EFFECTS OF DRIED POTATO EXTRACT ON YIELD, SHELF STABILITY, AND SENSORY CHARACTERISTICS OF BEEF PATTIES, CHICKEN FRANKFURTERS, AND BEEF TOP ROUND

A Thesis

Presented in Fulfillment of the Requirements for the

Degree of Master of Science

with a

Major in Animal Science

in the

College of Graduate Studies

University of Idaho

by

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June 2015

AUTHORIZATION TO SUBMIT THESIS

This thesis of Matthew C. Colle, submitted for the degree of Master of Science with a Major in Animal Science and titled "Effects of Dried Potato Extract on Yield, Shelf Stability, and Sensory Characteristics of Beef Patties, Chicken Frankfurters, and Beef Top Round," has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

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ABSTRACT

My objective was to compare three potato extracts, X-TEND™ (potato extract), X-TEND™ M (potato extract with mustard), and X-TEND™ S (potato extract with sodium acid pyrophosphate), incorporated into processed meats with a control and common industry binders. Cook yield increased ($P < 0.0001$) in beef patties from potato extract treatments compared to Textured Vegetable Protein (TVP) and Control. In retail display patties, X-TEND™ M decreased discoloration ($P < 0.0001$) and lipid oxidation ($P < 0.0001$) relative to all other treatments. Each potato extract treatment outperformed Control and TVP in juiciness ($P < 0.001$), and were generally higher in texture and overall acceptability. Consumers scored chicken frankfurters with X-TEND™ M higher for texture than Control, TVP, and Corn Syrup Solids frankfurters ($P < 0.05$). Precooked top round roasts injected with potato extracts had reduced lipid oxidation compared with Control roasts ($P < 0.05$). Potato extracts were most beneficial in beef patties.

ACKNOWLEDGEMENTS

I am thankful for the financial support of both Basic American Foods and the Idaho Beef Council with funding by the Beef Checkoff. We are also grateful for the assistance Basic American Foods and AB Foods provided in procuring product.

Personally, I have to thank my major professor Dr. Matt Doumit for setting me up with Basic American Foods on a research project and guiding me through my research and report writing. Also, I am thankful for the assistance Mr. Ron Richard provided to me whether it was sharing his processing expertise, hands-on help, or making the meat lab available for my research. Thank you to Dr. Denise Smith for sharing ideas and knowledge she gained from similar research.

I am especially grateful for the help fellow graduate student and brother, Michael Colle, gave me, from organizing and running experiments to running statistics and just helping me see the big picture. Also, thanks to all the graduate students for their unwavering support. The lab crew that made all of this possible was a hardworking, dedicated group made up of Sara Gray, Zachary Reynolds, Hailey Sutton, James Nasados, and Will Loucks. Thank you to the whole lab crew, including Ron’s crew, and the whole Vandal community, including AVS faculty, staff, and students.

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LIST OF ABBREVIATIONS

AMSA	American Meat Science Association
CIE	Commission Internationale de l'Eclairage
CSS	Corn Syrup Solids
FSIS	Food Safety and Inspection Service
IMPS	Institutional Meat Purchase Specifications
LSM	Least Squares Means
M	X-TEND™ M (potato extract with mustard)
MDA	Malondialdehyde
S	X-TEND™ S (potato extract with sodium acid pyrophosphate)
SAS	Statistical Analysis Software
SEM	Standard Error of the Mean
TBARS	Thiobarbituric Acid Reactive Substances
TPA	Texture Profile Analysis
TVP	Textured Vegetable Protein (Soy Flour)
USDA	United States Department of Agriculture
WBSF	Warner-Bratzler shear force
X	X-TEND™ (potato extract)

