OPTIMIZATION OF INGREDIENT AND PROCESS PARAMETERS FOR CHICKEN NUGGETS

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PARAMETERS FOR CHICKEN NUGGETS

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CHAPTER I

INTRODUCTION

Chicken nuggets have increased in popularity in the food industry since being invented in the 1950’s by Robert Baker of Cornell University (Meat, 2006), who publicly published the recipe for all to use. Yet, it took until the early 1980s when McDonald’s launched the nugget on its menu and patented its recipe for Chicken McNuggets to gain public acceptance (Meat, 2006). When chicken nuggets are mentioned, McDonald’s is the fast food restaurant consumers think of and many assume they invented the nugget. However, they simply made a new product a mainstay for today’s consumer. Today, nearly all fast food restaurants and retail grocery stores have a chicken nugget item on the menu or in a frozen package. The chicken nugget is the only nugget accepted worldwide that has reached this level of popularity. In fact, the beef, pork, and vegetable industries version of the nugget have been unable to gain enough consumer acceptability to succeed. Over the years, chicken nuggets have been made in a wide range of shapes, simple circles to dinosaur figures, for the increased eating experience of the customer, most commonly young children. The nugget has not gone through many formulation changes since its creation in the 1950’s. The nugget is most commonly made of a mixture of chicken meat and skin, salt, phosphates, and water. Over the years, the nugget has kept up with consumer demands for change and has used a mixture of white and dark mechanically separated chicken meat, to a whole muscle product using white breast meat. The amount of chicken skin has varied in formulations to keep the cost down and allow the nugget to bind together for the cooking process.

The United States Department of Agriculture (USDA) has standards for the proper identity that must be followed in order to be labeled as a chicken nugget. These standards listed in CFR 381.117, state that poultry products containing light and dark meat not used in natural proportions must have a qualifying statement. Natural proportions are 50-65 percent light meat and 50-35 percent dark meat; this also holds true for amount of skin, being 20 percent based on the whole chicken carcass (FSIS, 2003).

Increase in awareness for a healthier diet and the increase in demand for higher quality meat alternatives (Sadler, 2004) have led to changes in the formulation of the chicken nugget. Reducing fat content in nugget formulations is a simple change. However, the utilization of meat alternatives to reduce fat content has not been as easy to incorporate as they result in changes in flavors, textures, and other sensory attributes (Riaz, 2008). Meat alternatives, such as soy and wheat proteins, have made improvements in the areas of flavor and texture, thus being available for use in multiple applications of the meat industry (Riaz, 2005). The increased demand for vegetarian products has helped the meats industry better understand vegetable proteins and how they function

(Sadler, 2004). Utilizing vegetable proteins for cost benefits, health concerns, or over all functionality of the product allows their use in the meat industry (Sadler, 2004). The meat industry has been able to utilize many of the nutritional aspects of vegetable proteins by finding functional ways to incorporate them into their products, and still provide a product which is very similar in taste, aroma, texture, and appearance as the original all meat formulation. These newly developed, improved products should provide an additional market place for meat eating consumers, who are looking for more variety in their diet (Sadler, 2004). By providing healthier products via the incorporation of plant based foods into the diet, which in many cases has been proven to show potential health benefits such as reducing cholesterol and heart disease (Sadler, 2004).

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CHAPTER II

REVIEW OF LITERATURE

Vegetable Proteins

Increasing functionality of vegetable proteins will allow them to be used in a wider variety of meat products. Vegetable and meat proteins can beneficially serve as complements to one another when incorporated into the same product. Meat proteins are balanced complete proteins, where many vegetable proteins are not; yet vegetable proteins offer a good source of dietary fiber and are low in saturated fats (Food, 2008). Soy is the most commonly used vegetable protein. However, through new and improved uses and the increase in functionality, wheat, yeast, and rice are becoming more popular as they all provide beneficial nutritional qualities (Sadler, 2004). Health benefits have been seen with vegetable proteins as they help protect against heart disease, lower cholesterol, have potential in reducing the risk of cancer, and increased bone mass (Sadler, 2004). The biggest reason to use a vegetable protein from a processor's viewpoint is to reduce formulation cost. However, other attributes such as the ability of retaining water and moisture during cooking, reheating, freezing, and thawing can also be a benefit (Riaz, 2005). Textured vegetable proteins are commonly used together to provide the desired quality, in texture, binding ability, desired amount of chewiness, or to make a product firmer or softer (Riaz, 2005).

Soy Proteins

Soy proteins have been used in East Asia for centuries in products such as soy sauce, tofu, and miso. Soy protein flours, concentrates, and isolates have been developed to be incorporated into a wide range of food products, from beverages to meat and meat alternatives such as veggie burgers. Soy would be included in meat and meat alternatives to function similarly to the traditional sources of protein in meat and dairy products (IFIC 2005). Processing of soybeans is critical in determining the use of the soy protein; they are first cleaned, conditioned, cracked, dehulled, rolled into flakes, and dried, thus creating defatted soybean flakes (Solae, 2008). This defatted material is the basis for the three major soy protein product categories: flours, concentrates, and isolates (Solae, 2008). The soy categories are sorted based upon Codex general standards for soy proteins: soy flour contains between 50-65% protein, concentrate 65-90% protein, and an isolate 90% or more protein, all on a dry weight basis (Codex, 1989). These levels help determine the type of product it can be used in and how much should be used. Textured soy flour tends to be less functional in water holding ability when compared to other vegetable proteins, but is sweeter and possesses a softer texture after hydration, due in part to a higher concentration of soluble sugars (Riaz, 2005). The soy flour tends to contain a more pronounced bean-like and cereal flavor than the concentrates or isolates (Riaz, 2005). Soy concentrates will be able to absorb more water and retain it through the cooking process, along with losing some of the bean-like flavor, as it is removed in a water or alcohol wash during preparation (Riaz, 2005).

Soy has been under constant watch since the United States Food and Drug Administration (USFDA) approved the use of the following health claim: “soy protein may reduce heart disease if a diet contains 25 grams of soy protein”, which is equivalent to a food containing at least 6.25 grams of soy protein per serving (FDA, 2000). The FDA states that all foods, including soy, can be very beneficial to people, but when used inappropriately, such as taking concentrated pills in excess can be harmful (FDA 2000). Soy is not a cure-all in someone’s diet, but can be used to assist in the health benefits previously mentioned (FDA, 2000). Soy can be a good alternative protein source in a person’s diet and serve as a way to incorporate additional nutrients: such as fiber, potassium, B vitamins, and zinc into the food a person eats on a daily basis (FDA, 2000).

Wheat Protein

Wheat Protein has not been utilized as much as soy for multiple reasons. The market for wheat has always been geared towards its uses in food products such as flour, feeds, or seeds, and as such, only a small portion has been used as an alternative protein source in the form of wheat starch or gluten (Maningat *et al*, 1999). Wheat alone is a staple in our diets as it is used in most flours and many processed foods. The development of wheat protein used in food with soy proteins or as the main ingredient used in meat products is still in the early stages of development (Maningat *et al* , 1999).

