CONSUMER EVALUATION AND SHELF-LIFE OF GLUTEN-FREE PECAN BREADED CHICKEN NUGGETS

by

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(Under the Direction of William L. Kerr)

ABSTRACT

This study investigated the use of pecans in a breaded chicken nugget as a way to increase the use of an underutilized culinary nut. Several attributes were measured including moisture and lipid content, color analysis, and batter adhesion. Spectrophotometric determination of conjugated products by UV absorption and the TBARS assay were used to quantify primary and secondary oxidation products. Sensory studies were conducted using descriptive and consumer evaluation. For the physical properties, there was a significant difference in the color analysis for the b* value for the 100% cornflake breading compared to the 50% pecans to 50% cornflake breading and 75% pecans to 25% cornflake breading. Also, the 50% pecans to 50% cornflake breading and 75% pecans to 25% cornflake breading had significantly higher lipid content. For the storage study there was a significant difference for nuggets stored at -40°C and -15°C temperatures as well as for conjugated dienes and trienes (CDT) values for samples stored at different temperatures. The trained descriptive panel and the consumer panel for the storage study as well as the consumer panel that tested the breading with different ratios of pecans to cornflakes did not find any significant differences.

INDEX WORDS: pecans, fried, sensory evaluation, chicken pieces, conjugated dienes, thiobarbituric acid reactive substances (TBARS), and oxidative stability

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A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTERS OF SCIENCE

ATHENS, GEORGIA

2016

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May 2016

ACKNOWLEDGEMENTS

I would like to thank the Food Science Department at the University of Georgia for accepting me into their graduate school program. I would like to thank Dr. Kerr, Dr. Akoh, and Dr. Singh for their assistance with my research. I would like to thank my lab mates, Carl Ruiz, and Carlos Barrow for their assistance. I would like to thank the South Georgia Pecan Company for providing the pecans. Thank you to my friends and family who encouraged me throughout this process.

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CHAPTER 1

INTRODUCTION

The pecan tree is an important nut crop that contributes to the agricultural economy and history of the United States (Lombardini, Waliczek, and Zajicek 2008). Pecan, a common name for a species of Hickory, *Carya illinoinensis*, is a deciduous tree of the family Juglandaceae ("Pecan" 2014). Pecans are also known for being the only major native nut-producing tree in North America, with the bulk of the commercial crop coming from Georgia, Texas, New Mexico, Oklahoma, and Louisiana ("Nuts" 2016). In 2014, Georgia was the lead producer of pecans, with production for all pecans (improved varieties, native, and seedling) reaching 76 million pounds, followed by New Mexico at 67 million pounds, Texas at 61 million pounds, and Arizona at 21 million pounds (Gina Marzolo 2015).

Pecans, a culinary nut, are often included in baked goods, candies, ice cream and snacks. However, their benefits extend beyond the kitchen. A one-ounce serving of pecans contains 196 calories, 3 grams of dietary fiber and a plethora of other nutrients including vitamin E and A, zinc, potassium, and calcium ("Pecan Nutrition Fact Sheet" 2016). Not only are pecans a beloved snack in the United States, but exports continue to grow. Hong Kong, Mexico, and the European Union are the largest export markets, with over 47,000 metric tons exported to them in 2010 (Gorscak, 2012). Domestic consumption has stagnated for several years, and the industry is investing in the development of value-added foods. Breaded products that incorporate pecans is an example of one of the value-added foods.

The objectives of this study was to investigate the use of pecans in a breaded product by evaluating moisture and lipid content, consumer acceptability, batter adhesion and color analysis. Also, to quantify lipid oxidation by spectrophotometric methods and use sensory analysis to determine if oxidized flavors are detectable.

CHAPTER 2

LITERATURE REVIEW

PECAN OVERVIEW

Pecans are one of the few native U.S. food crops that are commercially grown outside the U.S. (such as Mexico, Australia, South Africa, Israel, Brazil, Argentina) (Santerre 1994). It is often referred to as a nut, but it is officially a drupe, a fruit with a single stone or pit surrounded by a husk. Ideally, a good pecan has a plump, golden colored kernel and is free of defects such as hulls that stick to meat during shelling or have discolored veins (Santerre 1994). They are perennial in their growth and bear fruit within 6 to 10 years (from seed) (Fred Brison 1986). The pecan has multiple uses such as pecan pie roasted nuts, pecan butter, pecan flour, pecan confections, and pecan ice cream.

Although domestic pecan consumption has been relatively flat for several years, there has been renewed interest in increasing its use. This is due to uncertainty in foreign export markets (e.g., China) and increased production in developing markets (Lillywhite, Simonsen, and Heerema 2014). Weak domestic sales were overlooked because profits were high internationally. Pecans are often thought of as a holiday treat but changing this perception can help increase domestic pecan consumption. Developing products that are enjoyed year round can help modify the pecan’s image of being only a seasonal treat.

In recent years, researchers have focused more on the health benefits of nuts. Nuts, such as pistachios, walnuts, almonds, pecans, peanuts, and hazelnuts, are energy dense and good sources of fiber and vitamins. Anti-inflammatory, cardioprotective, antioxidant, and anti-diabetic properties may provide health benefits that stem from consistent nut consumption. Single meals supplemented with nuts can have a favorable impact on postprandial events associated with atherogenesis, such as glucose and triglycerides peaks and inflammation (Ros 2010). Long-term nuts consumption has also been associated with decreased weight gain. There are several possible explanations that clarify how nut consumption may lead to lower body weight (C. L. Jackson and Hu 2014). First, there is increased satiety from proteins and dietary fiber. Secondly, oxidation of unsaturated fats may decrease fat accumulation. Third, increased thermogenesis caused by fiber, protein, and unsaturated fat content of nuts. And finally, consumers who regularly eat nuts have a tendency to consume less red meat and highly processed carbohydrates. Vadivel and associates found that misconceptions concerning the high-fat content of nuts and body weight gain tend to negatively affect nut intake (Vadivel, Kunyanga, and Biesalski 2012).

While health benefits of nuts also apply to pecans, there are studies focused solely on increased pecan consumption and its nutritional benefits. Health benefits specific to pecans include the ability to decrease low density lipoproteins (LDL) (Hudthagosol et al. 2011). Pecan components, γ-tocopherol and flavan-3-ol monomers, have shown antioxidant properties, but it is unknown if they are bioavailable. One study found that participants that ate 90 grams of pecans per test meal increased their blood antioxidant levels and decreased their LDL oxidation (Hudthagosol et al. 2011). Another benefit of a pecan-enriched diet is that it favorably alters the serum lipid profile of healthy men and women. Rajaram and associates found that a diet high in monounsaturated fatty acid such as those in pecans lowers cholesterol levels (Rajaram et al. 2001).

Increased consumer awareness of the health benefits associated with nut consumption and the large assortment of flavors offered, has driven demand for products in this segment

(IBISWorld 2016). It is estimated that nuts and nut butter account for 33.4% of the snack foods industry revenue (IBISWorld 2016). Not only are buyers snacking on nuts and seeds throughout the day but also incorporating them into meals. Even food service establishments are joining in on the trend by adding nuts, walnuts, almond slivers and pecans, into menu options such as salads. Nut butters continue to be a popular way to eat nuts. A survey conducted by Mintel found, “Three-quarters of US adults have purchased nut spreads in the last six months, including peanut butter (67%), almond butter (16%), and other nut or seed butters (12%) (Mintel 2016c). Respondents with one child purchased nut spreads at a significantly higher rate than those without children.

Food manufacturers have noticed the nut trend and have responded. Confectionary launches with nut-based flavors increase the perception of health by consumers and using nuts reduces the amount of chocolate needed in products (Mintel 2016a). Among snack, nutrition, and protein bars, nuts have grown as the top protein source (Mintel 2016d). Consumers have customized their breakfast at home by adding ingredients to their bowls such as nuts (Mintel 2016b). While pecans have been the main ingredient in products such as ice cream, baked goods, and candy, they are appearing in more unconventional products. Some unconventional products include pecan butter, beer, crackers, and oil.

GLUTEN-FREE PRODUCTS

Increased awareness of gastrointestinal diseases such as Celiac disease and consumer health trends for weight management fueled the growth of the gluten-free market. Last year, Prepared Foods reported that the U.S. gluten-free food retail market reached $973 million in sales and is projected to exceed $2 billion in 2019 (Prepared Foods 2015).

Wheat, rye, and barley are some of the cereal grains where gluten proteins are found. Gluten prevents crumbling of baked goods and gives them their desirable texture (Gallagher 2009). It is the glue that is responsible for the structure of things such as bread, cookies and cakes. Celiac disease is an auto-immune condition that is triggered by gluten, and while it is not life-threatening, it does decrease the quality of life. Once thought of as a rare disease of infancy, modern diagnostics methods have revealed an average prevalence of approximately 1% in Western populations (Wieser, Koehler, and Konitzer 2014). It is a lifelong disorder that calls for the complete avoidance of gluten.

Until recently, specialty food stores were the only source of gluten-free products. Today products that use gluten-free substitutes, or products made from wheat, rye, barley, and oats that have been rendered gluten-free, are readily available in your neighborhood grocery store. Gluten plays a central role in dough formation; it is responsible for the elasticity of the dough, it aids in the rising of baked goods and helps retain moisture. The food industry has used starchy flours, such as rice, corn, potato and tapioca to develop gluten-free bread. However, this is not without new problems. For example, high starch content in bread can reduce its shelf life (Gallagher 2009).

Regulations in the U.S. require that food companies label "in simple language" the eight major food allergens. The Food and Drug Administration (FDA) defines the term "gluten-free" to mean "the food bearing the claim does not contain an ingredient that is a gluten-containing grain (e.g., spelt-wheat); an ingredient that is derived from a gluten-containing grain and that has not been processed to remove gluten (e.g., wheat flour); or an ingredient that is derived from a gluten-containing grain and that has been processed to remove gluten (e.g., wheat starch), if the use of that ingredient results in the presence of 20 parts per million (ppm) or more gluten in the food (i.e., 20 milligrams (mg) or more gluten per kilogram (kg) of food); or inherently does not contain gluten; and that any unavoidable presence of gluten in the food is below 20 ppm gluten (i.e., below 20 mg gluten per kg of food) (Food and Drug Administration 2013)."

BATTERS AND BREADINGS

Batter is a mixture of ingredients used as a coating for food, but does not refer to an exact recipe. It is applied to food in an effort to increase its appeal. There are two general categories of battered foods. Interface/adhesion batter acts mainly as an adhesive layer and often a breading or bread crumb is applied to it before cooking (Kulp and Loewe 1990). Also, chemical leavening generally is not used in the batter. Puff/tempura batter is chemically leavened and typically not used with additional breading or breadcrumb (Kulp and Loewe 1990). Breadings, on the other hand, have been defined by Suderman and Cummingham as "(1) a flour-based bread crumb or cracker meal that is applied to a food in a dry form primarily to create a desired coating texture, and (2) a dry food coating made from flour , starch, seasonings, etc., that is coarse in nature and applied over moistened or battered food products (Kulp and Loewe 1990)." Characteristics important to both batters and breading include appealing appearance, attractive color, crispness, adhesion, and flavor (Kulp and Loewe 1990).

Appearance includes several qualities that contribute to overall acceptance and can be summarized as tenderness, toughness, thickness, texture, and translucency (Kulp and Loewe 1990). The amount and uniformity of the coating/breading applied to the food can affect these properties. For example, a coating that is very smooth and lacks texture may be perceived negatively. Coating appearance is also closely associated with the products' cooked color. Some factors that contribute to the color include the cooking method and medium, ingredient composition, and the condition of the frying oil. Frying is the cooking method that results in optimal browning followed by a conventional oven, and finally, a microwave oven results in little to no browning.

Heating time and the temperature are related to color development as well as the type and age of the frying oil. Perceived color is also affected by ingredient composition by chemical means (level of proteins or sugar) or physical means (granulation, adsorptive capacity) (Kulp and Loewe 1990).

Another vital characteristic is crispness, although it is difficult to quantify this sensory attribute. A product that lacks crispness may be deemed rubbery or mushy. Ideally, the product would have a structure that resists the initial bite but then breaks down easily in the mouth. Extended storage often has a negative effect on crispness, making it hard to maintain this attribute. External stresses such as those experienced during frozen storage and transportation, highlight the need for batters and breadings to maintain uniform adhesion to the product (Kulp and Loewe 1990). Broken pieces of frozen batter or breading become waste in the bottom of the package; this is both uneconomical and unattractive to the consumer, which may result in the product not being purchased again. Products shouldn’t form voids or pockets during home preparation, as this is evidence of poor adhesion. During deep frying, a lack of adhesion may result in the substrate pulling away from the cooked coating. Steaming, simmering, or boiling the food substrate beforehand has shown to increase the adhesive properties of the coatings (Kulp and Loewe 1990). Polyphosphates, modified breadings, yeast proteins, vegetable oils, oxidized starches and vegetable gums are a few ingredients that have been reported to increase adhesion (Suderman and Cunningham 1983).