CHAPTER 1: REVIEW OF LITERATURE

Binders

Binders are used in processed meat products to improve yield and enhance structural, storage, and sensory characteristics (Ray et al., 1981; Pena-Ramos and Xiong, 2003; Yang et al., 2001; Raut et al. 2011). Binders are typically proteins and carbohydrates (Yang et al., 2001). Protein extracted from whey, soy, wheat, and casein are used in ground and emulsified meat products, while corn, oat, potato, and maltodextrin are common sources for carbohydrate binders. The addition of binders improves water holding capacity of meat products, resulting in less water loss during cooking and improved product cooking yield in beef patties (Ray et al., 1981), pork patties (Pena-Ramos and Xiong, 2003), chicken patties (Raut et al. 2011), and low-fat beef and pork frankfurters (Crehan et al., 2000). USDA regulations allow fat and water to be substituted for one another in cooked sausage so long as their total does not exceed 40% of the meat product (USDA, 1988). Water is often added to reach the maximum limit in ground and comminuted meat products to reduce production cost. In low (~10%) fat products where water is added at up to 30%, binders are used in order to maintain acceptable product quality (Yang et al., 2001). The USDA Food Safety and Inspection Service (FSIS) limits the use of binders based on their nutrient make-up and the designated label of the final product. For instance, starch binders in precooked meat patties and cooked sausage are limited to 3.5% of the product finished weight, while protein binders cannot exceed 2% (USDA, 1995).

Velioglu et al. (2010) used one to 11% textured soy protein in hamburger patties that varied in fat (10-30%) and water (6.5-23.5%). They found that soy concentrations have a strong negative correlation to water and fat loss of patties. Ray et al. (1981) also reported a positive correlation of cook yield to concentration of soy added to beef patties. Crehan et al. (2000) showed that maltodextrin improves cook yield of frankfurters with 5, 12, and 30% fat. Furthermore, binders are typically less expensive than the portion of the meat block they replace (Gujral et al., 2002). Processors are able to minimize production costs by maximizing the usage of binders.

In addition to increasing product yield, binders may improve shelf stability by reducing lipid oxidation (Ray et al., 1981; Pena-Ramos and Xiong, 2003). Shelf stability is measured during product storage at refrigerator or freezer temperatures. Lipid oxidation leads to deterioration in shelf stability and hence, meat quality (Rhee, 1989; Singh, 1996). Lipid oxidation is controlled in processed meats through the addition of antioxidants (Giese, 1996). Soy has been shown to contribute antioxidant properties to processed meat products (Ray et al., 1981; Pena-Ramos and Xiong, 2003). However, research is continually being conducted on non-allergen plant-based protein or carbohydrate sources that act as binders and antioxidants to enhance water binding and storage stability of emulsified frankfurters (Yang et al., 2001) and ground meat patties (Naveena et al., 2008; Katsanidis et al., 2001).

Water holding capacity, juiciness, and texture

Water holding capacity is the ability of meat to retain moisture through storage and processing. Water holding capacity is determined by measuring fluid loss. Applying no force and/or applying thermal force are two common methods for measuring moisture loss. Applying no force is a time consuming, but accurate, method that uses gravity and produces drip or purge losses. Measuring cooking loss is the final and most essential method since most meat is cooked before it is consumed (Honikel and Hamm, 1994).

Water-holding capacity of fresh meat is affected by rate of pH decline early postmortem and ultimate pH. High temperature combined with rapid pH decline early postmortem causes proteins to denature, or unfold. Denaturing of proteins combined with a pH that falls closer to its isoelectric point or net zero charge of ~5.25 allows opposite charges on the proteins to attract each other causing myofibrillar space to decrease along with water holding capacity (Huff-Lonergan and Lonergan, 2005).

Composition of meat has also been shown to influence water-holding capacity. Fat, in addition to water content, is positively correlated to cooking loss in goat meat patties (Gujral et al., 2002) and emulsified meatballs (Hsu and Chung, 1998; Serdaroglu, 2006). In contrast, Crehan et al. (2000) reported an increase in cook loss of frankfurters with 5 and 12% fat compared to frankfurters with 30% fat. Furthermore, low (10%) fat frankfurters had purge of 11.0%, compared with 5.9% purge of high (22%) fat frankfurters after 4 weeks of storage in a vacuum package at 0°C (Yang et al., 2001).