Wheat protein or gluten is acquired through wet processing of wheat flour, is separated in the form of a protein-lipid-starch complex, and is a natural water-insoluble protein portion of the wheat endosperm (Maningat, 1994). Wheat protein is formed through extrusion of wheat gluten by forming a hot viscous mass called protein lava (Maningat *et al*, 1999). By controlling the moisture, pressure, and temperature, the lava is extruded to develop the desired fiber and texture, resulting in a product that has a visible pattern of fiber arrangement and closely resembling meat fibers (Maningat *et al*, 1999). Wheat can then be categorized into two areas: vital and devitalized wheat gluten or solubilized wheat proteins containing 80% or more protein or 60% or more protein, on a dry basis, respectively (Codex, 2001). Wheat protein easily mimics chicken protein, and with the addition of caramel or malt color can easily mimic beef protein, with the ability to absorb 2.5 to 4 times its weight (Maningat *et al*, 1999). Wheat protein has a low fat content, desirable texture and chewability, neutral flavor, cost benefit, and a nutritional balance (Maningat *et al*, 1999). Blending different textured vegetable proteins to form desired characteristics in a meat or a non-meat product is a standard procedure in making many foods and allows the strengths of each component to be better utilized within the product (Riaz, 2005). Wheat protein has the ability to provide a unique oriented fiber structure to meat products, allowing it to be a good source for binding ingredients together in meat analogs as well as having an interesting and desirable chewy texture (Riaz, 2005).

Nugget Formulations

The formulation to make a chicken nugget is rather simple: chicken meat trim, skin, water, phosphate, and salt. Consumer acceptance of a nugget may be altered based on changes in the formulation, such as the level and quality of ingredients used. The patent process for McDonald's nuggets has become accepted worldwide since the day it was put on the menu. Another restaurant chain may make a nugget which is flavored and visually different, but the basic formulation remains the same. The chicken meat protein in a nugget and the internal ingredients are similar, while many companies have worked very hard to develop a specific batter and breading for the outside to identify their nugget with a particular look or special flavor. Yet, in the last decade the formulation has made additional changes to stay current with the consumer driven market.

Vegetable proteins have made beneficial functionality advances in the quality of product produced. Thus, allowing meat processors to incorporate vegetable proteins into meat based nuggets, providing a nugget with added nutritional value. Incorporating meat and vegetable proteins into a nugget can cover up vegetable flavors and tastes which younger consumers may not like and will allow them to receive the nutritional benefits which vegetables provide. However, just mixing in vegetable proteins with the original formulation may not produce a consumer acceptable nugget. When adding a new ingredient into a current formulation many changes can be seen in the end product.

Vegetable proteins may reduce the cost of formulation for the end product. Currently, vegetable protein is less expensive than lean chicken protein (Riaz, 2005). Additionally, using a vegetable protein can allow for the addition of more fat trim to be replaced in the formulation, if desired, in order to maintain a similar eating experience, and fat trim is also cheaper (Riaz, 2005). Other areas to be addressed to effectively include vegetable proteins into a chicken nugget are how it may, if at all, impact texture, color, moisture, fat content, pH, cook yields, protein content, and the consumer sensory attributes of taste, flavor, and appearance. If a nugget containing vegetable proteins can meet the same standards as an all meat chicken nugget then it should be a successful transition to receiving consumer acceptability.

Nugget Formulations: Texture

The texture of a chicken nugget can be analyzed by a texture profile analyzer (TA.XTPlus) to simulate the first bite eating experience of the nugget, based on the type of tests performed: firmness, edge browning, crispness, toughness, mushiness, stiffness, and cohesiveness. These tests help to provide an idea of quality attributes of the product and help the manufacturer obtain desired information in developing the product. Another method which can be utilized is an Instron compression for springiness, a 9-pin hardness test, or a Warner Bratzler Meat Shear. These tests give an idea of the potential tenderness of the nugget. Studies have shown that using full-fat soy paste and textured soy granules in goat meat nuggets resulted in a lower hardness, springiness, and shear force value than an all goat meat control nugget (Das, 2008). In a fracturability test used to simulate first bite, using soy flour and rice flour in the nugget formulation, soy flour had a better fracturability score, meaning that it was crispier, than either rice flour or control chicken nugget (Dogan, 2005). When comparing soy and wheat gluten in a beef and pork meat batter, the wheat gluten had the lowest shear force compared to the soy and control batter (Patana-Anake, 1985). In a pork nugget study using carrageenan and konjac flour gel, the breaded chicken and breaded beef nuggets sheared with significantly lower values than nuggets containing the added konjac flour gel or carrageenan, as well as the all pork nuggets (Berry, 1996). Frankfurters produced with wheat, corn, or soy proteins all showed a lower shear force and firmness value than the control frankfurter (Gnanasambandam, 1992). In a study using soy, dry milk, milk protein, and yeast at various levels all had lower numerical values or were not significantly different in rupture or compression force than the (Beef and Pork) control frankfurter (Parks, 1987). When using rice starch in place of wheat starch, the wheat starch chicken nugget was numerically lower than the rice flour chicken nugget in shear force value (Jackson, 2006). When a Warner Bratzler shear was used to compare soy protein and sodium caseinate at different ratio levels in a chicken bologna, those with a greater amount of soy protein numerically had a greater shear force value (Yusof, 1996). Lowering shear force values in products made with vegetable proteins could be due to the addition of a hydrated protein source, as is the case with soy or wheat proteins (Riaz, 2005). The increased disruption of meat, fat, and vegetable proteins interacting during mixing allow the vegetable protein to attach to fat and retain more water throughout the cooking process (Riaz, 2005).

Nugget Formulations: Sensory Attributes

Sensory values from panelists are used to determine what consumers prefer in a product. In chicken nuggets, tenderness scores can be related to shear force values to see if a consumer rates a lower shear force value as a desired trait. Other aspects in sensory panels that aid in product evaluation are off flavors that may be detected, juiciness, visual appearance, and overall acceptability of a product when using a vegetable protein. Any of these attributes can drastically affect a consumer's preference of the product. Yusof and Babji (1996) documented that a chicken bologna made with a higher soy protein to sodium caseinate ratio was least acceptable for texture, chewiness, and juiciness. In a comminuted beef and pork frankfurter made with either wheat protein, soy protein or corn germ, the wheat and control frankfurter received significantly higher scores for meaty aroma, whereas the soy and corn germ samples received significantly higher scores for off-aroma and off-flavor (Gnanasambandam and Zayas, 1992). Berry and Binger (1996) documented that pork nuggets with konjac flour or carrageenan both received significantly lower scores for juiciness when compared to an all beef or all chicken nugget. In Das *et al.* (2008) a study with goat nuggets utilizing soy granules and soy paste, the soy granules received significantly lower scores for flavor and overall acceptability when compared to the soy paste and control chicken nugget. However, no difference in juiciness, texture, or appearance was found (Das *et al*, 2008). The majority of the sensory attributes in these studies point out that an off flavor is often detected, which affects the overall acceptability of nuggets when using a vegetable protein, particularly soy flour, concentrates or granules. This remains a consistent problem with the use of soy in many meat based products due to the heat treatment required to manufacture soy protein (Riaz, 2008). However, there is a non-heat treated soy flour available to assist in reducing the sometimes bitter, bean-like flavor that limits soy applications in some products (Riaz, 2008).