Lastly, the flavor is an essential characteristic of batter and breadings. The flavor of a product can cause it to be accepted or rejected. If the flavor is bland or undesirable, it will not matter that it had excellent texture, color, and crispness. Flavor, as well as, appearance, color, crispness, and adhesion play an important role in consumer acceptance.

FRYING

Frying is a common method for food preparation. It is a complex process that is not completely understood. What is known is that it involves the simultaneous transfer of heat and mass. Food immersed in hot oil causes water vapor to form due to high temperature. The water vapor is then transferred through the surface of the product as a result of pressure and concentration gradient (Sahin and Sumnu 2009). Fried products undergo high heat transfer rates that are mostly responsible for desired sensory properties (Shaker 2015).

Generally, food that is fried comes in contact with heated oil that is between 185-190°C. There is a transfer of heat and mass, where the heat leaves the oil and enters the food while the moisture leaves the food and enters the oil. Heat is transferred by both convection and conduction during frying. Convection takes place at the surface of the product where heat is transferred from the oil. Heat at the surface of the food is then transferred to the center of the product by conduction (Ballard 2003). While heat is being transferred, water moves from the center of the food to the exterior to replace that which is lost by dehydration. When water and the hot oil come into contact bubbles form and move vigorously through the oil (Blumenthal 1991). Heat transfer is promoted by the vigorous movement of the water. As the water vapor bubbles decrease with increased frying time so does the amount of water in the product.

LIPID OXIDATION

Lipid oxidation in food can cause undesirable qualities in the products that consumers purchase. It is described by Johnson and Decker (2015) as “the principal deteriorative reaction during food processing and storage that limits the shelf life of most microbiologically stable foods”. Hydroperoxides are byproducts of lipid oxidation, which can further decompose into secondary reaction products such as aldehydes, acids, alcohols, and ketones (St. Angelo 1992). The taste, aroma, flavor, nutritional quality and overall quality can be negatively affected. Hydroperoxides are primary oxidation products, that are relatively stable (depending on lipid structure) in spite of being intermediate compounds of lipid oxidation process (Barriuso, Astiasarán, and Ansorena 2013). Due to this characteristic, they are often used to evaluate lipid oxidation status in food samples. Hydroperoxides, or just peroxides for short, usually undergo additional oxidation and turn into secondary oxidation products (Barriuso, Astiasarán, and Ansorena 2013).

Initiation, propagation, and termination make up the three stages of lipid oxidation. When a hydrogen atom is removed from a fatty acid, deterioration is initiated, and an alkyl radical is formed. Unsaturated fatty acids can form free radicals via hydrogen abstraction mechanisms from initiating free radicals present in food. Π electrons of the double bond stabilize the free radical through delocalization over a conjugated diene structure after alkyl radical formation. This is done by converting one of the double bonds to the more stable trans form. After the formation of a lipid radical, triplet oxygen reacts with the alkyl radical to form a covalent bond with the lipid (Johnson and Decker 2015). The newly formed peroxyl radical abstracts another hydrogen from the unsaturated lipid to form hydroperoxides and propagate the free radical chain reaction by producing another free radical on the second fatty acid (Johnson and Decker 2015).

The detection, quantification, and monitoring of lipid oxidation is a crucial part of a food manufacturer activities. There are numerous assaying methods for lipid oxidation, such as (Barriuso, Astiasarán, and Ansorena 2013) titration, UV-Vis spectroscopic methods, chromatography, chemiluminescence, IR spectroscopy, Raman-scattering, nuclear magnetic resonance, and electron paramagnetic resonance.

Iodometry is one of the most commonly used methods for the analysis of peroxides. Hydroperoxides and other peroxides react under acidic conditions with iodide ions to generate iodine (Barriuso, Astiasarán, and Ansorena 2013). It is titrated with sodium thiosulfate solution, in the presence of starch. Besides the titration method, spectroscopic techniques are fairly simple, and moderately sensitive, reliable, and reproducible when performed under standardized conditions. Conjugated dienes/trienes and malondialdehyde are a few of the oxidation products that UV-Vis spectroscopic methods are used to detect. This assay usually involves the use of a solvent to extract the analyte and its absorbance measured at some specific wavelength. Gas chromatographic methods are growing in popularity but are usually time-consuming or involve complex experimental work and data processing. This procedure usually involves lipid extraction and a derivatization step.

Some alternative methods include chemiluminescence, fluorescence spectroscopy, infrared spectroscopy, ramen spectroscopy, nuclear magnetic resonance and electron paramagnetic resonance, and are based on direct spectroscopic analysis of samples. Chemiluminescence relies on the fact that some chemical reactions generate electromagnetic radiation, and this can be applied to detect and quantify compounds of interest. For fluorescence spectroscopy, free amino groups of protein react with aldehydes from lipid oxidation or reducing sugars to give Schiff bases (Barriuso, Astiasarán, and Ansorena 2013). The resulting high color intensity and characteristic fluorescence spectra are specific to the type of protein and adduct. Infrared spectroscopy has been used to determine the peroxide value in oxidized oil (Barriuso, Astiasarán, and Ansorena 2013). It measures fundamental vibrational transitions of a specific compound and includes the absorption of discrete energy levels from the IR region (Barriuso, Astiasarán, and Ansorena 2013). Raman spectroscopy is based on the scattering of monochromatic light which is usually from a laser (Xu, Riccioli, and Sun 2015). This method has been used extensively to analyze fish and related products. Nuclear magnetic resonance relies on the trait of certain atoms absorbing and re-emitting energy in the presence of a strong magnetic field due to the excitation of their atomic nuclei (Barriuso, Astiasarán, and Ansorena 2013). Electron paramagnetic resonance is similar to nuclear magnetic resonance, but it is the spins of single electrons that energy excites.

Hydroperoxides and a variety of aldehydes are used to indicate lipid oxidation. Each compound correlates with a specific state of oxidation. It is best practice to combine different methods to measure oxidative status. Each of the above methods has its advantages and limitations. This study utilized VIS-UV spectroscopic methods to monitor lipid oxidation. The quantification of conjugated dienes/trienes was used to monitor primary oxidation products and the development of 2-thiobarbituric acid reactive substances to monitor secondary oxidation products.

SHELF-LIFE STUDIES

Hough and Garitta reported the definition of shelf-life as, "the time during which the food product will: 1) remain safe; 2) retain desired sensory, chemicals, physical and microbiological characteristics; and 3) comply with any label declaration of nutritional data when stored under recommended conditions (Hough and Garitta 2012)." While the spoilage and deterioration cannot be stopped; it is in the best interest of the food producer to slow the rate of decay through processing, formulation, packaging, storage and handling (Steele 2004). Food manufacturer test their products to obtain knowledge about when and why the product deteriorates. This knowledge helps to ensure the customer is consuming the food in its ideal state.

Food spoilage can present itself as a food safety issue when the product causes the consumer to become ill or even die. More commonly food spoilage may be in the form of color, aroma, flavor, or texture changes that result in the product being unacceptable. Physical, chemical and microbiological spoilage are the three main categories of food spoilage (Steele 2004). With this in mind, a few types of deterioration associated with frozen foods during storage are moisture migration, oxidation, breakage and ice crystal formation. Microbial growth tends not to be a problem for frozen foods since they cannot grow at freezing temperatures unless subjected to extensive temperature abuse above the freezing point (Fu and Labuza 1997). Temperature, pH, water activity, exposure to light and oxygen, and nutrients or chemicals available in the products are several main factors that influence most types of spoilage (Steele 2004). Also, products containing multiple components such as a breaded meat product will have all the problems of the stability characteristics and a few extra (Man and Jones 2000). This may include aroma migration between components and the likelihood of spaces in packaging which leads to easy access to oxygen. A frequent complaint with frozen multi-compartment prepared foods "sameness" of flavor. This may be due to the start of aroma migration between the components with the more highly flavored components transferring flavor to the bland ones (Man and Jones 2000).

REFERENCES

Addis, P. B. 1986. "Occurrence of Lipid Oxidation Products in Foods." *Food and Chemical Toxicology: An International Journal Published for the British Industrial Biological Research Association* 24 (10–11): 1021–30.

Albert, A., Perez-Munuera, I., Quiles, A., Salvador, A., Fiszman, S., and Hernando, I.,. 2009. "Adhesion in Fried Battered Nuggets: Performance of Different Hydrocolloids as Predusts Using Three Cooking Procedures." *Food Hydrocolloids* 23 (5): 1443–48. doi:10.1016/j.foodhyd.2008.11.015.

ASTM Committee E-18, ed. 1981. *Guidelines for the Selection and Training of Sensory Panel Members*. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959: ASTM International. http://www.astm.org/doiLink.cgi?STP758-EB.

Ballard, T. 2003. "Application of Edible Coatings in Maintaining Crispness of Breaded Fried Foods." http://scholar.lib.vt.edu/theses/available/etd-09302003-161735/.

Barriuso, B., Astiasarán, I., and Ansorena, D. 2013. "A Review of Analytical Methods Measuring Lipid Oxidation Status in Foods: A Challenging Task." *European Food Research and Technology* 236 (1): 1–15.

Blumenthal, M. 1991. "A New Look at the Chemistry and Physics of Deep-Fat Frying." *Food Technology* 45 (2): 68.

Dermesonluoglu, E., Katsaros, G., Tsevdou, M., Giannakourou, M., and Taoukis, P., 2015. "Kinetic Study of Quality Indices and Shelf Life Modelling of Frozen Spinach under

Dynamic Conditions of the Cold Chain." *Journal of Food Engineering*, SI: Cold Chain refrigeration, 148 (March): 13–23. doi:10.1016/j.jfoodeng.2014.07.007.

do Nascimento, A., Bagolin, G., Medeiros Rataichesck Fiates, A. dos Anjos, C., and Evanilda T. 2014. "Gluten-Free Is Not Enough – Perception and Suggestions of Celiac Consumers." *International Journal of Food Sciences and Nutrition* 65 (4): 394–98. doi:10.3109/09637486.2013.879286.

Doyle, E. 2015. "Autoimmune Conditions Associated With Type 1 Diabetes." *Pediatric Nursing* 41 (2): 89–91.

Dusty, W. 2003. "Value Added: The Means to a More Profitable End." *Green Horizons*. http://agebb.missouri.edu/agforest/archives/v7n3/gh1.htm.

Fernández, J., Pérez-Álvarez, J., and Fernández-López, J. 1997. "Thiobarbituric Acid Test for Monitoring Lipid Oxidation in Meat." *Food Chemistry* 59 (3): 345–53. doi:10.1016/S0308-8146(96)00114-8.

Firdevs, D., Seyhan, F., Serpil S., and Gulum S., 2005. "Effects of Soy and Rice Flour Addition on Batter Rheology and Quality of Deep-Fat Fried Chicken Nuggets." *Journal of Food Engineering* 71 (1): 127–32. doi:10.1016/j.jfoodeng.2004.10.028.

Food and Drug Administration. 2013. "Federal Register | Food Labeling; Gluten-Free Labeling of Foods." August 5. https://www.federalregister.gov/articles/2013/08/05/2013-18813/food-labeling-gluten-free-labeling-of-foods.

Frankel, E. 2005. *Lipid Oxidation*. 2. ed. Oily Press Lipid Library 18. Bridgwater: Oily Press.

Brison, F. 1986. *Pecan Culture*. College Station, TX: Texas Pecan Growers Association.

Bin, F. and Labuza, T., 1997. “Shelf-Life Testing: Procedures and Prediction Methods.” In *Quality in Frozen Food*, edited by Marilyn C. Erickson and Yen-Con Hung, 377–415. Springer US. http://link.springer.com/chapter/10.1007/978-1-4615-5975-7_19.

Gallagher, E., ed. 2009. *Gluten-Free Food Science and Technology*. Chichester, U.K. ; Ames, Iowa: Wiley-Blackwell.

Greene, B., and Cumuze, T., 1982. “Relationship between TBA Numbers and Inexperienced Panelists’ Assessments of Oxidized Flavor in Cooked Beef.” *Journal of Food Science* 47 (1): 52.