Juiciness was defined by Blumer (1963) as the liquid detectable when chewing a bite of meat, and is therefore measured by sensory analysis. Many factors influence juiciness, including water-holding capacity, degree of doneness, fat content, storage conditions, and processing (Winger and Hagyard, 1994). In fresh meat, juiciness decreases as degree of doneness increases (Parrish et al., 1973; Kregel et al., 1986). In beef patties, Serdaroglu (2006a) reported that both juiciness and texture scores increased as fat levels increased from 5% to 10 and 20%. However, perception of juiciness does not correlate with water holding capacity in certain processed meats (Chang and Carpenter, 1997). Increased cook yields and decreased purge leads to reduced juiciness in frankfurters (Chang and Carpenter, 1997).

Juiciness affects mouth feel and texture as well (Dransfield et al., 1984; Hutchings and Lillford, 1988). Texture profile analysis is commonly used to mechanically measure textural parameters such as hardness, cohesiveness, chewiness, and springiness (Tan et al., 2006). However, Hutchings and Lillford (1988) described texture as a dynamic process that takes place in the mouth, therefore requiring consumer sensory analysis similar to evaluation of juiciness. Yang et al. (2001) noted a negative correlation between trained panelist juiciness scores of frankfurters and mechanical hardness, which positively correlated to panelist scores for textural parameters, firmness, springiness, and cohesiveness.

Schnell et al. (1972) determined emulsion viscosity of frankfurters by measuring the shear press force it takes to extrude the sample through a 3.8 mm orifice. Frankfurters with greater water binding have increased emulsion viscosity resulting in greater shear press values. However, improved emulsion stability correlated with lower consumer juiciness scores. The decrease in juiciness scores can be attributed to less unbound water detected during chewing, as opposed to the amount of moisture retained during cooking. Increased unbound water in frankfurters results in increased expressible moisture, which was measured by calculating the weight lost of a sample compressed to 25% of its original height for 30 seconds. Softness or excessive juiciness are the main qualities that lead to reduced overall consumer acceptability of frankfurters (Yang et al. 2001).

Currently, attention is being focused on lower cost processed meat products made from poultry meat with added water. Lower fat levels, less saturated fat, and hence, increased moisture lead to decreased product hardness (Sams and Diez, 1991). Chang and Carpenter (1997) added water at 10, 20, and 30% to chicken frankfurters with low fat: 15.28, 14.37, and 13.44%, respectively. Increasing water from 10 to 30% led to increased expressible moisture from 6.59 to 11.49% and decreased sensory hardness from 7.05 to 5.32 (Chang and Carpenter, 1997). Frankfurters with scores lower for sensory juiciness had higher texture scores and ultimately, greater overall acceptability (Yang et al. 2001).

Binders improve water holding capacity

Binders are important ingredients in processed meats for improving water holding capacity (Velioglu et al., 2009). Water levels in meat products are maximized, resulting in a need for binders to maintain quality and structural characteristics (Yang et al., 2001). Soy protein, a known allergen, is a commonly used binder in the meat industry today. The protein structure of soy contributes water binding ability in processed meat products. Soy protein reduces shrinkage due to fat and moisture loss during cooking. Velioglu et al. (2010) showed soy levels have a strong negative correlation to water and fat loss of patties. Raut et al. (2011) reported cooking loss, including moisture, protein, and fat, was decreased in chicken patties containing soy, rice, and lentil flour. Cooking yield was improved from 82.13% in control patties to 86.30, 84.80, and 85.26% with the addition of 5% soy, rice, or lentil flour, respectively.

Ray et al. (1981) incorporated soy into beef patties at 0, 2.5, 4.0, 5.5, and 6.7%. The soy was hydrated to four times its weight before addition into ground beef, resulting in hydrated soy levels of 0, 10, 16, 21, and 26%. Despite higher moisture in patties containing 26% hydrated soy compared to patties containing 0, 10, 16, and 21% hydrated soy, cooking yield remained greater at 73.0% compared to patties containing 0, 10, 16, and 21% hydrated soy, which had cooking yields of 63.4, 66.1, 68.1, and 69.9%, respectively. These results clearly demonstrate soy's ability to bind added water. Soy's water binding ability was also evident in beef frankfurters (Lacomte et al., 1993) as well as chicken (Raut et al., 2011) and pork (Pena-Ramos and Xiong, 2003) patties, an indication soy is an effective binder in a variety of meat systems.