Nugget Formulations: Color

Color is another attribute that, if changed due to a new formulation, can affect consumer acceptability. Using L*, a*, and b* color values can help determine what color differences occurred. The L* value shows white to black color ratio on a 0 (absolute white) to 100 (absolute black) scale (AMSA, 1991). The a* values indicate red (positive) to green (negative) color ratios and b* values indicate yellow (positive) to blue (negative) color ratios (AMSA, 1991). In a study with frankfurters using wheat protein, soy protein, and corn germ, the soy protein and corn germ had the lowest L* values, while the wheat protein had the lowest a* and b* values among all treatments (Gnanasambandam and Zayas, 1992). In nuggets containing soy flour or rice flour in the batter, the soy flour had the lowest L* values, but the highest a* values, compared to rice flour and control nuggets (Dogan *et al,* 2004) . This may be partly due to the higher protein content from soy in the flour batter (Dogan, 2004). In a study using chicken nuggets with and without salt and/or sodium tripolyphosphate, there were no differences in b* values for all treatments, yet nuggets containing salt had the highest L* values among all treatments, and the L* values were lowest in nuggets containing salt and tripolyphosphate (O'Sullivan, 2004). In chicken nuggets fried in different hydrogenated oils for different times, the L* values decreased over time regardless of the hydrogenation level, a* values increased significantly with time and hydrogenation level, and nuggets with the lowest hydrogenation levels had lower b* values for all times (Ngadi, 2007). It needs to be noticed that in some cases the addition of vegetable proteins in fried foods, have potential to be darker in color, due to the addition of more protein incorporated into the formulation (Dogan, 2004). These color differences do not mean that the product is unacceptable. That is to be determined by the company and the target appearance for the market they are working towards.

Nugget Formulations: Chemical Composition

The chemical analysis must be considered if the vegetable protein is the cause of changes in fat moisture, protein, or pH as a result of modification. These types of changes may affect sensory attributes, which can be beneficial to the product or a set back when used in the formulation. In Das (2008), incorporating soy paste or soy granules into goat nuggets the percent protein was highest numerically in the control nuggets, and the pH, moisture, and fat percents had no differences among all three treatments. Perlo (2006) when comparing mechanically deboned, hand deboned, and washed mechanically deboned chicken in chicken nuggets, found that hand deboned nuggets had the lowest pH and highest protein, washed chicken nuggets had the highest moisture percent, and mechanically deboned nuggets had the highest fat percent. When soy flour and rice flour where added to the batter of chicken nuggets no moisture differences were documented between treatment groups (Dogan, 2004). When using pork nuggets formulated with carrageenan or konjac flour, the carrageenan had the highest percent moisture and lowest percent fat of all treatments, while the all pork nuggets had the highest percent fat (Berry, 1996). Gnanasambandam and Zayas (1992) found when comparing beef and pork frankfurters made with wheat protein, soy protein, or corn germ, wheat protein frankfurters contained the highest percent protein, while the beef and pork control frankfurters had the lowest, wheat germ frankfurters had significantly higher percent moisture and lower fat percent than soy protein or corn germ frankfurters. In Jackson (2006), when utilizing rice starch in place of wheat flour, wheat flour had the highest moisture percent across all treatments, and highest protein content. The chemical analysis of adding vegetable proteins to a chicken nugget shows that differences are going to occur; many seem to be beneficial to the product, adding more moisture believed to occur due to the vegetable protein retaining more water throughout the cooking and reheating processes, pH does not seem to be affected, and fat content becomes lower in many cases.

Conclusion

The utilization of vegetable proteins into chicken nuggets is an area that demonstrates many potential benefits from production to consumption. The popularity of wheat, soy, rice, corn and other vegetable proteins is a growing area of interest and being able to utilize them in the food industry has a multitude of possibilities. The ultimate goal is to produce a product that has the ability to incorporate a vegetable protein, reduce production cost and at the same time provide the consumer the same quality product in taste and appearance. The ability to do this has its restrictions. Vegetable proteins tend to alter the overall flavor of the final product (Riaz, 2005). Vegetable proteins have benefits of adding retained moisture to nuggets, at the same time reducing fat content. The ability to incorporate meat and vegetables seems like a great idea for people who do not consume enough vegetables in their diet, but how much is needed to meet those requirements has yet to be decided by the FDA, but any addition should be seen as a step in the right direction. From an industry perspective, rising food costs across the food sector is a concern and being able to reduce cost of the formulation and maintain an acceptable, quality product is a benefit. Vegetable proteins are an option to help in this area, as they are a lower cost alternative to lean meat proteins. However, adding a new ingredient into a formulation can cause adjustments in timing, flow of product manufacturing, and more storage space. These aspects need to be addressed on a company-by-company basis to see how it may affect the day-to-day production practices. Additional research can to be done in order to find out the best combination of vegetable proteins used in a chicken nugget. Also, with the benefits of cost reduction, retained moisture, reduced fat content, and increased cook yields, what additional changes can be made to the vegetable proteins themselves, through changes in manufacturing and hydration methods or using different types of breading to overcome the bean-like off-flavors sometimes detected.

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CHAPTER III

OPTIMIZATION OF INGREDIENT AND PROCESS PARAMETERS FOR CHICKEN NUGGETS

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Abstract

The optimization of five different vegetable proteins (Arcon soy protein concentrate [ASP], Arcon Textured Vegetable Protein flour [ATVP], Supramax soy protein [SMXP], Solae Response soy protein [SRSP], and textured wheat protein, {Wheatex WP]) at three usage levels (10%, 20%, and 30%) were compared to a control industry standard chicken nugget. All nuggets were made uniform shape and size to evaluate weights throughout manufacturing: raw, battered and breaded, cooked (fried), frozen, and reheated. Control nuggets had the lowest ($P < 0.05$) raw, frozen and reheated weights among all treatments. Cooked weights were heaviest ($P < 0.05$) for WP 30%, among all treatments, excluding ASP 10%. Compositional properties, fat, moisture, protein, and pH were all taken in duplicate. There were no differences ($P < 0.05$) for compositional properties, fat, moisture, and protein among treatments. The pH of nuggets showed control to have the lowest ($P < 0.05$) pH of percentage treatment levels, except 10%. Sensory evaluations were performed using a consumer sensory panel. All nuggets scored in the acceptable category,

regardless of percentage treatment level. Flavor profile was similar among all treatments. However, ATVP 30% and SRSP 30% scored lowest ($P < 0.05$) among all treatments and control. Wheat Protein 30% scored highest ($P < 0.05$) for juiciness and tenderness compared to all treatments and control, except WP 20%. Texture, overall likeability, and off-flavor showed no differences ($P < 0.05$) among all treatments and control. Texture profile was analyzed and showed ATVP to have the highest numerical value among all treatments and control. Vegetable proteins had the ability to be incorporated into chicken nuggets for the purpose of reducing production costs, by adding and retaining weight throughout manufacturing, when compared to a control nugget. Sensory attributes are not affected below the acceptable range across all treatments, yet some treatments where preferred in particular areas such as juiciness and tenderness.