Hale, K., and Goodwin, T., 1968. “Breaded Fried Chicken: Effects of Precooking, Batter Composition, and Temperature of Parts before Breading.” *Poultry Science* 47 (3): 739.

Halliwell, B., and Chirico, S., 1993. “Lipid Peroxidation: Its Mechanism, Measurement, and Significance.” *The American Journal of Clinical Nutrition* 57 (5): 715S–724S.

Hanson, H. L., and Fletcher, L. R., 1963. “Adhesion of Coatings on Frozen Fried Chicken.” *Food Technology*, no. 17: 793.

Hoey, N., 2010. “Gluten Intolerance.” In *Magill’s Medical Guide*, 6thed. Vol. 6. Pasadena, CA: Salem Press.

Hough, G. and Garitta, L., 2012. “Methodology for Sensory Shelf-Life Estimation: A Review.” *Journal of Sensory Studies* 27 (3): 137–47. doi:10.1111/j.1745-459X.2012.00383.x.

Min, H. and Jacobsen, C., 2016. *Oxidative Stability and Shelf Life of Foods Containing Oils and Fats*. Elsevier.

Hudthagosol, C., Hasso H., McCarthy, K., Wang, P., Keiji O., and Sabaté, J. 2011. “Pecans Acutely Increase Plasma Postprandial Antioxidant Capacity and Catechins and Decrease

LDL Oxidation in Humans." *The Journal of Nutrition* 141 (1): 56–62. doi:10.3945/jn.110.121269.

IBISWorld. 2016. "IBISWorld US - Industry, Company and Business Research Reports and Information." Accessed January 25. http://clients1.ibisworld.com.proxy-remote.galib.uga.edu/reports/us/industry/productsandmarkets.aspx?entid=271.

International Union of Pure and Applied Chemistry, and Charles Paquot, eds. 1979. *Standard Methods for the Analysis of Oils, Fats, and Derivatives*. 6th ed. Oxford ; New York: Pergamon Press.

Jackson, C., and Hu, F., 2014. "Long-Term Associations of Nut Consumption with Body Weight and Obesity." *American Journal of Clinical Nutrition* 100 (July): 408S–411S. doi:10.3945/ajcn.113.071332.

Jackson, V., Schilling, M. W., Coggins, P. C., and Martin, J. M., 2006. "Utilization of Rice Starch in the Formulation of Low-Fat, Wheat-Free Chicken Nuggets." *The Journal of Applied Poultry Research* 15 (3): 417–24. doi:10.1093/japr/15.3.417.

Johnson, D., and Decker, E., 2015. "The Role of Oxygen in Lipid Oxidation Reactions: A Review." *Annual Review of Food Science and Technology* 6 (1): 171–90. doi:10.1146/annurev-food-022814-015532.

Karwowska, M., Wójciak, K., and Dolatowski, Z., 2015. "The Influence of Acid Whey and Mustard Seed on Lipid Oxidation of Organic Fermented Sausage without Nitrite." *Journal of the Science of Food and Agriculture* 95 (3): 628–34. doi:10.1002/jsfa.6815.

Ketjarut, S., and Rungnaphar P., 2015. "Influence of Tapioca Starch on Thermal Properties of Wheat Flour-Based Batter and Quality of Fried Battered Chicken Wingsticks." *International Journal of Food Engineering* 11 (5): 641–50. doi:10.1515/ijfe-2015-0017.

Kılıç, B., Şimşek, J., Claus, E., Atılgan, S., and Aktaş, N. 2015. “Effects of Different End-Point Cooking Temperatures on the Efficiency of Encapsulated Phosphates on Lipid Oxidation Inhibition in Ground Meat.” *Journal of Food Science* 80 (10): C2161–69. doi:10.1111/1750-3841.13009.

Kulp, K., and Loewe, R., eds. 1990. *Batters and Breadings in Food Processing*. St. Paul, Minn., USA: American Association of Cereal Chemists.

Labuza, T., and Schmidl, M., 1985. “Accelerated Shelf-Life Testing of Foods.” *Food Technology* 39 (9): 57.

Lai, S., Crackel, R., Gill, J., Gray, J., and Booren, A., 1995. “Assessment of Off-Flavor Development in Restructured Chicken Nuggets Using Hexanal and TBARS Measurements and Sensory Evaluation.” *Journal of the Science of Food and Agriculture* 67 (4): 447–52.

Landes, D. R., and Blackshear, C., 1971. “The Effects of Different Cooking Oils on Flavor and Color of Fried Chicken Breading Material.” *Poultry Science* 50 (3): 894.

Lillywhite, J., Simonsen, J., and Heerema, R., 2014. “U.S. Consumer Purchases and Nutritional Knowledge of Pecans.” *HortTechnology* 24 (2): 222–30.

Lombardini, L., Waliczek, T., and Zajicek, J., 2008. “Consumer Knowledge of Nutritional Attributes of Pecans and Factors Affecting Purchasing Behavior.” *HortTechnology* 18 (3): 481–88.

Majzoobi, M., Farahnaky, A., and Agah, S., 2011. “Properties and Shelf-Life of Part-and Full-Baked Flat Bread (Barbari) at Ambient and Frozen Storage.” *Journal of Agricultural Science and Technology* 13: 1077–1090.

Mäkelä, M., Eriksson, C., Kotaniemi-Syrjänen, A., Palosuo, K., Marsh, J., Borres, M. Kuitunen, M., and Pelkonen, A. S. 2014. "Wheat Allergy in Children - New Tools for Diagnostics." *Clinical & Experimental Allergy* 44 (11): 1420–30. doi:10.1111/cea.12393.

Man, C. M. D., and Jones, A. A., eds. 2000. *Shelf-Life Evaluation of Foods*. 2nd ed. Gaithersburg, MD: Aspen Publishers.

Maskat, M., and Kerr, W., 2002. "Coating Characteristics of Fried Chicken Breasts Prepared with Different Particle Size Breading." *Journal of Food Processing and Preservation* 26 (1): 27–38. doi:10.1111/j.1745-4549.2002.tb00475.x.

———. 2004. "Effect of Breading Particle Size on Coating Adhesion in Breaded, Fried Chicken Breasts." *Journal of Food Quality* 27 (2): 103–13. doi:10.1111/j.1745-4557.2004.tb00641.x.

Meilgaard, M., Civille, G., and Carr, T. 2007. *Sensory Evaluation Techniques*. 4th ed. Boca Raton: Taylor & Francis.

Mintel. 2016a. "Chocolate Confectionery - US - February 2015." Accessed January 25. http://academic.mintel.com.proxy-remote.galib.uga.edu/display/730932/?highlight#hit1.

———. 2016b. "Hot and Cold Cereals - US - August 2014." Accessed January 25. http://academic.mintel.com.proxy-remote.galib.uga.edu/display/712381/?highlight#hit1.

———. 2016c. "Nut-Based Spreads and Sweet Spreads - US - March 2015." Accessed January 25. http://academic.mintel.com.proxy-remote.galib.uga.edu/display/732059/.

———. 2016d. "Snack, Nutrition and Protein Bars - US - March 2015." Accessed January 25. http://academic.mintel.com.proxy-remote.galib.uga.edu/display/733409/?highlight#hit1.

Mukprasirt, A., Herald, T., Boyle, D., and Rausch. K., 2000. “Adhesion of Rice Flour-Based Batter to Chicken Drumsticks Evaluated by Laser Scanning Confocal Microscopy and Texture Analysis.” *Poultry Science* 79 (9): 1356–63.

Murray, J., Delahunty, C., and Baxter, I., 2001. “Descriptive Sensory Analysis: Past, Present and Future.” *Food Research International* 34 (6): 461–71. doi:10.1016/S0963-9969(01)00070-9.

Naveena, B., Muthukumar, M., Muthulakshmi, L., Anjaneyulu, A., and Kondaiah, N., 2014. “Effect of Different Cooking Methods on Lipid Oxidation and Microbial Quality of Vacuum-Packaged Emulsion Products from Chicken.” *Journal of Food Processing and Preservation* 38 (1): 39–47.

Niels, M. 2014. “Pecan.” *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks*. http://www.ba.ars.usda.gov/hb66/pecan.pdf.

Nollet, L., and F. Toldrá, eds. 2009. *Handbook of Muscle Foods Analysis*. Boca Raton: CRC Press.

“Pecan.” 2014. *Encyclopædia Britannica*, Research Starters, . http://eds.a.ebscohost.com/eds/detail/detail?sid=098fed7b-634d-45af-9a09-95bc331d7f45%40sessionmgr4002&vid=15&hid=4103&bdata=JnNpdGU9ZWRzLWxpdmU%3d#AN=87996803&db=ers.

“Pecan Nutrition Fact Sheet.” 2016. *Georgia Pecans*. Accessed January 5. http://georgiapecans.org/science-nutrition/pecan-nutrition-fact-sheet/.

Prepared Foods. 2015. “U.S. Gluten-Free Food Retail Market Reaches $973 Million.” January 19. http://www.preparedfoods.com/articles/114866-us-gluten-free-food-retail-market-reaches-973-million).

Rajaram, S., Burke, K., Connell, B., Myint, T., and Sabaté, J., 2001. “A Monounsaturated Fatty Acid–Rich Pecan-Enriched Diet Favorably Alters the Serum Lipid Profile of Healthy Men and Women.” *The Journal of Nutrition* 131 (9): 2275–79.

Rhee, K., Anderson, L., and Sams, A., 1996. “Lipid Oxidation Potential of Beef, Chicken, and Pork.” *Journal of Food Science* 61 (1): 8–12. doi:10.1111/j.1365-2621.1996.tb14714.x.

Ros, E. 2010. “Health Benefits of Nut Consumption.” *Nutrients* 2 (7): 652–82. doi:10.3390/nu2070652.

Sahin, S., and Sumnu, S., eds. 2009. *Advances in Deep-Fat Frying of Foods*. Contemporary Food Engineering. Boca Raton: CRC Press.

Santerre, C., ed. 1994. *Pecan Technology*. New York: Chapman & Hall.

Shaker, M. 2015. “Comparison between Traditional Deep-Fat Frying and Air-Frying for Production of Healthy Fried Potato Strips.” *International Food Research Journal* 22 (4): 1557–63.

“Show Foods.” 2016. Accessed April 23. https://ndb.nal.usda.gov/ndb/foods/show/764?fgcd=&man=&lfacet=&count=&max=&sort=&qlookup=&offset=&format=Full&new=&measureby=.

Singh, T., and Cadwallader, K., 2002. “The Shelf Life of Foods: An Overview.” In *Freshness and Shelf Life of Foods*, edited by Keith R. Cadwallader and Hugo Weenen, 836:2–21. Washington, DC: American Chemical Society. http://pubs.acs.org/doi/abs/10.1021/bk-2003-0836.ch001.

St. Angelo, A., 1992. *Lipid Oxidation in Food*. ACS Symposium Series 500. Washington, DC: American Chemical Society.

Steele, R., ed. 2004. *Understanding and Measuring the Shelf-Life of Food*. Woodhead Publishing in Food Science and Technology. Boca Raton : Cambridge: CRC Press ; Woodhead Pub.

Suderman, D., and Cunningham, F., eds. 1983. *Batter and Breading*. Westport, Conn: AVI Pub. Co.

Tsironi, T., Dermesonlouoglou, E., Giannakourou, M., and Taoukis, P., 2009. “Shelf Life Modelling of Frozen Shrimp at Variable Temperature Conditions.” *LWT - Food Science and Technology* 42 (2): 664–71. doi:10.1016/j.lwt.2008.07.010.

Vadivel, V., Kunyanga, C., and Biesalski, H., 2012. “Health Benefits of Nut Consumption with Special Reference to Body Weight Control.” *Nutrition* 28 (11/12): 1089–97. doi:10.1016/j.nut.2012.01.004.

Wieser, H., Koehler, P., and Konitzer, K., 2014. *Celiac Disease and Gluten: Multidisciplinary Challenges and Opportunities*. Amsterdam: Elsevier : Academic Press.

Wrolstad, R., Acree, T., Decker, E., Penner, M., Reid, D., Schwartz, S., Shoemaker, C., Smith, D., and Sporns, P., 2005. *Handbook of Food Analytical Chemistry, Volume 1: Water, Proteins, Enzymes, Lipids, and Carbohydrates*. John Wiley & Sons.

Xu, J., Riccioli, C., and Sun, D., 2015. “An Overview on Nondestructive Spectroscopic Techniques for Lipid and Lipid Oxidation Analysis in Fish and Fish Products.” *Comprehensive Reviews in Food Science and Food Safety* 14 (4): 466–77. doi:10.1111/1541-4337.12138.