Soy, in addition to other protein binders, provides improved water binding, texture, and emulsifying properties to processed meat. Water absorption and binding is contributed to meat products by hydrogen bonding of water by hydrophilic amino acids of soy. Furthermore, hydrophobic side chains of soy protein interact with fat in frankfurter type products to maintain a fat emulsion. The amphiphilic nature of soy proteins allows for binding of the protein at the oil-water interface. Intramolecular disulfide bonds, along with stearic interaction of protein molecules to prevent fat coagulation, act to stabilize emulsions. Gelation occurs when proteins denature into unfolded polypeptides during processes such as cooking and reform a gel matrix. The gel is formed through disulfide bonds, hydrogen bonds, and/or hydrophobic interations that result in improved water binding or emulsion stability (deMan, 1999).

Pena-Ramos and Xiong (2003) found a further reduction in cooking loss when soy protein isolate and whey protein isolate were hydrolyzed prior to addition in ground pork patties. Addition of soy protein isolate and whey protein isolate to patties reduces cooking loss from 21.5% in the control to 17.4 and 15.1% respectively. However, addition of 2% hydrolyzed soy or whey protein isolate reduces cooking loss over the intact protein by 10.9

and 12.9%, respectively. The peptide cleavage during protein hydrolysis exposes more charged, polar amino and carboxylic acid groups to interact with water (Pena-Ramos and Xiong 2003).

Along with protein binders, carbohydrate binders such as corn starch (Yang et al., 2001) and dehydrated potato extract (Katsanidas et al. 2001) improve water holding capacity. Potato extract with mustard was incorporated into low (9.3%) fat comminuted beef patties at 0, 0.6, 1.2, and 1.8% and cooked to 68-70°C, resulting in yields of 80.50, 83.33, 82.00, and 85.33%, respectively. Patties made with 0.6 and 1.8% potato extract had greater cooking yield than patties made with no potato extract. Frankfurters with 10% fat and either 4% soy protein, corn starch, or wheat gluten, or 1% carrageenan had purge levels ranging from 3.8 to 7.8% over 4 weeks of vacuum packaged storage at 0°C, while control frankfurters had 11% purge. Waxy maize starch frankfurters had 3.8% purge, which was lowest among all low fat frankfurter treatments (Yang et al., 2001).

Potato starch, along with other plant starches, improves water binding and viscosity of processed meat products. Starch is made up of two polymers, amylopectin, a branched polymer, and amylose, a linear polymer. Potato starch consists of mainly amylopectin with ranges of amylose reported from 17 to 27% (Waterschoot et al., 2015). In a water to starch ratio of at least 2:1, swelling of amylopectin during cooking opens up the structure of starch to interact with water through hydrogen bonding. In addition, phosphates in potato starch contribute to additional water absorption. Potato granules are large in diameter and generally swell in the presence of water and gelatinize during cooking at relatively low temperatures of 59 to 67°C (Waterschoot et al., 2015). Moreover, long amylose polymers of potato starch make the incidence of gel retrogradation low in potato starch (deMan, 1999), making potato starch an effective water binder in precooked, refrigerator stored beef patties (Katsanidis et al., 2001).

Improved water binding is evident in frankfurters made with sodium caseinate from an observed increase in emulsion viscosity, which leads to lower taste panel scores for juiciness (Schnell et al., 1972). Raut et al. (2011) reported chicken patties made with soy flour have greater juiciness scores than patties made with rice and lentil flour, but were no different than control patties. In addition, patties made with soy flour also received higher consumer texture scores than all other treatments. However, in both high (22%) and low (10%) fat frankfurters, 5% added binder (1% isolated soy protein and 4% potato starch) resulted in lower consumer juiciness scores, improved texture, and greater overall acceptability than control frankfurters (Yang et al. 2001). Texture profile analysis (TPA) characteristics for the high and low fat frankfurters were similar to each other as long as they contained 1% isolated soy protein and 4% potato starch (Yang et al., 2001). Low fat (10%) frankfurters made with modified waxy maize starch, isolated muscle protein, and isolated soy protein performed as well as the high fat control for TPA and consumer texture, juiciness, and overall acceptability (Yang et al. 2001). Low fat frankfurters with carrageenan or wheat gluten performed least like high fat frankfurters in TPA and consumer sensory analysis. Lack of firmness and excess juiciness in these products resulted in decreased acceptability (Yang et al. 2001).