MATERIALS AND METHODS

Chicken Meat & Skin

Chicken breast meat trim and skin was obtained from the Tyson Foods Company located in Springdale, AR. Uncooked chicken breast meat trim pieces with rib meat and raw frying chicken skins were transported to Oklahoma State Robert M. Kerr Food & Agricultural Products Center (FAPC) where it was kept frozen (-23℃) until ready for use (approx. ~ 1 week) . Chicken trim and skin was tempered 24h at 5℃ prior to use and maintained belo w 5℃ for production.

Vegetable Protein

Five vegetable proteins were obtained from three companies for incorporation into the chicken nugget formulations. These protein sources consisted of the textured wheat protein (Wheatex, WP), Arcon textured vegetable protein flour (ATVP), Arcon soy protein concentrate (ASP), Solae Response soy protein concentrate (SRSP), and Supramax soy protein (SMXP). The five proteins where formulated into the chicken nugget recipe at three levels 10, 20, or 30% and formulations were constructed into 6 individual replications. (Note: the 10, 20, and 30% addition of textured protein extenders was in the form of fully hydrated product and all where hydrated up to 3 to 3.5% of dry weight).

Nugget Manufacturing

Replications (n = 6) of each of the chicken nugget formulations (n = 16) were produced representing the control chicken along with the five protein sources at three incorporation levels. Chicken nuggets were formulated according to the ingredients listed in Table 1. Boneless, skinless chicken breast trim was passed through a Biro grinder (The Biro MFG Co., Marblehead, OH) with a size 32 head equipped with a 6.35 mm plate. Chicken skins were ground twice through the same grinder equipped with a 3.2 mm plate. Ground chicken breasts, skins, and ingredients were then mixed in a Leland-Southwest 100DA mixer (Fort Worth, TX) for 3-5 minutes. The mixture was formed to a uniform nugget shape tube (38 mm X 610 mm) using a Handtmann VF 608 vacuum filler (Buffalo Grove, IL), placed on trays, and frozen at -23º C. After 24h, nuggets were removed, tempered, and formed to a uniform nugget size (13mm thick X

38mm diameter) and weight (13-18 g) across all treatment groups using a Biro bandsaw model 44 (Marblehead, OH). All nuggets where tempered in a freezer to maintain a temperature between -1.1℃ and -3.3℃ before batter application. All nuggets where separated into groups of ten, identified, and group weights recorded prior to being placed in a Stein T-1 (Sandusky, OH) series applicator for batter placement. Batter mixture was mixed in a 50/50 water to batter ratio and a recirculation pump was used to prevent any settling out of batter during the process. Immediately following batter application, battered nuggets were processed through a Koppens PR400C-52 (Bakel, Holland) breading applicator; all nuggets were then weighed in the same groups of ten and weights were recorded. All treatment groups were fried in cottonseed oil obtained from Producers Cooperative Oil Mill (Oklahoma City, OK) at 177-204℃ for approx. 2.5 min. in a Heat and Control Fryer CF350ES (Pembrooke, NH). Nuggets were cooked to an internal temperature of 74℃; following thermal processing, all sets were cooled to room temperature for 30 min. and a final cooked weight of the same ten nuggets was obtained and recorded. Nuggets were then frozen at -23ºC and 24h were re-weighed for a frozen weight. After 30d of storage nuggets were reheated, weights were taken and recorded. Nuggets were reheated at 204℃ for 15 min., using instructions from packages of curr ent chicken nugget products available at retail facilities. Typical reheating conditions consisted of 1 min. per four nuggets on high setting in a microwave oven or 10-12 min. at 204℃ in a conventional oven. The conventional oven method was used on all nuggets for reheating.

Cooked Yield

Cooked yield measurements were taken for each group of ten (10) nuggets per treatment group for each replication. Cooked weights were taken after each of the following: raw nuggets being formed, following batter breading application, after frying and being allowed to cool for 30 min., after freezing for 24h, and after reheating following 30d of shelf life.

Color Analysis

Color measurements were performed using a Hunterlab Colorimeter. Color measurements were obtained on raw nugget batter during production (raw), and following nugget reheating (internal measurements). Objective measurements for L* absolute black (0) to absolute white (100), a* red (positive) to green (negative), b* yellow (positive) to blue (negative) were obtained.

Compositional Properties

Proximate composition was determined on all nugget formulations (raw and cooked). Fat, protein, and moisture percentages were determined utilizing standard AOAC procedures. Additionally, pH measurements were obtained on all cooked nugget formulations prior to obtaining proximate composition.

Textural Analysis

Texture Profile Analyzer (TPA) Analysis was determined using a TA-XT2I texture analyzer (Texture Technologies Corp. Hamilton, MA). Using a TA-42 blade 3mm thick and 7cm wide with a 45° chisel angle, nu ggets (n = 25) from each formulation were reheated using the microwave oven method previously mentioned. Nuggets were allowed to cool to room temperature for 45 min. to determine nugget firmness and obtain potential textural differences among formulations.

Sensory Evaluation

Sensory preference tests were performed on all treatment groups after one month in frozen storage (-23°C). A consumer panel consisting of faculty, staff, and students was utilized for this investigation. Nuggets were reheated at 204°C for 15 min., using instructions for conventional oven reheating currently on packages in retail facilities as described above. Panelists evaluated nuggets on the basis of visual appearance, flavor intensity, texture, juiciness, tenderness, and overall likeability. Panelists utilized a nine-point hedonic scale to rate each of the above mentioned categories. The categories were defined as follows: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, or 9 = like extremely. Panelists also evaluated nuggets for any detection of off-flavor using a three-point scale defined as follows: 1 = none, 2 = slightly noticeable, 3 = extremely noticeable.

Statistical Analysis

This study was analyzed as a 3 X 5 factorial design plus a control with 3 inclusion levels and 5 vegetable proteins. Data were analyzed using general linear models and the model included all main effects and their interaction. Least squares means were determined and separated if a significant model was identified (α = 0.05)

RESULTS AND DISCUSSION

Nugget Manufacturing

Raw nugget weights across all treatment levels showed control nuggets weighed significantly less (P < 0.05) than nuggets containing vegetable proteins and ATVP raw nuggets weighed more than (P < 0.05) all other nuggets containing vegetable proteins (Table 2). In Riaz (2005), it is stated that textured soy proteins hold water very tenaciously. The same proved true for all textured vegetable proteins in this study, as raw numerical weights were greater than the control, (containing no added vegetable protein). In 30-day reheated weights, control and ATVP nuggets were lighter (P < 0.05) compared to all treatment groups (Table 2). All vegetable proteins except ATVP nuggets showed a significant difference (P < 0.05) in retaining more of their initial total weight through the 30-day reheated weight than the control nugget (Table 2). Maningat *et al*. (1999) stated that, in processed meat products, the binding ability of wheat gluten at 1-13% levels contribute to high yields, low cooking loss, and good rehydration properties.