CHAPTER 3

SENSORY AND PHYSICAL EVALUATION OF GLUTEN-FREE PECAN BREADED CHICKEN PIECES

Introduction

The pecan, common to south-central and southeastern regions of the United States, has a rich buttery flavor that is often used in sweet desserts. With increased production in new markets such as South Africa and Australia, U.S. pecan growers are focusing on developing value-added products that will increase domestic demand for pecans. Also, pecans halves are more valuable than small or midget pieces but incorporating the smaller pieces into a breaded product can help increase the profits realized from the goods produced (Dusty Walter 2003). Nuts incorporated into batters and breading add flavor, unique textures, and nutritional benefits. For developers who want to add flavorful variety to a product that also offers crunch and healthy monounsaturated fat, fiber, and nutrients, nuts are advantageous. They are commercially under-utilized when it comes to batters and breadings.

The Celiac Disease Foundation approximates that 1 in 100 people internationally are affected by Celiac disease (Doyle 2015). It is an illness that causes the body to form antibodies to gluten, which then attack the intestinal lining. The villi of the intestines become damaged and nutrient absorption decreases (do Nascimento et al. 2014). With the increasing occurrence of this ailment, the demand for gluten-free products is steadily rising. In addition to Celiac disease, there are other allergy-based reasons for gluten avoidance such as wheat allergies and gluten intolerance. A wheat allergy is an overreaction of the immune system to a particular food protein

(Mäkelä et al. 2014). Non-celiac gluten sensitivity occurs in individuals who cannot tolerate gluten and experience symptoms similar to those with Celica disease but lack the same antibodies and intestinal damage as seen in Celiac disease (Hoey 2010).

While there are gluten-free breaded chicken products available, there is a noticeable lack of options incorporating culinary nuts, specifically pecans. Nuts such as pecans offer numerous health benefits, such as contributing to lower cholesterol levels, and they are nutrient dense – containing 19 vitamins and minerals.

While there is not a gold standard for gluten-free breading, the ideal characteristics of a batter and breading system are still the same. Factors affecting consumer acceptance of batters and breadings include appearance, color, crispness, adhesion, and flavor. The appearance of a coated product is a primary concern for the consumer (Kulp and Loewe 1990). It is important that it has an even and uniform batter, or the food will be perceived as unacceptable. However, some non-uniformity is desirable. Researchers have found that thicker coatings made with waxy rice flour and corn flour caused the batter to be too smooth to be attractive (Hanson and Fletcher 1963). However, when the same ingredients were used for a thinner coat, this allowed for bubbles to appear on the surface of the product and resulted in it being more acceptable. Thus, the ingredient formulation plays an essential part in the development of an acceptable coating appearance. The final cooked color of a product is a closely related feature of coating appearance. The formulation of the batter and breading largely determines the extent of Maillard color development. Protein and sugar sources play an important role in the final cooked color of the product. Wheat flour has been reported to contribute a grayish-brown color while potato flour caused a golden brown appearance (Suderman and Cunningham 1983). Landes and Blackshear (1971) found the color of the coating more greatly depended on cooking time and temperature, breading material composition and cooking oil characteristics. They found that soybean oil produces a superior color than peanut oil.

Crispness is another characteristic that is important to acceptability. It can be adjusted in numerous ways such as, different ratios of thickening agents, adjusting the time and temperature of cooking, adding a precooking step, cooking method, or altering the ingredient composition. When researchers substituted a portion of wheat flour with tapioca starch, the crispness of the final fried crust and the liking scores increased (Ketjarut and Pongsawatmanit 2015). Dogan et al. (2005) reported that when soy flour and rice flour were added to the batter formulation of deep-fat fried chicken nuggets, soy flour improved the crispness and color the most. Crispness is an important attribute as it can convey freshness and high quality in breaded fried foods.

In addition to appearance, color, and crispness, flavor affects the senses and stimulates our desire to eat or reject various foods. Adjusting the cooking time and temperature, the composition of the breading material, and composition of the cooking oil can have both good and bad results. Hale and Goodwin (1968) cooked chicken two ways: deep-fat frying and microwave cooking followed by deep-fat frying. They found that deep-fat frying produced a significantly better flavor. But even if the product has an ideal flavor, color, and crispness, if the adhesion of the batter and breading is poor the consumer will most likely reject the item. The coating should not be crumbly or have gaps of missing batter. This results in yield loss, which is uneconomical and aesthetically unpleasing. There are steps that can be taken to avoid this such as choosing the right cooking method, adjustment of the formulation and the use of a pre-dust. Albert et al. (2009) reported that when oxidized starch, xanthan gum, and hydroxypropylmethylcellulose were used as pre-dust agents, oxidized starch produced the best adhesion results. Batters and breadings improve the quality of the foods we eat. It is important to monitor the appearance, crispness, color, flavor, and adhesion to avoid problems that would make the product unacceptable.

A breading system incorporating nuts was not commercially available, but there are recipes in cookbooks and on food websites. Some of the images for the recipes show a golden color and uniform adhesion of the breading, but some are very light in color or lacked uniform distribution of pecans. Typically, these recipes incorporated corn flakes into the breading. Preliminary work in our laboratory showed that breadings made with 100% pecans were very dark in appearance. By combining cornflakes with pecan pieces into the breading, a more golden color was achieved and the texture was crisper. Sample preparation included a pre-frying step because the final product was prepared by baking for a set period of time. The pre-frying helps set the batter and breading to the substrate and prevent separation.

The purpose of this study was to investigate the use of pecans in a breaded product. As part of the objective, key properties were determined including consumer acceptability, moisture and lipid content, color, and batter adhesion.

Materials and Methods

Sample preparation protocol

A summary of the formulation can be seen in Table 3.1. All ingredients for the pre-dust, batter, and breading were weighed separately and blended with a wire whisk for 60 seconds. Midget size pecans (2.36 – 4.76 mm) were used in the breading. Blended formulas were stored in zip-lock bags prior to the application. The dry batter mixture was mixed with water using a wire whisk for 60 seconds. Frozen chicken breast chunks (Kroger Co., Cincinnati, OH) were thawed overnight at refrigeration temperature (4°C) to ensure all ice crystals melted before coating. The chicken was coated with the pre-dust, and then immersed in batter solution for 10 seconds and drained for another 10 seconds. The battered chicken was then placed in a bowl that contained the breading and shaken for 30 seconds to thoroughly coat the pieces. The chicken pieces were then pre-fried for 60 seconds at 190 °C (375°F). Pre-fried chicken pieces were allowed to drain for 30 seconds to remove excess oil. A polypropylene bag (12.7 x 35.5 inches) with a PVDC barrier layer (WinPak Films Inc, Senoia, GA) was used to contain the nuggets. The pre-fried samples were placed in an air-blast freezer (-12 °C) immediately after cooling until needed. An image of each formulation is in Figure 3.1.

Color analysis

The color of the coatings after final baking was measured instrumentally using a Minolta CM-700d Spectrophotometer (Konica Minolta Sensing, Inc., Ramsey, NJ) based on the L*, a*, b* system (Maskat and Kerr 2002). L* is the lightness component which ranges from 0 to 100, a* measures from green to red on a scale of -120 to 120, while b* measures from blue to yellow on a scale of -120 to 120. The test was completed in duplicate.

Moisture Content

The moisture of the coatings after final baking was obtained by placing samples in thimbles and drying in a vacuum oven (Model 1430 MS, VWR Scientific Products, Radnor, PA) at 100°C until a constant mass was reached, the moisture content was determined from the change in mass. Measurements were taken in duplicate per treatment.

Lipid content

The oil in the baked samples was extracted for 8 hours using the Soxhlet extraction method with petroleum ether. The crucibles were dried in the oven until a constant weight was reached. The lipid content was gravimetrically determined. Measurements were taken in duplicate per treatment.

Batter adhesion

Coating adhesion was measured by placing pre-weighed baked samples on a gyratory shaker (Model G76, New Brunswick Scientific Co., Inc, New Brunswick, NJ) (Maskat and Kerr 2004). The amount of coating loss was determined by weight difference. The samples were shaken on a sieve with a mesh size of 3.35 mm and attached to the shaker. The speed of the shaker was set at 50, 150, 250, and 350 rpm. A new sample was placed on the sieve for each speed and shaken for one minute. Percent coating loss was calculated according to the following formula.

$$\%\ \text{coating loss} = \frac{\text{wt lost coating}}{\text{wt cooked sample}} * 100\%$$

Preparation for sensory testing

Samples were previously pre-fried and placed in the freezer. Chicken pieces were baked for 20 minutes at 190 °C (375°F). Samples were stored in a thermal holding cabinet (C5-3 Series, InterMetro, Wilkes-Barre, PA) for up to 30 minutes. Three chicken pieces (one control and two treatment nuggets) were randomly presented in soufflé cups with a three-digit code, and balanced order of presentation was utilized. Forty-eight students and staff from the University of Georgia were recruited to serve as sensory panelists. Most of the participants had some previous experience as a sensory panelist. All were aware of the objectives of the experiment. The panel rated four attributes of the breaded chicken on a 9-point scale: flavor, texture, appearance, and overall acceptability (1-dislike extremely to 9-like extremely). Data was also collected on intent to purchase (1-would never buy to 6-would buy often), and pecan consumption (1-never to 4-several times a week). Panelists were provided with water, a napkin, and carrots (Grimmway Farms, Bakersfield, CA) to eat in-between evaluations.

Statistical analysis

The results were subjected to one-way ANOVA tests with post-hoc Student-Newman-Keuls (S-N-K) test or independent sample T-test when appropriate using the IBM SPSS Statistics software (version 21, IBM Corp., Armonk, NY). The level of significance was $p < 0.05$.

Results and discussion

Color analysis

Color values for pecan-breaded chicken nuggets are shown in Table 3.2. L* and a* values did not differ significantly amongst coatings made with different ratios of cornflakes to pecans. However, the b* value of the control (100% cornflake) was significantly higher, with a value of 17.7, compared to that of the 50/50 ratio (10.8) or 75/25 ratio (11.7). Thus, the control had a slightly more yellow hue. This is likely due to the higher β-carotene content inherent in the all cornflake formulation. Also, Maillard reactions produce color changes in food that may account for the higher b* value. A previous study investigating a wheat-free chicken nugget formulation reported that their fried nuggets had higher yellow value than their baked only nuggets (V. Jackson et al. 2006). This study used a combination of frying and baking to prepare the nuggets and the frying step may have led to increased yellow color development.

Moisture and lipid content

The result for moisture and lipid content of the breading is summarized in Table 3.2. The moisture content of the coatings ranged from 28.4 to 30.0%, but there was not a significant difference in moisture amongst breadings coatings. The lipid content of the coatings ranged from 11.5 to 32.7%, with the coating made with 100% cornflake (no pecans) having significantly less fat content than the breading with 50/50 ratio of pecans to cornflakes or 75/25 ratio of pecans to cornflakes. This was to be expected, as pecans have 55 to 75% oil content by weight (Niels Maness 2014) and the 100% cornflake breading did not contain any pecans in the formulation. Also, the high standard deviation for the lipid content may have been caused by the inability to ensure the same amount of pecans adhered to each sample.

Batter adhesion

The percent loss of coating after the gyratory shaker was used to shake the samples at different speeds is shown in Table 3.3. Nuggets were shaken to test how well the batter and breading would adhere to the chicken under stress. For speeds up to 350 rpm, there were no significant differences in coating loss. The binding of the batter to the chicken and the breading to batter was strong enough to withstand shaking at various speeds. None of the breadings had a coating loss greater than 1%. The use of xanthan gum in the batter may have contributed to the coating adhering as well as it did. Other researchers have reported that xanthan gum increased the viscosity of batter which led to increased batter pickup (Mukprasirt et al. 2000). Uniform batter coverage on food is less susceptible to coating loss.

Sensory testing

Hedonic scores and ratings on flavor, texture, appearance and overall acceptability of the breaded chicken nuggets by a sensory panel are presented in Table 3.4. There were no significant differences among the chicken nuggets prepared with different ratios of pecans and cornflakes in all sensory attributes: appearance, texture, flavor, acceptability and intent to purchase. There was no evidence that the panelists found any one of the sample more acceptable than the other. The majority of the panelist (52%) indicated that they consume pecans or pecan-products several times a year, followed by 37.5% of panelist consuming pecans several times a month and only 10% consumed pecans or pecan-products several times a week.

