

Type II Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Trt	3	6	6.40	0.0267
Week	1	8	1.61	0.2407
Trt*Week	3	8	0.61	0.6277

Trt Least Squares Means

Trt	Estimate	SE	DF	t Value	Pr > F
1.6	0.04553	0.01518	6	3.00	0.0240
12.8	0.1347	0.01518	6	8.87	0.0001
6.4	0.09309	0.01518	6	6.10	0.0009
Control	0.07620	0.01518	6	5.02	0.0024

Dependent Variable: Flavor

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	588
Number of Observations Used	587

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error
Batch*Trt	0	.
Residual	2.6710	0.1567

Type II Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Batch	2	6	3.56	0.0958
Trt	3	6	1.61	0.0005

Trt Least Squares Means

Trt	Estimate	SE	DF	t Value	Pr > [t]
Control	5.7823	0.1348	6	42.90	<.0001
1.6	5.6327	0.1348	6	41.79	<.0001
6.4	4.7211	0.1348	6	35.02	<.0001
12.8	4.2312	0.1353	6	31.28	<.0001

Dependent Variable: Texture

Class Level Information

Class	**Levels**	**Values**
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	588
Number of Observations Used	588

Covariance Parameter Estimates

Cov Parm	**Estimate**	**Standard Error**
Batch*Trt	0.08710	0.09134
Residual	3.4763	0.2048

Type II Tests of Fixed Effects

Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Batch	2	6	0.06	0.9452
Trt	3	6	1.41	0.3277

Trt Least Squares Means

Trt	**Estimate**	**SE**	**DF**	**t Value**	**Pr > [t]**
Control	5.2925	0.2295	6	23.06	<.0001
1.6	4.9592	0.2295	6	21.61	<.0001
6.4	5.4422	0.2295	6	23.71	<.0001
12.8	4.8639	0.2295	6	21.19	<.0001

Dependent Variable: Appearance

Class Level Information

Class	Levels	Values
Batch	3	1 2 3
Treatment	4	1.6 12.8 6.4 Control

Number of Observations

Number of Observations Read	588
Number of Observations Used	588

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error
Batch*Trt	0	.
Residual	2.6637	0.1561

Type II Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Batch	2	6	1.47	0.3027
Trt	3	6	36.76	0.0003

Trt Least Squares Means

Trt	Estimate	SE	DF	t Value	Pr > [t]
Control	6.0000	0.1346	6	44.57	<.0001
1.6	5.5714	0.1346	6	41.39	<.0001
6.4	5.1769	0.1346	6	38.46	<.0001
12.8	4.0952	0.1346	6	30.42	<.0001

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