Within the interaction of percent protein and vegetable protein source for nuggets receiving batter and breading, the control nugget was significantly lower (P < 0.05) in weight than all other vegetable protein treatment levels (Table 3). While WP 30%, ATVP 20% & 30% nuggets showed a higher (P < 0.05) batter and breading weight compared to all other vegetable protein treatment levels and control nuggets (Table 3). Cooked weight for WP 30% nuggets was heavier (P < 0.05) than all other treatment groups, with the exception to ASP 10% nuggets

(Table 3). The control and ATVP 10% groups had the lowest cooked weight nuggets ($P < 0.05$), with the exception of the SRSP 20% groups (Table 3). Sorted by percent vegetable protein added to the formulation, frozen weight and 30-day reheated weight of control (0%) nuggets were significantly lower ($P < 0.05$) across all treatment levels (Table 4). Numerically, the 30% treatment level had the heaviest nugget weights followed by 20%, and the 10% nuggets were the lightest weight (Table 4). In the Gnanasambandam and Zayas (1992) study, beef and pork frankfurters utilizing wheat germ protein, corn germ, and soy protein, all three treatments showed a significant ($P < 0.05$) increase in water holding capacity and less cook loss when compared to both control groups containing no vegetable proteins. Thus, the nuggets weighed more and retained more water throughout the cooking, freezing, and reheating process. This was also evident in Riaz (2005) where beef patties incorporated with soy protein concentrate demonstrated higher numerical cook yields at 20, 30, and 40% incorporation levels when compared to an all beef patty, indicating that textured vegetable proteins improve cook yields and increased moisture retention. This remained evident within the current study as the control nugget throughout manufacturing consistently had the lowest weights, numerically, when compared to all other vegetable protein treatment levels. Maningat *et al*. (1999) also stated that wheat gluten at levels ranging from 3-80% added as an extender in restructured meat products provided benefits such as moisture retention, increased yields, and cooking stability.

Color Analysis

The 30%, 20%, and 10% nuggets made with textured wheat protein had a higher ($P < 0.05$) L* raw color value over all vegetable proteins and control, except the ASP 30% nugget (Table 5). All nuggets containing ATVP vegetable protein had the lowest ($P < 0.05$) raw L* value in comparison to other vegetable proteins and control nuggets (Table 5). The L* cooked value for WP 30% nuggets were significantly higher ($P < 0.05$) and ATVP 30% nuggets were significantly lower ($P < 0.05$) than all treatment groups (Table 5). Raw a* values were higher in control nuggets ($P < 0.05$) than all vegetable protein nuggets, while ATVP 30% and WP 30% nuggets had the lowest ($P < 0.05$) raw a* values (Table 5). Yet, for cooked a* values, ATVP 30% and SMXP 30% nuggets displayed a significantly higher ($P < 0.05$) value over all treatments and control, excluding SRSP 30% nuggets (Table 5). The ASP 10% nuggets were the only treatment to have cooked a* value below one, thus being the lowest ($P < 0.05$) of all treatments and control (Table 5). Raw b* values in the ASP 20% nuggets were higher ($P < 0.05$) than all treatments and control, excluding ASP 30% nugget, thus being closer to yellow in color (Table 5). Cooked b* values showed ATVP 30% nuggets to be significantly higher ($P < 0.05$) than all treatments and control. Cooked b* values in WP 10%, WP 20%, and SMX 10% nuggets were lower ($P < 0.05$), with SMX 10% being the lowest ($P < 0.05$) among all treatments and control (Table 5). According to Gnanasambandam and Zayas (1992) in regards to color in frankfurters, L* values were highest ($P < 0.05$) in control as compared to samples made with wheat germ, soy flour, and corn germ vegetable protein samples, a* values in control frankfurters were the highest ($P < 0.05$). Dogan *et al*. (2005) showed L* values for nuggets made with soy flour were numerically lower than all treatment levels of rice flour and control chicken nuggets. The a* values for the soy flour nuggets were always numerically higher than the control or rice flour nuggets and all b* treatment values were not significantly different ($P < 0.05$). Jackson *et al*. (2006) found no differences ($P < 0.05$) between rice flour and wheat flour chicken nuggets for L*, a*, or b* color values.

Compositional Properties

Chicken nuggets across all treatments showed no significant differences ($P < 0.05$) for fat, moisture or protein levels, therefore the two fat levels used where combined as a single control group throughout the study. The overall averages were: fat 10.27 ± 2.83, moisture 53.37 ± 3.31, and protein 15.67 ± 1.92. Das *et al*. (2008) found no significant differences ($P < 0.05$) for moisture or fat content in goat nuggets made with soy paste, soy granules, and the control. Dogan *et al*. (2005) also found no differences ($P < 0.05$) in moisture content of chicken nuggets made with soy flour and rice flour when compared to a control. Gnanasambandam and Zayas (1992) found no differences ($P < 0.05$) between wheat germ, soy flour, and control when used in a beef and pork frankfurter. Parks and Carpenter (1987) also found no differences ($P < 0.05$) among beef and pork frankfurters incorporated with multiple levels of soy flour, concentrate, and isolates in the area of moisture and protein. Berry and Binger (1996), when using konjac flour and carrageenan in pork nuggets, found no differences (P <

0.05) in moisture content when compared to the control pork nugget. Jackson *et al*. (2006) found that fried wheat flour chicken nuggets had a higher ($P < 0.05$) moisture and fat content than those incorporated with rice flour, however protein content in the same study showed no differences ($P < 0.05$).

The pH of chicken nuggets in control (0%) nuggets was lower ($P < 0.05$) than the 20% and 30% incorporation levels, but was similar to the 10% level (Table 6). Between the individual vegetable protein nuggets and control, pH of ASP and WP nuggets were significantly higher ($P <0.05$) than all treatments, excluding the SRSP nuggets (Table 6). Hung and Zayas (1992) stated that protein solubility or water retention generally increased with an increase in pH level, checked between pH of 5 and 8 when using corn germ, whey protein, or sodium caseinate in food products. Das *et al*. (2008) showed that the incorporation of soy paste and soy granules in goat nuggets numerically increased pH when compared to the control goat nugget.

Sensory Evaluation

Visual appearance of chicken nuggets was similar across all treatments with a range of 6.2 to 6.7 on a 9 point scale, however, the ATVP nuggets were scored lower for visual appearance ($P < 0.05$) among treatments excluding WP nuggets (Table 7). This was also seen in the L* values were ATVP nuggets received the lowest numerical scores (Table 5). Flavor profile of the nuggets was similar; ATVP 30% nuggets were significantly lower ($P < 0.05$) than SRSP 30% nuggets which were significantly lower ($P < 0.05$) than all treatments and control in flavor (Table 8). Juiciness was similar across all treatment levels as well, with