Conclusion

The effects of varying the pecan to cornflake ratio on breaded chicken were not significant regarding moisture content, batter adhesion, and sensory attributes (appearance, texture, flavor, acceptability, and intent to purchase). There was a significant difference in the color analysis for the b* value for the 100% cornflake breading compared to the 50% pecans to 50% cornflake breading and 75% pecans to 25% cornflake breading. Also, the 50% pecans to 50% cornflake breading and 75% pecans to 25% cornflake breading had significantly higher lipid content. The following chapter will study whether storage temperature has an effect on the rate of lipid oxidation and whether it has an impact on consumer acceptability.

REFERENCES

Albert, A., Perez-Munuera, I., Quiles, A., Salvador, A., Fiszman, S. M., and Hernando, I., 2009. "Adhesion in Fried Battered Nuggets: Performance of Different Hydrocolloids as Predusts Using Three Cooking Procedures." *Food Hydrocolloids* 23 (5): 1443–48. doi:10.1016/j.foodhyd.2008.11.015.

do Nascimento, A., Bagolin, G., Medeiros Rataichesck Fiates, A., dos Anjos, S, and Teixeira, E., 2014. "Gluten-Free Is Not Enough – Perception and Suggestions of Celiac Consumers." *International Journal of Food Sciences and Nutrition* 65 (4): 394–98. doi:10.3109/09637486.2013.879286.

Doyle, E. A., 2015. "Autoimmune Conditions Associated with Type 1 Diabetes." *Pediatric Nursing* 41 (2): 89–91.

Dusty, W., 2003. "Value Added: The Means to a More Profitable End." *Green Horizons*. http://agebb.missouri.edu/agforest/archives/v7n3/gh1.htm.

Firdevs, D., Seyhan, F., Serpil S., and Gulum S., 2005. "Effects of Soy and Rice Flour Addition on Batter Rheology and Quality of Deep-Fat Fried Chicken Nuggets." *Journal of Food Engineering* 71 (1): 127–32. doi:10.1016/j.jfoodeng.2004.10.028.

Hale, K. K., and Goodwin, T. L., 1968. "Breaded Fried Chicken: Effects of Precooking, Batter Composition, and Temperature of Parts before Breading." *Poultry Science* 47 (3): 739.

Hanson, H. L., and Fletcher, L. R., 1963. "Adhesion of Coatings on Frozen Fried Chicken." *Food Technology*, no. 17: 793.

Hoey, N. 2010. “Gluten Intolerance.” In *Magill’s Medical Guide,* 6th ed. Vol. 6. Pasadena, CA: Salem Press.

Ketjarut, S., and Pongsawatmanit, R., 2015. “Influence of Tapioca Starch on Thermal Properties of Wheat Flour-Based Batter and Quality of Fried Battered Chicken Wingsticks.” *International Journal of Food Engineering* 11 (5): 641–50. doi:10.1515/ijfe-2015-0017.

Kulp, K., and Loewe, R., eds. 1990. *Batters and Breadings in Food Processing*. St. Paul, Minn., USA: American Association of Cereal Chemists.

Landes, D. R., and Blackshear, C., 1971. “The Effects of Different Cooking Oils on Flavor and Color of Fried Chicken Breading Material.” *Poultry Science* 50 (3): 894.

Mäkelä, M., Eriksson, C., Kotaniemi-Syrjänen, A., Palosuo, K., Marsh, J., Borres, M., Kuitunen, M., and Pelkonen, A. S., 2014. “Wheat Allergy in Children - New Tools for Diagnostics.” *Clinical & Experimental Allergy* 44 (11): 1420–30. doi:10.1111/cea.12393.

Maskat, M., and Kerr, W., 2002. “Coating Characteristics of Fried Chicken Breasts Prepared With Different Particle Size Breading.” *Journal of Food Processing and Preservation* 26 (1): 27–38. doi:10.1111/j.1745-4549.2002.tb00475.x.

———. 2004. “Effect of Breading Particle Size on Coating Adhesion in Breaded, Fried Chicken Breasts.” *Journal of Food Quality* 27 (2): 103–13. doi:10.1111/j.1745-4557.2004.tb00641.x.

Mukprasirt, A., Herald, T. J., Boyle, D. L., and Rausch, K. D., 2000. “Adhesion of Rice Flour-Based Batter to Chicken Drumsticks Evaluated by Laser Scanning Confocal Microscopy and Texture Analysis.” *Poultry Science* 79 (9): 1356–63.

Niels, M., 2014. “Pecan.” *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks*. http://www.ba.ars.usda.gov/hb66/pecan.pdf.

Suderman, D., and Cunningham, F., eds. 1983. *Batter and Breading*. Westport, Conn: AVI Pub. Co.

Table 3.1: Formulation of gluten-free pecan breaded chicken.

Pre-dust	Weight (g)	Product information
Cornstarch	69.3	ACH Food Co. In., Memphis, TN
Rice flour	29.7	Bob's Red Mill Natural Foods, Inc., Milwaukie, OR
Methylcellulose	1.00	Penford Food Ingredients, Tucson, AZ
Batter		
Corn flour	36.7	Gruma, Monterrey, Mexico
Rice flour	55.0	Bob's Red Mill Natural Foods, Inc., Milwaukie, OR
Xanthan	0.30	Penford Food Ingredients, Tucson, AZ
Spice	8.00	Tony Chachere's Creole Foods of Opelousas, LA
Water	250	Kroger Co., Cincinnati, OH
1-Breading (Control)		
Cornflakes	50.0	Kellogg, Battle Creek, MI
2-Breading (50/50)		
Pecan	25.0	South Georgia Pecan Co., Valdosta, GA
Cornflakes	25.0	Kellogg, Battle Creek, MI
3-Breading (75/25)		
Pecan	37.5	South Georgia Pecan Co., Valdosta, GA
Cornflakes	12.5	Kellogg, Battle Creek, MI

Table 3.2: Color, moisture content, and fat content of breadings prepared with different ratios of pecans to cornflakes

Sample	Color			Moisture Content (%)	Fat Content
	L*	a*	b*		
	--------------------Mean±SD[1]--------------------				
1-Breading[2] (Control)	40.79±1.69a	11.44±0.84a	17.78±1.75a	29.3±2.32a	11.5±4.16a
2-Breading[2] (50/50)	37.80±3.34a	9.87±1.44a	10.85±4.53b	30.0±4.05a	25.2±8.87b
3-Breading[2] (75/25)	37.97±2.01a	9.67±0.39a	11.72±2.12b	28.4±6.94a	32.7±7.78b

[1]Means±SD followed by the same letter in a row are not significantly different according to one-way ANOVA and post hoc S-N-K test for equality of means ($p<0.05$).
[2]The 1-breading consisted of cornflakes. 2-breading (50/50 ratio) and 3-breading (75/25 ratio) consisted of pecans and cornflakes.

Table 3.3: Percent coating loss[1] for each treatment

Sample	RPM	% Coating Loss
1-Breading[2] (Control)	50	0.30±0.26a
	150	0.22±0.38a
	250	0.17±0.30a
	350	0.77±0.75a
2-Breading[2] (50/50)	50	0.00±0.00a
	150	0.41±0.35a
	250	0.67±0.76a
	350	0.56±0.26a
3-Breading[2] (75/25)	50	0.15±0.26a
	150	0.00±0.00a
	250	0.41±0.38a
	350	0.00±0.53a

[1]Means±SD followed by the same letter in a row are not significantly different according to one-way ANOVA and post hoc S-N-K test for equality of means ($p<0.05$).
[2]The 1-breading consisted of cornflakes. 2-breading (50/50 ratio) and 3-breading (75/25 ratio) consisted of pecans and cornflakes.

Table 3.4: Sensory scores[1] on appearance, texture, flavor, overall acceptability, and intent to purchase (n=48)

Sample	Appearance[3]	Texture[3]	Flavor[3]	Overall Acceptability[3]	Purchase Intent[4]
	--------------------	------------	Mean±SD	------------	--------------------
1-Breading[2] (Control)	7.02±2.22a	7.06±1.85a	6.42±1.67a	6.63±1.78a	3.41±1.39a
2-Breading[2] (50/50)	6.21±2.05a	6.98±1.60a	6.77±1.94a	6.67±1.71a	3.65±1.34a
3-Breading[2] (75/25)	6.60±1.98a	6.94±1.48a	7.10±1.73a	6.94±1.52a	3.75±1.30a

[1]Means±SD followed by the same letter in a row are not significantly different according to one-way ANOVA and post hoc S-N-K test for equality of means ($p>0.05$).

[2]The 1-breading consisted of cornflakes. 2-breading (50/50 ratio) and 3-breading (75/25 ratio) consisted of pecans and cornflakes.

[3]The panel rated four attributes of the breaded chicken on a 9-point scale: flavor, texture, appearance, and overall acceptability (1-dislike extremely to 9-like extremely).

[4]Data was also collected on intent to purchase (1-would never buy to 6-would buy often)

100% cornflake - control 50% pecan to 50% cornflake 75% pecan to 25 % cornflake

Figure 3.1: Pecan-breaded chicken nuggets

CHAPTER 4

LIPID OXIDATION DURING STORAGE OF PECAN BREADED CHICKEN PIECES

Introduction

Pecans are a healthy addition to our diet and add a unique flavor and texture to our meals. In this chapter, further research was performed on the formulation containing the most pecans (75% pecans to 25% cornflakes) to determine if lipid oxidation is an issue with the product being precooked and frozen. This formulation was chosen because it utilized the most pecans without the product becoming too dark in appearance. Midget pieces are not as valuable as whole pecan halves and this product could increase the utilization of midget pieces.

Frying is one of the oldest cooking processes, dating back to as early as 1600 BC, with many cultures consuming fried foods in one form or another (Sahin and Sumnu 2009). Immersion-oil frying involves submerging food in heated oil for a short duration. Edible oils from plant and animal origin are used to fry various types of food products such as potato chips, French fries, donuts, chicken and fish. Reduced cooking time and desirable sensory characteristics (i.e., crispy texture and taste) are a few reasons why frying is often the preferred method of cooking.

A primary cause of product deterioration is lipid oxidation. It may result in discoloration, off-odor and off-flavor development, loss of nutritive value and texture defects (Kılıç et al. 2015). Foods that are fried may experience higher rates of oxidation due to unsaturated fats being exposed to high temperatures (Frankel 2005). Other factors that influence the lipid oxidation rate include oxygen concentration, moisture content, surface area of lipids exposed to air, and prooxidants (Naveena et al. 2014). This study focused on chemical methods for measuring lipid oxidation and sensory testing to determine the loss of quality of the product.

Methods for the assessment of lipid oxidation can be assigned into one of two groups: primary oxidative changes are measured by the first group and the second assesses the formation of secondary oxidation products that originate from the breakdown of primary oxidation products (Nollet and Toldrá 2009). The oxidation of polyunsaturated fatty acids is followed by the formation of conjugated dienes, which absorb ultraviolet light in the wavelength range of 230 to 235 nm and 260 to 280 nm for trienes (Halliwell and Chirico 1993). Conjugated dienes are a result of radical formation in polyunsaturated fatty acids causing a shift in double bond position (Hu and Jacobsen 2016). During the later stages of oxidation, conjugated trienes form in higher polyunsaturated fatty acid by concurrent oxidation at both ends (C9 and C16) of linolenic acid and the reduction of hydroperoxides to alcohols by dehydration (Hu and Jacobsen 2016).

Malondialdehyde (MDA), a highly reactive compound, is a three-carbon dialdehyde with carbonyl groups at the C-1 and C-3 position (Nollet and Toldrá 2009). It remains bound to other food ingredients until an acid/heat treatment is applied and the food presumably releases the bound MDA (Nollet and Toldrá 2009). The colorimetric technique, thiobarbituric acid test (TBA), is thought to measure malonaldehyde which absorbs at 532-535 nm. This method is not without criticism for example, it lacks specificity. Addis (1986) has noted that “while TBA procedures are useful for the measurement of numerous lipid oxidation products, it shouldn’t be considered as a procedure for the malonaldehyde quantification. Instead, the term thiobarbituric acid reactive substances or TBARS value should be used to avoid inaccuracies.” Despite its shortcomings, MDA-TBA methods are widely used because some studies have found that it correlates with sensory evaluation of oxidation in meat products (Fernández, Pérez-Álvarez, and Fernández-López 1997).

Most food manufacturers do not have the time or financial resources to determine the true shelf-life of a food item and often place the product under abuse conditions to determine when the product is no longer acceptable. Some factors that affect food preservation and quality are temperature, water activity, and gas composition (Singh and Cadwallader 2002). Many accelerated models utilize higher temperature as this will quicken the aging process. Usually, only temperature is regulated in frozen storage. For frozen foods, suggested temperatures of -40 (control), -15, -10, and -5°C (Labuza and Schmidl 1985).

By conducting accelerated shelf-life testing manufacturers can obtain some preliminary shelf-life knowledge. Tsironi et al. (2009) held frozen shrimp at variable temperature (-5, -8, -12, -15, and -30°C) for 12 months and found that this model allowed for good estimation of the shelf-life of the frozen shrimp. This was also the case with frozen spinach. This experiment used the same temperatures mentioned previously and determined that this model provided a realistic assessment of frozen spinach remaining shelf-life (Dermesonluoglu et al. 2015).

Descriptive sensory analysis is used to develop a profile for products on its perceived sensory characteristics (Murray, Delahunty, and Baxter 2001). This type of test seeks to detect and describe both the qualitative and quantitative sensory components of a consumer product by trained panels of judges (Meilgaard, Civille, and Carr 2007). Qualitative characteristics include appearance, flavor, texture, aroma, aftertaste, and sound properties. The trained panel quantifies the different aspects to generate a description of the perceived product attributes (Murray, Delahunty, and Baxter 2001). The application of descriptive sensory analysis has increased, as well as its application within the food industry. It is used to track changes in the product over time concerning understanding shelf-life, monitor product quality, and investigate the effects of ingredients on the final sensory quality of the product (Murray, Delahunty, and Baxter 2001).

While there are numerous types of methods such as the Texture Profile Method, Spectrum Method, Quantitative Flavor Profiling, Free-choice Profiling, and generic descriptive analysis, they all start with the selection of panelists. Panelists are often examined using a prescreening questionnaire, a set of acuity tests, set of rating/ranking test, and a personal interview (ASTM 1981). Terminology development is after panel training and involves the team working with the panel trainer to identify product attributes that can be assessed with the use of a prototype or commercially available sample as a frame of reference (Meilgaard, Civille, and Carr 2007). Panelists are also introduced to the scaling method and practice evaluating sample products so that they are familiar with the procedures. Once training is complete the panel evaluates the actual product, and the performance is monitored by the trainer. Descriptive analysis is a useful and comprehensive method that is expected to see continued growth in use.

The purpose of this study was to investigate the use of pecans in a breaded product. As part of the objective, key properties were determined using sensory analysis, both consumer acceptance and a trained descriptive sensory panel. The primary and secondary oxidation products were measured using chemical analysis, such as spectrophotometric determination of conjugated products by UV absorption and the TBARS assay.

Materials and Methods

Sample preparation protocol

As determined in Chapter 3, chicken nuggets prepared with breading containing 75% pecans to 25% cornflake were the optimal formulation, and used to conduct the storage study in this chapter. The storage study was conducted using the modified method of Majzoobi et al.

(2011). The pre-dust formulation included methylcellulose (1%), rice flour (29.7%), and cornstarch (69.3%). The batter formulation included xanthan gum (0.30%), spices (8%), corn flour (36.7%), and rice flour (55%). The dry batter was reconstituted (powder/water 1:2.5). All ingredients for the pre-dust, batter, and breading were weighed separately and blended with a wire whisk for 60 seconds. Midget size pecans (2.36 – 4.76 mm) were used in the breading. Blended formulas were stored in gallon zip-lock bags before application. The dry batter mixture was mixed with the water using a wire whisk for 60 seconds. Frozen chicken breast chunks (Kroger Co., Cincinnati, OH) were thawed overnight at refrigeration temperature (4°C) to ensure all ice crystals had melted before the pieces were coated. The chicken was coated with the pre-dust, and then immersed in batter solution for 10 seconds and drained for another 10 seconds. The battered chicken was then placed in a bowl that contained the breading and shaken for 30 seconds to thoroughly coat the pieces. The chicken pieces were then pre-fried for 60 seconds at 190 °C (375°F). Pre-fried chicken pieces were allowed to drain for 30 seconds to remove excess oil. A vacuum packed polypropylene bag (5x14 inches) with a PVDC barrier layer (WinPak Films Inc, Senoia, GA) was used to contain the nuggets. The pre-fried samples were placed in the air-blast freezer immediately after cooling until needed. The control was stored at -40°C and the treatment at -15°C for the storage study. Every 15 days samples were removed and tested for 2-thiobarbituric acid reactive substances and conjugated dienes and trienes.

Thiobarbituric Acid Reactive Substances Test

The 2-thiobarbituric acid reactive substances (TBARS) values were determined according to the method of Buege and Aust (1978). The breading was homogenized for 15 seconds using a Nutribullet (Nutribullet, LLC, Pacoima, CA). Duplicate 1.5 g samples were weighed out and placed in a 15 mL centrifuge tube containing 7.5 mL of TBA stock solution

(0.375% w/v thiobarbituric acid; 15% w/v trichloroacetic acid; 0.25 N hydrochloric acid). The TBA stock solution was prepared fresh before each test to make sure it was free from precipitates. Samples were heated in boiling water for 20 minutes. Tubes were centrifuged with a Sorvall RC 6 Plus (Thermo Scientific, Waltham, MA) at 5,000 g for 20 minutes at 4°C. Contents were filtered and pipetted into a quartz cuvette. The absorbance at 532 nm was read in a Shimadzu UV-1601 Spectrophotometer (Shimadzu Corporation, Kyoto, Japan). The resulting data was reported as TBARS value according to the following equation:

$$TBARS = A_{532}\left(\frac{1M\ chromagen}{156{,}000}\right) \times \left(1\,\frac{mol}{L}\right) \times \left(\frac{0.003L}{1.5g\ coating}\right) \times \left(72.07\,\frac{g\ MDA}{mol\ MDA}\right) \times 10^{6}\,\frac{mg}{kg}$$

<u>Conjugated Dienes and Trienes</u>

Spectrophotometric determination of conjugated dienes by UV absorption at 232 nm and 268 nm for conjugated trienes was carried out according to IUPAC standard method 2.505 (International Union of Pure and Applied Chemistry and Paquot 1979) with minor modifications. After baking the frozen chicken pieces, the chicken was removed from the breading and discarded. From the breading a 40 mg sample was placed in a screwcap tube and filled with 10 mL of hexane (Fisher Scientific, Fair Lawn, NJ). The solution was vortexed for one minute and centrifuged using a Sorvall RC 6 Plus (Thermo Scientific, Waltham, MA) at 3,000 g for 10 minutes at 4°C. Contents were pipetted into a quartz cuvette and the absorbance measured against a blank. The absorbance at 232 and 268 nm was read in a Shimadzu UV-1601 Spectrophotometer (Shimadzu Corporation, Kyoto, Japan). The resulting data was reported according to the following equation:

$$\mathrm{E}\,\frac{1\%}{1cm} = \frac{A_{\lambda}}{c \times d}$$

where E, $A_{\lambda,}$ c, and d represent the extinction value, the absorbance measured at 232 nm (for CDs) or 268 nm (for CTs), the concentration of the lipid solution in g/ 100 mL, and the path length of the cuvette in cm.

Storage Conditions for Sensory Testing

Samples were stored at three different temperatures -40°C, -15°C, and -10°C for six weeks. The trained panel tested the samples every two weeks for six weeks and the consumer panel only once at the end of the six weeks. Sample order presentations to panelists were randomized throughout sessions.

Descriptive Sensory Panel Training

Eight panelists were recruited from University of Georgia staff and students and screened for allergies, availability to attend all training and testing sessions, health, attitude about the product class and ability to communicate (ASTM Committee E-18 1981). Potential panelists were screened to test their capacity to distinguish between different taste, smell, and ability to rate intensity (Meilgaard, Civille, and Carr 2007). Those that were selected had signed a human subject consent form before screening tests were administered. They were compensated with a gift card at the conclusion of the study. Training sessions lasted for 1-hour, and a total of three sessions were conducted. During this time, the lexicon (Table 4.1) and test procedure were developed to describe the flavor, aromatics, and texture characteristics of the chicken samples. The final list of attributes, definition, and testing instructions was developed through panel consensus. A 150 mm unstructured line scale with anchors at 0 and 15, corresponding to lowest and highest, respectively. Standard references were provided for each session as well as their intensities (Table 4.1) were included.

Consumer Acceptance Testing

Chicken nuggets were baked for 20 minutes at 190 °C (375°F). Samples were stored in a thermal holding cabinet (C5-3 Series, InterMetro, Wilkes-Barre, PA) for up to 30 minutes. Three chicken pieces (1 control and 2 treatment nuggets) were randomly presented in soufflé cups with a three-digit code, and balanced order of presentation was utilized. Eighty students and staff from the University of Georgia were recruited to serve as sensory panelists. Most of the participants had some previous experience as a sensory panelist. All were aware of the objectives of the experiment. The panel rated four attributes of the breaded chicken on a 9-point scale: flavor, texture, appearance, and overall acceptability (1-dislike extremely to 9-like extremely). Panelists were provided with water, a napkin, and unsalted crackers (Kroger Co., Cincinnati, OH).

Statistical analysis

The results were subjected to one-way ANOVA tests with post-hoc Student-Newman-Keuls (S-N-K) test using the IBM SPSS Statistics software (version 21, IBM Corp., Armonk, NY). The level of significance was $p < 0.05$.

Results and discussion

Thiobarbituric Acid Reactive Substances Test

As shown in Table 4.2, the storage time had a statistically significant effect on TBARS values of pecan breaded chicken nuggets. The TBARS values ranged from 0.222 to 0.781 for nuggets stored at -40 °C and from 0.263 to 0.552 for nuggets stored at -15 °C. Greene and Cumuze (1982) claimed that meat consumers from the general population would not detect oxidation flavors until oxidation products reached levels of at least 2.0 mg/kg tissue. For this study, TBARS values did not reach this level and indicate that an oxidized flavor would not be detectable in the product. Also, the majority of the fatty acids in pecans are monounsaturated, which are less prone to oxidation. There was an ascending trend in TBARS value with slight fluctuations during storage, as also observed in chicken nuggets (Lai 1995). Rhee et al. (1996) also reported variations in TBARS values of chicken.

Conjugated Dienes and Trienes

Table 4.2 shows that the nuggets stored at -40 C had a significantly lower amount of conjugated dienes and trienes. The CDT values ranged from 16.237 to 19.639 for nuggets stored at -40 °C and from 16.206 to 21.624 for nuggets stored at -15 °C. The nuggets had limited exposure to oxygen because they were vacuum packed. This may have also contributed to lower conjugated dienes and trienes value. Antioxidants, γ-tocopherol and flavan-3-ol monomers, can also limit oxidation. Both are present in pecans. Oxidation in meat products causes the double bonds of unsaturated fatty acids to undergo a rearrangement. Conjugated dienes and trienes form during the initial stages of lipid peroxidation and usually decompose to secondary products (Karwowska, Wójciak, and Dolatowski 2015). While the changes in absorption are not easily related to the extent of oxidation, during the early stages of oxidation, the increase in UV absorption due to the formation of CDTs is proportional to the uptake of oxygen (Wrolstad et al. 2005). CDTs can serve as a relative measure of oxidation for this reason.

Descriptive sensory panel

Table 4.3 summarizes the results for the descriptive panel sensory scores on grainy, oxidized, oily, nutty, roasted, hardness, and crispness according to test date. Table 4.4 summarizes the results for the descriptive panel sensory scores on grainy, oxidized, oily, nutty, roasted, hardness, and crispness according to sample storage temperature. There were no significant differences among the gluten-free nuggets stored at different temperatures in all sensory attributes according to test date or sample storage temperature. The findings indicate that there was no difference detected by the trained panel between samples stored at -40, -15, and -10°C.

Consumer acceptance panel

Table 4.5 summarizes the results for consumer panel sensory scores on appearance, texture, flavor, and overall acceptability for shelf life. There was no significant difference among the gluten-free nuggets stored at different temperatures in all sensory attributes according to the consumer sensory panel. The findings indicate that there was no difference detected by the consumer panel between samples stored at -40, -15, and -10°C.

CONCLUSION

The effects of different storage temperatures were not significant in terms of sensory analysis. The trained descriptive panel, as well as the consumer panel, was not able to detect a difference in the pecan breaded chicken nuggets stored at -40, -15, and -10°C. There was a significant difference in TBARS values for nuggets stored at different temperatures. There was also a significant difference in the CDT values for samples stored at different temperatures. In general, the different storage temperatures did not negatively impact the acceptability of the product, and frozen storage is a viable way to store this product.