WP 30% nuggets being significantly higher (P < 0.05) than all treatment levels except WP 20% nuggets, the WP 30% nuggets received the only score over a 6 on the same scale (Table 8). Tenderness of WP 30% nuggets was higher (P < 0.05) than all treatments except WP 20% nuggets, and the ATVP 30% nuggets had the lowest score (P < 0.05) among all treatments and control (Table 8). The lower flavor score for the ATVP nuggets agrees with findings of previous studies and is a continued problem with soy flours as stated by Riaz (2005). Soy flours usually possess more pronounced bean-like flavor and cereal flavor compared to concentrates or isolates. In the Gnanasambandam and Zayas (1992) study, control and wheat germ frankfurters received the highest score for meaty aroma over soy flour and corn germ frankfurters, whereas soy flour and corn germ frankfurters received highest scores for off-flavors. Das *et al*. (2008) in a study with soy granule nuggets, soy paste nuggets and a control goat nugget documented no differences in appearance, and nuggets made with soy granules had the lowest numerical scores for flavor when compared to soy paste and control nuggets, which might be in part due to a bean-like flavor detected by panelists. Texture, overall likeability, and off-flavor expressed no measurable differences (P <0.05) in the sensory panels across all treatments and control, the averages for these attributes were: texture 5.50 ± 0.55, overall likeability 5.60 ± 0.81, and off-flavor 1.27 ± 0.17. All nugget scores were in the acceptable range across all treatment groups and control, on a 9 point scale. Perlo *et al*. (2006) found no significant differences (P < 0.05) in sensory attributes for color, appearance, or chewiness of washed mechanically deboned chicken or mechanically deboned chicken nuggets. Berry and Binger (1996) found konjac flour and carrageenan nuggets to be, numerically, slightly juicier than an all pork nugget, but the breaded chicken nugget was significantly ($P < 0.05$) juicier. Walsh *et al*. (2008) found that beef patties incorporated with 50% whey protein were rated higher ($P < 0.05$) for appearance, texture, flavor, and overall acceptability when compared to patties made with 50% textured soy flour (vegetable) protein.

Textural Analysis

The texture profile of all treatments was very similar, ATVP nuggets had the highest value ($P < 0.05$) among all other treatments (Table 9). Das *et al*. (2008) documented a significantly lower ($P < 0.01$) shear value for soy paste nuggets when compared to soy granule and control goat nuggets. Gnanasambandam and Zayas (1992) documented that beef and pork frankfurters made with wheat germ, soy flour, and corn germ showed no differences for shear force value. Patana-Anake and Foegeding (1985) stated that there were no significant differences in stability or textural changes among vital wheat gluten and soy protein concentrates used in a beef and pork meat batter. Yusof and Babji (1996) also found no differences ($P < 0.05$) among soy protein isolate and sodium caseinate used in a chicken bologna.

Conclusion

Vegetable proteins serve as a method to reduce formulation costs of chicken nuggets, as they are cheaper than lean chicken protein currently used. From a production standpoint, nuggets incorporated with vegetable protein have the ability to add weight to a uniform size product. Chicken nuggets incorporated with vegetable proteins were able to retain added weight throughout manufacturing, from initial raw weight, batter and breading, freezing, and the reheating process, as control nuggets were consistently the lowest in those categories. Vegetable proteins did not adversely affect fat, moisture, or protein levels, as no significant differences ($P > 0.05$) were found, therefore nothing is sacrificed in these areas when incorporated up to the 30% level. Consumer acceptability cannot be ignored when using vegetable proteins, all nuggets on average where deemed acceptable by panelists. Yet, differences among type of vegetable protein used showed differences in tenderness, juiciness, and flavor, but the wheat protein was preferred in the tenderness and juiciness categories. The 30% incorporation levels of ATVP and SRSP had the poorest flavor scores, similar to other studies utilizing soy proteins, as a bean-like flavor is often detected at higher usage levels.

Vegetable proteins show benefits in all areas and should be considered for use in chicken nuggets were cost reduction is important, particularly with food and transportation costs on the rise. The levels of usage need to be carefully considered, based on type of protein used, or if incorporating more than one vegetable protein into the formulation. The different vegetable proteins offer specific benefits, such as the individual cost will vary based upon the quality and type of vegetable protein used. Vegetable proteins can enhance chicken nuggets by adding weight, increased juiciness, tenderness, flavor, or even the possibility of using a health claim. These benefits are enough reason to include vegetable proteins in a chicken nugget. However, areas of concern noticed within the study which should be looked at on a company by company basis. The ability to incorporate a new ingredient into a formulation and manufacturing process will require adjustments to the processing flow. The vegetable proteins all had to be hydrated for a minimum of 30 minutes prior to being added to the formulation, they are very heavy when hydrated, utilize space in storage and on the manufacturing floor, of which is not always available. Further research could be performed to find optimum combinations of the various vegetable proteins, to maximize the benefits and improve the sensory attributes. Focusing on the biggest group of chicken nugget consumers, young children and the school lunch program to find what preferences are desired in a nugget, if they are different than currently thought and what usage level is most acceptable. Lastly, is it possible to get enough vegetable protein in a chicken nugget that meets the Food and Drug Administrations requirements to label it with the health claim they have approved and still be consumer acceptable.

Table 1. Formulation of high-fat and industry standard chicken nugget stratified by vegetable protein (%).

	Added vegetable protein[a], %				Added vegetable protein[a], %			
Ingredients	0[b]	10	20	30	0[c]	10	20	30
Chicken breast trim pieces	48.15	42.65	37.15	31.65	75.55	65.55	55.55	45.55
Chicken skins	39.40	34.90	30.40	25.90	12.00	12.00	12.00	12.00
Salt	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Water/ice	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20
Phosphate	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

[a]All vegetable proteins were added in the hydrated form
[b]0, served as a high fat nugget (39.40% fat), control
[c]0, served as an industry-standard (12% fat), control

Table 2. Least Squares Means ± SEM for nugget raw weight (g) and 30-day reheated weight (g) stratified by vegetable protein added to the formulation

Protein[a]	Raw weight, g	Reheated weight[b], g
CON[c]	141.66[g] ± 0.63	130.72[e] ± 1.93
ASP	147.43[e] ± 0.71	140.47[d] ± 0.96
ATVP	151.91[d] ± 0.27	134.07[e] ± 1.40
SMXP	146.60[ef] ± 0.40	138.12[d] ± 1.48
SRSP	147.83[e] ± 0.32	138.43[d] ± 0.95
WP	145.55[f] ± 0.87	140.59[d] ± 1.43

[a] ASP: Arcon soy protein concentrate, WP: textured wheat Protein, SRSP: Solae Response soy protein concentrate, ATVP: Arcon textured vegetable protein flour, SMXP: Supramax soy protein

[b] Reheated weight: nuggets were weighed following a 30-day frozen period (-23℃)

[c] Control, no vegetable protein added

[d, e, f, g] Mean, values in the same column, with different superscripts are significantly different ($P < 0.05$).