REFERENCES

Addis, P. B. 1986. "Occurrence of Lipid Oxidation Products in Foods." *Food and Chemical Toxicology: An International Journal Published for the British Industrial Biological Research Association* 24 (10–11): 1021–30.

Albert, A., Perez-Munuera, I., Quiles, A., Salvador, A., Fiszman, S., and Hernando, I., 2009. "Adhesion in Fried Battered Nuggets: Performance of Different Hydrocolloids as Predusts Using Three Cooking Procedures." *Food Hydrocolloids* 23 (5): 1443–48. doi:10.1016/j.foodhyd.2008.11.015.

ASTM Committee E-18, ed. 1981. *Guidelines for the Selection and Training of Sensory Panel Members*. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959: ASTM International. http://www.astm.org/doiLink.cgi?STP758-EB.

Ballard, T. 2003. "Application of Edible Coatings in Maintaining Crispness of Breaded Fried Foods." http://scholar.lib.vt.edu/theses/available/etd-09302003-161735/.

Barriuso, B., Astiasarán, I., and Ansorena, D., 2013. "A Review of Analytical Methods Measuring Lipid Oxidation Status in Foods: A Challenging Task." *European Food Research and Technology* 236 (1): 1–15.

Blumenthal, M. 1991. "A New Look at the Chemistry and Physics of Deep-Fat Frying." *Food Technology* 45 (2): 68.

Dermesonluoglu, E., Katsaros, G., Tsevdou, M., Giannakourou, M., and Taoukis, P.,2015. "Kinetic Study of Quality Indices and Shelf Life Modelling of Frozen Spinach under

Dynamic Conditions of the Cold Chain.” *Journal of Food Engineering*, SI: Cold Chain refrigeration, 148 (March): 13–23. doi:10.1016/j.jfoodeng.2014.07.007.

do Nascimento, A., Bagolin, G., Medeiros Rataichesck Fiates, A. dos Anjos, C., and Evanilda T., 2014. “Gluten-Free Is Not Enough – Perception and Suggestions of Celiac Consumers.” *International Journal of Food Sciences and Nutrition* 65 (4): 394–98. doi:10.3109/09637486.2013.879286.

Doyle, E. A. 2015. “Autoimmune Conditions Associated with Type 1 Diabetes.” *Pediatric Nursing* 41 (2): 89–91.

Dusty, W., 2003. “Value Added: The Means to a More Profitable End.” *Green Horizons*. http://agebb.missouri.edu/agforest/archives/v7n3/gh1.htm.

Fernández, J., Pérez-Álvarez, J., and Fernández-López, J., 1997. “Thiobarbituric Acid Test for Monitoring Lipid Oxidation in Meat.” *Food Chemistry* 59 (3): 345–53. doi:10.1016/S0308-8146(96)00114-8.

Firdevs, D., Seyhan, F., Serpil S., and Gulum S., 2005. “Effects of Soy and Rice Flour Addition on Batter Rheology and Quality of Deep-Fat Fried Chicken Nuggets.” *Journal of Food Engineering* 71 (1): 127–32. doi:10.1016/j.jfoodeng.2004.10.028.

Food and Drug Administration. 2013. “Federal Register | Food Labeling; Gluten-Free Labeling of Foods.” August 5. https://www.federalregister.gov/articles/2013/08/05/2013-18813/food-labeling-gluten-free-labeling-of-foods.

Frankel, E. N. 2005. *Lipid Oxidation*. 2. ed. Oily Press Lipid Library 18. Bridgwater: Oily Press.

Brison F., 1986. *Pecan Culture*. College Station, TX: Texas Pecan Growers Association.

Bin, F. and Labuza, T., 1997. “Shelf-Life Testing: Procedures and Prediction Methods.” In *Quality in Frozen Food*, edited by Marilyn C. Erickson and Yen-Con Hung, 377–415. Springer US. http://link.springer.com/chapter/10.1007/978-1-4615-5975-7_19.

Gallagher, E., ed. 2009. *Gluten-Free Food Science and Technology*. Chichester, U.K. ; Ames, Iowa: Wiley-Blackwell.

Greene, B., and Cumuze, T., 1982. “Relationship between TBA Numbers and Inexperienced Panelists’ Assessments of Oxidized Flavor in Cooked Beef.” *Journal of Food Science* 47 (1): 52.

Hale, K. K., and Goodwin, T. L., 1968. “Breaded Fried Chicken: Effects of Precooking, Batter Composition, and Temperature of Parts before Breading.” *Poultry Science* 47 (3): 739.

Halliwell, B., and Chirico, S., 1993. “Lipid Peroxidation: Its Mechanism, Measurement, and Significance.” *The American Journal of Clinical Nutrition* 57 (5): 715S–724S.

Hanson, H. L., and Fletcher, L. R., 1963. “Adhesion of Coatings on Frozen Fried Chicken.” *Food Technology*, no. 17: 793.

Hoey, N. 2010. “Gluten Intolerance.” In *Magill’s Medical Guide*, 6thed. Vol. 6. Pasadena, CA: Salem Press.

Hough, G., and Garitta, L., 2012. “Methodology for Sensory Shelf-Life Estimation: A Review.” *Journal of Sensory Studies* 27 (3): 137–47. doi:10.1111/j.1745-459X.2012.00383.x.

Hu, Min, and C. Jacobsen. 2016. *Oxidative Stability and Shelf Life of Foods Containing Oils and Fats*. Elsevier.

Hudthagosol, C., Hasso H., McCarthy, K., Wang, P., Keiji O., and Sabaté, J., 2011. “Pecans Acutely Increase Plasma Postprandial Antioxidant Capacity and Catechins and Decrease

LDL Oxidation in Humans." *The Journal of Nutrition* 141 (1): 56–62. doi:10.3945/jn.110.121269.

IBISWorld. 2016. "IBISWorld US - Industry, Company and Business Research Reports and Information." Accessed January 25. http://clients1.ibisworld.com.proxy-remote.galib.uga.edu/reports/us/industry/productsandmarkets.aspx?entid=271.

International Union of Pure and Applied Chemistry, and Charles Paquot, eds. 1979. *Standard Methods for the Analysis of Oils, Fats, and Derivatives*. 6th ed. Oxford ; New York: Pergamon Press.

Jackson, C., and Hu, F., 2014. "Long-Term Associations of Nut Consumption with Body Weight and Obesity." *American Journal of Clinical Nutrition* 100 (July): 408S–411S. doi:10.3945/ajcn.113.071332.

Jackson, V., Schilling, M. W., Coggins, P. C., and Martin, J. M., 2006. "Utilization of Rice Starch in the Formulation of Low-Fat, Wheat-Free Chicken Nuggets." *The Journal of Applied Poultry Research* 15 (3): 417–24. doi:10.1093/japr/15.3.417.

Johnson, D., and Decker, E., 2015. "The Role of Oxygen in Lipid Oxidation Reactions: A Review." *Annual Review of Food Science and Technology* 6 (1): 171–90. doi:10.1146/annurev-food-022814-015532.

Karwowska, M., Wójciak, K., and Dolatowski, Z., 2015. "The Influence of Acid Whey and Mustard Seed on Lipid Oxidation of Organic Fermented Sausage without Nitrite." *Journal of the Science of Food and Agriculture* 95 (3): 628–34. doi:10.1002/jsfa.6815.

Ketjarut, S., and Rungnaphar P., 2015. "Influence of Tapioca Starch on Thermal Properties of Wheat Flour-Based Batter and Quality of Fried Battered Chicken Wingsticks." *International Journal of Food Engineering* 11 (5): 641–50. doi:10.1515/ijfe-2015-0017.

Kılıç, B., Şimşek, J., Claus, E., Atılgan, S., and Aktaş, N. 2015. “Effects of Different End-Point Cooking Temperatures on the Efficiency of Encapsulated Phosphates on Lipid Oxidation Inhibition in Ground Meat.” *Journal of Food Science* 80 (10): C2161–69. doi:10.1111/1750-3841.13009.

Kulp, K., and Loewe, R. eds. 1990. *Batters and Breadings in Food Processing*. St. Paul, Minn., USA: American Association of Cereal Chemists.

Labuza, T., and Schmidl, M., 1985. “Accelerated Shelf-Life Testing of Foods.” *Food Technology* 39 (9): 57.

Lai, S., Crackel, R., Gill, J., Gray, J., and Booren, A., 1995. “Assessment of Off-Flavor Development in Restructured Chicken Nuggets Using Hexanal and TBARS Measurements and Sensory Evaluation.” *Journal of the Science of Food and Agriculture* 67 (4): 447–52.

Landes, D. R., and Blackshear, C., 1971. “The Effects of Different Cooking Oils on Flavor and Color of Fried Chicken Breading Material.” *Poultry Science* 50 (3): 894.

Lillywhite, J. M., J. E. Simonsen, and R. J. Heerema. 2014. “U.S. Consumer Purchases and Nutritional Knowledge of Pecans.” *HortTechnology* 24 (2): 222–30.

Lombardini, L., T. M. Waliczek, and J. M. Zajicek. 2008. “Consumer Knowledge of Nutritional Attributes of Pecans and Factors Affecting Purchasing Behavior.” *HortTechnology* 18 (3): 481–88.

Majzoobi, M., Farahnaky, A., and Agah, S., 2011. “Properties and Shelf-Life of Part-and Full-Baked Flat Bread (Barbari) at Ambient and Frozen Storage.” *Journal of Agricultural Science and Technology* 13: 1077–1090.

Mäkelä, M., Eriksson, C., Kotaniemi-Syrjänen, A., Palosuo, K., Marsh, J., Borres, M. Kuitunen, M., and Pelkonen, A. S., 2014. "Wheat Allergy in Children - New Tools for Diagnostics." *Clinical & Experimental Allergy* 44 (11): 1420–30. doi:10.1111/cea.12393.

Man, C. M. D., and Jones, A. A., eds. 2000. *Shelf-Life Evaluation of Foods*. 2nd ed. Gaithersburg, MD: Aspen Publishers.

Maskat, M., and Kerr, W. 2002. "Coating Characteristics of Fried Chicken Breasts Prepared with Different Particle Size Breading." *Journal of Food Processing and Preservation* 26 (1): 27–38. doi:10.1111/j.1745-4549.2002.tb00475.x.

———. 2004. "Effect of Breading Particle Size on Coating Adhesion in Breaded, Fried Chicken Breasts." *Journal of Food Quality* 27 (2): 103–13. doi:10.1111/j.1745-4557.2004.tb00641.x.

Meilgaard, M., Civille, G., and Carr, T.2007. *Sensory Evaluation Techniques*. 4th ed. Boca Raton: Taylor & Francis.

Mintel. 2016a. "Chocolate Confectionery - US - February 2015." Accessed January 25. http://academic.mintel.com.proxy-remote.galib.uga.edu/display/730932/?highlight#hit1.

———. 2016b. "Hot and Cold Cereals - US - August 2014." Accessed January 25. http://academic.mintel.com.proxy-remote.galib.uga.edu/display/712381/?highlight#hit1.

———. 2016c. "Nut-Based Spreads and Sweet Spreads - US - March 2015." Accessed January 25. http://academic.mintel.com.proxy-remote.galib.uga.edu/display/732059/.

———. 2016d. "Snack, Nutrition and Protein Bars - US - March 2015." Accessed January 25. http://academic.mintel.com.proxy-remote.galib.uga.edu/display/733409/?highlight#hit1.

Mukprasirt, A., Herald, T., Boyle, D., and Rausch. K., 2000. "Adhesion of Rice Flour-Based Batter to Chicken Drumsticks Evaluated by Laser Scanning Confocal Microscopy and Texture Analysis." *Poultry Science* 79 (9): 1356–63.

Murray, J., Delahunty, C., and Baxter, I., 2001. "Descriptive Sensory Analysis: Past, Present and Future." *Food Research International* 34 (6): 461–71. doi:10.1016/S0963-9969(01)00070-9.

Naveena, B., Muthukumar, M., Muthulakshmi, L., Anjaneyulu, A., and Kondaiah, N., 2014. "Effect of Different Cooking Methods on Lipid Oxidation and Microbial Quality of Vacuum-Packaged Emulsion Products from Chicken." *Journal of Food Processing and Preservation* 38 (1): 39–47.

Niels, M., 2014. "Pecan." *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks*. http://www.ba.ars.usda.gov/hb66/pecan.pdf.

Nollet, L., and F. Toldrá, eds. 2009. *Handbook of Muscle Foods Analysis*. Boca Raton: CRC Press.

"Pecan." 2014. *Encyclopædia Britannica*, Research Starters, . http://eds.a.ebscohost.com/eds/detail/detail?sid=098fed7b-634d-45af-9a09-95bc331d7f45%40sessionmgr4002&vid=15&hid=4103&bdata=JnNpdGU9ZWRzLWxpdmU%3d#AN=87996803&db=ers.

"Pecan Nutrition Fact Sheet." 2016. *Georgia Pecans*. Accessed January 5. http://georgiapecans.org/science-nutrition/pecan-nutrition-fact-sheet/.

Prepared Foods. 2015. "U.S. Gluten-Free Food Retail Market Reaches $973 Million." January 19. http://www.preparedfoods.com/articles/114866-us-gluten-free-food-retail-market-reaches-973-million).

Rajaram, S., Burke, K., Connell, B., Myint, T., and Sabaté, J., 2001. “A Monounsaturated Fatty Acid–Rich Pecan-Enriched Diet Favorably Alters the Serum Lipid Profile of Healthy Men and Women.” *The Journal of Nutrition* 131 (9): 2275–79.

Rhee, K., Anderson, L., and Sams, A., 1996. “Lipid Oxidation Potential of Beef, Chicken, and Pork.” *Journal of Food Science* 61 (1): 8–12. doi:10.1111/j.1365-2621.1996.tb14714.x.

Ros, E., 2010. “Health Benefits of Nut Consumption.” *Nutrients* 2 (7): 652–82. doi:10.3390/nu2070652.

Sahin, S., and Sumnu, S., eds. 2009. *Advances in Deep-Fat Frying of Foods*. Contemporary Food Engineering. Boca Raton: CRC Press.

Santerre, C. R., ed. 1994. *Pecan Technology*. New York: Chapman & Hall.

Shaker, M. A. 2015. “Comparison between Traditional Deep-Fat Frying and Air-Frying for Production of Healthy Fried Potato Strips.” *International Food Research Journal* 22 (4): 1557–63.

“Show Foods.” 2016. Accessed April 23. https://ndb.nal.usda.gov/ndb/foods/show/764?fgcd=&man=&lfacet=&count=&max=&sort=&qlookup=&offset=&format=Full&new=&measureby=.

Singh, T., and Cadwallader, K., 2002. “The Shelf Life of Foods: An Overview.” In *Freshness and Shelf Life of Foods*, edited by Keith R. Cadwallader and Hugo Weenen, 836:2–21. Washington, DC: American Chemical Society. http://pubs.acs.org/doi/abs/10.1021/bk-2003-0836.ch001.

St. Angelo, A., 1992. *Lipid Oxidation in Food*. ACS Symposium Series 500. Washington, DC: American Chemical Society.

Steele, R., ed. 2004. *Understanding and Measuring the Shelf-Life of Food*. Woodhead Publishing in Food Science and Technology. Boca Raton : Cambridge: CRC Press ; Woodhead Pub.

Suderman, D., and Cunningham, F., eds. 1983. *Batter and Breading*. Westport, Conn: AVI Pub. Co.

Tsironi, T., Dermesonlouoglou, E., Giannakourou, M., and Taoukis, P.,. 2009. "Shelf Life Modelling of Frozen Shrimp at Variable Temperature Conditions." *LWT - Food Science and Technology* 42 (2): 664–71. doi:10.1016/j.lwt.2008.07.010.

Vadivel, V., Kunyanga, C., and Biesalski, H., 2012. "Health Benefits of Nut Consumption with Special Reference to Body Weight Control." *Nutrition* 28 (11/12): 1089–97. doi:10.1016/j.nut.2012.01.004.

Wieser, H., Koehler, P., and Konitzer, K., 2014. *Celiac Disease and Gluten: Multidisciplinary Challenges and Opportunities*. Amsterdam: Elsevier : Academic Press.

Wrolstad, R., Acree, T., Decker, E., Penner, M., Reid, D., Schwartz, S., Shoemaker, C., Smith, D., and Sporns, P., 2005. *Handbook of Food Analytical Chemistry, Volume 1: Water, Proteins, Enzymes, Lipids, and Carbohydrates*. John Wiley & Sons.

Xu, J., Riccioli, C., and Sun, D., 2015. "An Overview on Nondestructive Spectroscopic Techniques for Lipid and Lipid Oxidation Analysis in Fish and Fish Products." *Comprehensive Reviews in Food Science and Food Safety* 14 (4): 466–77. doi:10.1111/1541-4337.12138.

Table 4.1: Lexicon for sensory flavor attributes of gluten-free pecan breaded chicken nuggets. Intensities based on a modified Spectrum Intensity Scale (Meilgaard, Civille, and Carr 2007).

Attribute	Definition	Reference Materials
Grainy/starchy	General terms used to describe the aromatics of raw grains that can't be tied to a specific grain by name	Whole wheat flour= 3 Cream of Wheat (Nabisco)= 6.5
Oxidized	The aromatic associated with aged or highly used oil and fat	Microwave Oven Heated Wesson Vegetable Oil = 6.0 Preparation: Add 300ml of oil from a newly purchased and opened bottle of Wesson Vegetable Oil to a 1000 ml glass beaker. Heat in the microwave oven on high power for 3- minutes. Remove from microwave and let sit at room temperature to cool for approximately 25-minutes. Then heat another 3-minutes, let cool another 25-minutes, and heat for one additional 3-minute interval. Let beaker sit on counter uncovered overnight Wet cardboard= 3 Linseed Oil= 15
Oily	The light aromatics associated with vegetable oil	Pringles potato chips = 1.0 Kroger Dry Roasted and Salted Macadamia Nuts = 9.0
Overall nutty	A measurement that reflects the total of the nutty characteristics and the degree to which these characteristics fit together. These nutty characteristics are: sweet, oily, light brown, slightly musty and/or buttery, earthy, woody, astringent, bitter, etc. Examples: nuts, wheat germ, certain whole grains.	Gold Medal Whole Wheat Flour = 2.5 Mixture of Diamond Slivered Almonds and Kroger Chopped Hazelnuts = 5.5 Preparation: Puree the almonds and hazelnuts separately in blenders for 45 seconds on high speed. Combine equal amounts of the chopped nuts. Serve in individual 1 oz. cups. Serve pecans and walnuts in 1 oz cups. Diamond Pecan Halves = 11.0
Roasted	Dark brown impression characteristic of products cooked to a high temperature by dry heat (no bitter or burnt notes)	Pecan Halves (unroasted)= 0 Pecan Halves (5 min roast)= 7.5 Pecan Halves (12 min roast)= 14
Crispness	The noise and force of which the sample breaks or fractures	Club Cracker (Keebler)= 5 (½ cracker) Corn Flakes (Kellogg's)= 14 (1 oz)
Hardness	Force required to bite through sample	Olives queen-sized= 6, 1 olive Peanuts (Planters)= 9.5, 1 nut, whole Carrots (fresh)= 11, ½ in. slice

Table 4.2: Effect of storage temperature on TBARS and conjugated dienes/trienes of chicken nuggets.

	TBARS		Conjugated dienes/trienes	
Day of storage	1-Breading[a] (100% Cornflake)	3-Breading[a] (75/25)	1-Breading[a] (100% Cornflake)	3-Breading[a] (75/25)
	-40 °C	**-15 °C**	**-40 °C**	**-15 °C**
1	0.222	0.263	19.542	20.014
15	0.393	0.472	16.925	18.278
30	0.436	0.449	17.535	18.925
45	0.401	0.358	17.131	18.913
60	0.381	0.342	16.237	16.206
75	0.421	0.380	17.814	20.277
90	0.436	0.440	16.950	18.030
105	0.471	0.434	9.731	10.643
120	0.441	0.530	16.295	20.171
135	0.435	0.366	18.346	18.812
150	0.579	0.444	17.397	16.569
165	0.781	0.552	18.972	21.624
180	0.435	0.425	19.639	18.165

[a]The 1-breading consisted of cornflakes. The 3-breading (75/25 ratio) consisted of pecans and cornflakes.

Table 4.3: Lipid compositions per 100g of pecans

Lipid Type	**Raw[a] (g)**
Fatty acids, total saturated	6.180
16:0	4.366
18:0	1.745
20:0	0.069
Fatty acids, total monounsaturated	40.801
18:1	40.594
20:1	0.207
Fatty acids, total polyunsaturated	21.614
18:2	20.628
18:3	0.986

[a]Data from the USDA National Nutrient Database for Standard Reference, (USDA 2016)

Table 4.4: Descriptive panel sensory scores[1] on grainy, oxidized, oily, nutty, roasted, hardness, and crispness according to test date (n=8)

Week	Grainy[2]	Oxidized[2]	Oily[2]	Nutty[2]	Roasted[2]	Hardness[2]	Crispness[2]
	---Mean±SD---						
0	2.37±0.98a	2.02±1.57a	3.62±1.73a	3.87±1.75a	4.16±2.32a	5.27±1.72a	4.79±2.54a
2	2.52±1.30a	2.00±1.68a	3.06±1.63ab	4.33±2.32a	4.16±1.92a	5.06±1.79a	4.04±2.36a
4	2.45±1.25a	1.81±1.38a	3.06±1.41ab	4.41±1.86a	4.50±2.11a	5.93±1.48a	5.52±2.13a
6	3.04±1.66a	2.20±1.63a	2.45±0.90b	3.79±1.34a	4.85±1.88a	4.62±2.07a	4.41±2.33a

[1]Means±SD followed by the same letter in a row are not significantly different according to one-way ANOVA and post hoc S-N-K test for equality of means ($p>0.05$) (SSPS version 21, IBM Corp., Armonk, NY).

[2]The panel rated seven attributes of the breaded chicken on a 150 mm unstructured line scale: grainy, oxidized, oily, nutty, roasted, crispness, and hardness.

Table 4.5: Descriptive panel sensory scores[1] on grainy, oxidized, oily, nutty, roasted, hardness, and crispness according to sample storage temperature (n=8)

Sample Storage Temperature	Grainy[2]	Oxidized[2]	Oily[2]	Nutty[2]	Roasted[2]	Hardness[2]	Crispness[2]
	-----------	-----------	-----------	Mean±SD	-----------	-----------	-----------
-40°C	2.68±1.17a	2.04±1.61a	3.21±1.50a	4.21±1.91a	4.51±1.78a	5.57±1.75a	5.01±2.64a
-15°C	2.68±1.45a	1.78±1.51a	2.81±1.45a	4.03±1.97a	4.50±1.97a	5.23±1.87a	5.04±2.39a
-10°C	2.42±1.36a	2.20±1.54a	3.12±1.53a	4.06±1.67a	4.25±2.40a	4.85±1.80a	4.01±1.95a

[1]Means±SD followed by the same letter in a row are not significantly different according to one-way ANOVA and post hoc S-N-K test for equality of means ($p>0.05$) (SSPS version 21, IBM Corp., Armonk, NY).
[2]The panel rated seven attributes of the breaded chicken on a 150 mm unstructured line scale: Grainy, oxidized, oily, nutty, roasted, crispness, and hardness.

Table 4.6: Consumer panel sensory scores[1] on appearance, texture, flavor, and overall acceptability for shelf life (n=80)

Temperature	Appearance[2]	Texture[2]	Flavor[2]	Overall Acceptability[2]
	----------------------------	---------------Mean±SD	---------------	----------------------------
-40°C	6.06±1.62a	7.56±6.74a	6.96±1.51a	6.77±1.36a
-15°C	5.97±1.75a	6.43±1.55a	6.92±1.30a	6.63±1.19a
-10°C	5.97±1.86a	6.62±1.54a	6.97±1.37a	6.73±1.21a

[1]Means±SD followed by the same letter in a row are not significantly different according to one-way ANOVA and post hoc S-N-K test for equality of means (p>0.05) (SSPS version 21, IBM Corp., Armonk, NY).
[2]The panel rated four attributes of the breaded chicken on a 9-point scale: flavor, texture, appearance, and overall acceptability (1-dislike extremely to 9-like extremely).

CHAPTER 5

CONCLUSION

The goal of this study was to evaluate the use of pecans in a breaded chicken nugget as a way to increase the use of an underutilized culinary nut. The pecans did not have a significant effect on moisture content, batter adhesion, or consumer acceptability. Chicken nuggets made with pecans had a higher lipid content and the nuggets made with only cornflakes had a higher b* value (slightly yellow tint). In addition, storage temperature did not have an effect on the trained descriptive panel or consumer acceptance panel. Samples stored at -40°C had lower values for thiobarbituric acid reactive substances and conjugated dienes and trienes. Overall, pecans can be used as an ingredient in breaded chicken nuggets. Future studies might focus on extending the storage study past 180 days to further monitor for changes.