Table 3. Least Squares Means ± SEM for nugget batter & breading weight (g) and cooked weight (g) stratified by vegetable protein type and percent vegetable protein incorporation interaction added to the formulation

Protein Types [a]	Percent Incorporation	Batter & Breading weight, g	Cooked weight, g
CON [b]	0%	171.45^{k} ± 0.55	135.54^{j} ± 2.12
ASP	10%	177.91^{d} ± 0.70	147.36^{cd} ± 1.86
ASP	20%	177.51^{de} ± 0.84	147.14^{d} ± 1.71
ASP	30%	173.21^{j} ± 1.45	144.04^{efg} ± 1.84
ATVP	10%	176.64^{ef} ± 2.36	138.55^{j} ± 1.80
ATVP	20%	180.72^{c} ± 0.53	141.95^{hi} ± 2.64
ATVP	30%	180.69^{c} ± 0.46	144.33^{efg} ± 2.51
SMXP	10%	174.68^{ghi} ± 0.54	141.04^{hi} ± 2.66
SMXP	20%	177.39^{de} ± 1.26	143.87^{efg} ± 2.04
SMXP	30%	177.02^{de} ± 0.68	146.77^{d} ± 1.12
SRSP	10%	175.09^{gh} ± 0.95	144.70^{ef} ± 0.84
SRSP	20%	173.51^{ij} ± 1.65	140.32^{ij} ± 2.03
SRSP	30%	174.16^{hij} ± 2.14	142.71^{gh} ± 1.63
WP	10%	175.19^{gh} ± 1.10	141.34^{hi} ± 2.45
WP	20%	175.41^{fg} ± 2.25	145.89^{de} ± 1.43
WP	30%	179.73^{c} ± 0.57	149.11^{c} ± 1.32

[a] ASP: Arcon soy protein concentrate, WP: textured wheat protein, SRSP: Solae Response soy protein concentrate, ATVP: Arcon textured vegetable protein flour, SMXP: Supramax soy protein
[b] Control, no vegetable protein added
[c, d, e, f, g, h, I, j, k] Mean values, in the same column, with different superscripts are significantly different ($P < 0.05$).

Table 4. Least Squares Means ± SEM for cooked nugget frozen weight (g) and 30-day reheated weight (g) stratified by percent vegetable protein added to the formulation

Percent Protein	Frozen weight, g	Reheated weight[a], g
30%	144.25g[c] ± 0.84	140.18g[c] ± 0.93
20%	142.22g[cd] ± 0.94	138.71g[cd] ± 1.01
10%	140.62g[d] ± 1.08	136.12g[d] ± 1.11
0% [b]	134.22g[e] ± 2.10	130.72g[e] ± 1.93

[a] Reheated weight: nuggets were weighed following a 30-day frozen period (-23°C)
[b] Control, no vegetable protein added
[c, d, e] Mean values, in the same column, with different superscripts are significantly different ($P < 0.05$).

Table 5. Least Squares Means ± SEM for nugget raw and cooked L*, a*, b* values stratified by vegetable protein type and percent vegetable protein incorporation interaction added to the formulation

Protein Types[a]	Percent Incorporation	Raw L*[b]	Cook L*[b]	Raw a*[c]	Cook a*[c]	Raw b*[d]	Cook b*[d]
CON[e]	0%	70.70^{jk} ± 0.29	79.31^{g} ± 0.19	8.10^{f} ± 0.13	1.14^{o} ± 0.09	19.95^{lm} ± 0.15	18.56^{lm} ± 0.15
ASP	10%	67.62^{n} ± 0.31	77.90^{h} ± 0.15	6.83^{kl} ± 0.10	0.89^{p} ± 0.05	21.17^{h} ± 0.14	18.65^{lm} ± 0.13
ASP	20%	70.85^{j} ± 0.19	77.90^{h} ± 0.10	6.71^{lm} ± 0.08	1.16^{no} ± 0.08	21.92^{f} ± 0.12	18.97^{i} ± 0.13
ASP	30%	72.37^{gh} ± 0.22	76.87^{k} ± 0.17	6.24^{n} ± 0.10	1.46^{jk} ± 0.06	21.39^{fg} ± 0.21	18.81^{jk} ± 0.10
ATVP	10%	66.59^{p} ± 0.32	75.77^{l} ± 0.30	7.12^{hi} ± 0.16	1.52^{ij} ± 0.10	19.83^{lm} ± 0.33	20.31^{g} ± 0.19
ATVP	20%	66.99^{o} ± 0.35	75.89^{l} ± 0.21	6.78^{kl} ± 0.15	1.57^{hi} ± 0.08	20.73^{i} ± 0.25	20.34^{g} ± 0.21
ATVP	30%	67.15^{o} ± 0.34	74.74^{m} ± 0.30	6.05^{o} ± 0.14	1.72^{f} ± 0.11	21.20^{gh} ± 0.33	21.13^{f} ± 0.21
SMXP	10%	70.75^{jk} ± 0.21	77.89^{h} ± 0.19	6.90^{jk} ± 0.09	1.32^{l} ± 0.07	20.26^{j} ± 0.21	18.06^{o} ± 0.16
SMXP	20%	69.46^{l} ± 0.26	77.64^{i} ± 0.18	7.20^{h} ± 0.17	1.42^{k} ± 0.08	20.67^{i} ± 0.19	18.89^{ij} ± 0.14
SMXP	30%	68.98^{m} ± 0.31	76.91^{k} ± 0.23	6.81^{kl} ± 0.12	1.77^{f} ± 0.10	21.12^{h} ± 0.14	19.63^{h} ± 0.15
SRSP	10%	70.75^{jk} ± 0.19	77.91^{h} ± 0.22	7.04^{ij} ± 0.11	1.23^{mn} ± 0.10	19.76^{m} ± 0.16	18.52^{m} ± 0.18
SRSP	20%	69.91^{k} ± 0.27	77.30^{j} ± 0.27	7.09^{hi} ± 0.16	1.19^{no} ± 0.07	19.91^{lm} ± 0.22	18.68^{kl} ± 0.15
SRSP	30%	71.26^{i} ± 0.28	77.29^{j} ± 0.26	6.52^{n} ± 0.13	1.71^{fg} ± 0.08	20.02^{kl} ± 0.18	18.81^{jk} ± 0.15
WP	10%	72.14^{h} ± 0.36	79.35^{g} ± 0.26	7.44^{g} ± 0.19	1.24^{mn} ± 0.07	20.18^{jk} ± 0.22	18.34^{n} ± 0.12
WP	20%	72.64^{g} ± 0.35	79.35^{g} ± 0.20	6.64^{mn} ± 0.17	1.30^{lm} ± 0.06	20.03^{kl} ± 0.18	18.25^{n} ± 0.16
WP	30%	74.11^{f} ± 0.48	79.69^{f} ± 0.20	6.01^{o} ± 0.23	1.64^{gh} ± 0.08	20.02^{kl} ± 0.23	18.81^{jk} ± 0.16

[a] ASP: Arcon soy protein concentrate, WP: textured wheat Protein, SRSP: Solae Response soy protein concentrate, ATVP: Arcon textured vegetable protein flour, SMXP: Supramax soy protein

[b] L*: 0-100, where 0=Black, 100= White

[c] a*: positive= red, negative=green

[d] b*: positive= yellow, negative=blue

[e] Control, no vegetable protein added

[f, g, h, i, j, k, l, m, n, o, p] Mean values in the same column with different superscripts are significantly different ($P < 0.05$).

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Table 6. Least Squares Means ± SEM for cooked nugget pH stratified by percent protein or vegetable protein added to the formulation

Percent Protein	pH	Vegetable Protein[a]	pH
30%	6.51[c] ± 0.02	ASP	6.55[c] ± 0.26
20%	6.50[c] ± 0.02	WP	6.51[cd] ± 0.35
10%	6.43[cd] ± 0.01	SRSP	6.46[de] ± 0.34
0%[b]	6.36[d] ± 0.04	ATVP	6.45[e] ± 0.44
		SMXP	6.43[ef] ± 0.46
		CON[b]	6.36[f] ± 0.78

[a] ASP: Arcon soy protein concentrate, WP: textured wheat Protein, SRSP: Solae Response soy protein concentrate, ATVP: Arcon textured vegetable protein flour, SMXP: Supramax soy protein

[b] Control, no vegetable protein added

[c,d,e,f] Mean values, in the same column, with different superscripts are significantly different ($P < 0.05$).

Table 7. Least Squares Means ± SEM cooked nugget visual appearance (internal and external) stratified by vegetable protein added to the formulation

Vegetable Protein[a]	Visual Appearance[b]
CON[c]	6.78[d] ± 0.17
ASP	6.76[d] ± 0.06
ATVP	6.25[e] ± 0.12
SMXP	6.54[d] ± 0.10
SRSP	6.70[d] ± 0.09
WP	6.47[de] ± 0.08

[a] ASP: Arcon soy protein concentrate, WP: textured wheat Protein, SRSP: Solae Response soy protein concentrate, ATVP: Arcon textured vegetable protein flour, SMXP: Supramax soy protein
[b] Visual Appearance scale (1-9): 9= like extremely, 5= neither like nor dislike,1= dislike extremely
[c] Control, no vegetable protein added
[d, e] Mean values with different superscripts are significantly different ($P < 0.05$).

Table 8. Least Squares Means ± SEM for cooked nugget flavor, juiciness, and tenderness stratified by vegetable protein type and percent vegetable protein incorporation interaction added to the formulation

Protein Types[a]	Percent Incorporation	Flavor[b]	Juiciness[c]	Tenderness[d]
CON[e]	0%	5.80^{f} ± 0.23	5.44^{hij} ± 0.27	6.27^{ghi} ± 0.22
ASP	10%	5.99^{f} ± 0.12	5.69^{gh} ± 0.21	6.15^{hij} ± 0.20
ASP	20%	6.01^{f} ± 0.21	5.83^{g} ± 0.14	6.40^{gh} ± 0.18
ASP	30%	5.84^{f} ± 0.15	5.29^{ijk} ± 0.26	5.66^{l} ± 0.19
ATVP	10%	5.73^{fg} ± 0.07	5.24^{jkl} ± 0.14	5.63^{l} ± 0.17
ATVP	20%	5.57^{gh} ± 0.27	5.15^{kl} ± 0.34	6.20^{hij} ± 0.47
ATVP	30%	4.71^{k} ± 0.22	4.51^{l} ± 0.28	4.17^{m} ± 0.37
SMXP	10%	5.83^{f} ± 0.32	5.31^{ijk} ± 0.40	5.67^{l} ± 0.34
SMXP	20%	5.35^{i} ± 0.10	5.43^{ij} ± 0.08	5.95^{jk} ± 0.16
SMXP	30%	5.45^{hi} ± 0.35	5.90^{g} ± 0.09	6.38^{gh} ± 0.13
SRSP	10%	6.29^{f} ± 0.22	5.54^{h} ± 0.34	6.06^{ijk} ± 0.33
SRSP	20%	5.87^{f} ± 0.35	5.29^{ijk} ± 0.44	5.97^{jk} ± 0.44
SRSP	30%	5.10^{j} ± 0.22	5.27^{jk} ± 0.30	5.81^{kl} ± 0.34
WP	10%	5.49^{hi} ± 0.21	5.09^{kl} ± 0.25	5.59^{l} ± 0.30
WP	20%	5.76^{fg} ± 0.27	5.94^{fg} ± 0.22	6.53^{fg} ± 0.30
WP	30%	5.86^{f} ± 0.11	6.19^{f} ± 0.16	6.77^{f} ± 0.15

[a] ASP: Arcon soy protein concentrate, WP: textured wheat Protein, SRSP: Solae Response soy protein concentrate, ATVP: Arcon textured vegetable protein flour, SMXP: Supramax soy protein
[b] Flavor scale (1-9): 9= like extremely, 5= neither like nor dislike,1= dislike extremely
[c] Juiciness scale (1-9): 9= like extremely, 5= neither like nor dislike,1= dislike extremely
[d] Tenderness scale (1-9): 9= like extremely, 5= neither like nor dislike,1= dislike extremely
[e] Control, no vegetable protein added
[f, g, h, I, j, k, l, m] Mean values, in the same column, with different superscripts are significantly different ($P < 0.05$).

Table 9. Least Squares Means ± SEM (kg) for cooked nugget texture profile stratified by vegetable protein added to the formulation

Vegetable Protein[a]	Texture, kg
CON[b]	4.08[c] ± 0.27
ASP	4.13[c] ± 0.13
ATVP	4.77[b] ± 0.12
SMXP	4.00[c] ± 0.06
SRSP	3.98[c] ± 0.12
WP	4.03[c] ± 0.09

[a] ASP: Arcon soy protein concentrate, WP: textured wheat Protein, SRSP: Solae Response soy protein concentrate, ATVP: Arcon textured vegetable protein flour, SMXP: Supramax soy protein

[b] Control, no vegetable protein added

[c, d] Mean values with different superscripts are significantly different ($P < 0.05$).

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The optimization of five different vegetable proteins (Arcon soy protein concentrate [ASP], Arcon Textured Vegetable Protein flour [ATVP], Supramax soy protein [SMXP], Solae Response soy protein [SRSP], and textured wheat protein, {Wheatex WP]) at three usage levels (10%, 20%, and 30%) were compared to a control industry standard chicken nugget. All nuggets were made uniform shape and size to evaluate weights throughout manufacturing: raw, battered and breaded, cooked (fried), frozen, and reheated. Control nuggets had the lowest ($P < 0.05$) raw, frozen and reheated weights among all treatments. Cooked weights were heaviest ($P < 0.05$) for WP 30%, among all treatments, excluding ASP 10%. Compositional properties, fat, moisture, protein, and pH were all taken in duplicate. There were no differences ($P < 0.05$) for compositional properties, fat, moisture, and protein among treatments. The pH of nuggets showed control to have the lowest ($P < 0.05$) pH of percentage treatment levels, except 10%. Sensory evaluations were performed using a consumer sensory panel. All nuggets scored in the acceptable category, regardless of percentage treatment level. Flavor profile was similar among all treatments. However, ATVP 30% and SRSP 30% scored lowest ($P < 0.05$) among all treatments and control. Wheat Protein 30% scored highest ($P < 0.05$) for juiciness and tenderness compared to all treatments and control, except WP 20%. Texture, overall likeability, and off-flavor showed no differences ($P < 0.05$) among all treatments and control. Texture profile was analyzed and showed ATVP to have the highest numerical value among all treatments and control. Vegetable proteins had the ability to be incorporated into chicken nuggets for the purpose of reducing production costs, by adding and retaining weight throughout manufacturing, when compared to a control nugget. Sensory attributes are not affected below the acceptable range across all treatments, yet some treatments where preferred in particular areas such as juiciness and tenderness.

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