Shelf stability

Shelf stability is the ability of meat to maintain desirable product appearance, aroma, and safety during storage. Shelf stability is important because meat purchasing decisions are influenced heavily by product color (AMSA, 2012; Mancini and Hunt, 2005). Consumers relate discoloration to old, less wholesome product (Faustman and Cassens, 1990). Color can be affected pre-slaughter by factors such as genetics, muscle fiber type, age, diet, and stress. Post-slaughter factors such as pH, muscle type, water holding capacity, microbial growth, storage temperature and time, packaging, and lighting can also influence color (AMSA, 2012). Faustman and Cassens (1990) also noted a correlation between lipid oxidation and color deterioration due to myoglobin oxidation.

When meat is temperature abused, microorganisms in meat can multiply quickly with the potential to cause spoilage and foodborne illness. Sofos (1994) reported that microbial contamination of meat can result from unsanitary conditions antemortem and during harvest. Initial microbial contamination, along with factors that control or enhance microbial growth such as ingredients, processing, storage temperature, packaging, and handling can affect spoilage microorganisms and therefore product quality. An ingredient can serve as a nutrient for a certain bacteria, but act as an inhibitor for another (Sofos, 1994). Nitrite is an essential ingredient in curing processed meats. Although the exact mechanism is not known, nitrite is generally recognized as an antimicrobial. Still, nitrite has not been shown to effectively control certain pathogenic bacteria such as *Salmonella* and *Escherichia coli O157:H7* (Sindelar and Milkowski, 2011). Refrigeration can deter mesophilic bacterial growth since they thrive at temperatures above refrigeration; however, psychrotrophic bacteria grow at refrigeration temperatures. During storage, off odors and flavors, discoloration, softening in texture, and slime formation can result from microbial enzymatic activity (Sofos, 1994). Alakali et al. (2010) reported a continuous increase in microbial growth in cooked beef patties at 0, 7, 14, and 21 days of storage at 4°C. The 21 day bacterial count was 4.82 log CFU/g, which is still below the spoilage point of meat: 10^6 CFU/cm^2 (Jensen et al., 2003).

Lipid oxidation is often the cause of deterioration in meat quality (Rhee, 1989; Singh, 1996). Lipid oxidation can lead to discoloration, purge, off-odor, and off-flavor in meat. Furthermore, Karpinska et al. (2001) reported lipid oxidation relates with consumer detection of rancid off-flavor in meatballs and results in decreased overall sensory scores. Aldehydes, ketones, alcohols, and acids are oxidative products that result in off-odors and off-flavors of meat. These products result when unsaturated fatty acids lose a hydrogen atom to form unstable free radicals that bind oxygen. The resulting reactive peroxyl group propagates additional lipids to auto-oxidize and eventually form hydroperoxides, which get broken into aldehydes, ketones, alcohols, and acids. Exposure of unsaturated fatty acids to oxygen and metal pro-oxidants such as iron speeds up oxidation (Giese, 1996).

Measurement of thiobarbituric acid reactive substances (TBARS) is a common method used to quantify lipid oxidation. The method measures milligrams malondialdehyde (MDA) per kilogram of meat. MDA results from lipid oxidation and is reactive with thiobarbituric acid, forming a pink chromogen that absorbs strongly at 532 to 535 nm. Oxidative rancidity is first detectable at approximately 1 mg MDA/kg (Baker et al., 1972). The TBARS rapid, wet method is the quickest method for determining lipid oxidation since it allows for several samples to be processed in one day. However, the lack of a distillation step allows for sugars present in the sample to produce a yellow chromogen that absorbs strongly at 453 nm and therefore, hinders absorbance at 532 to 535 nm (AMSA, 2012).

Wu and Brewer (1994) noted a strong correlation between lipid oxidation measured by thiobarbituric acid reactive substances (TBARS) and sensory rancid odor scores. The precooking of meat products is important to the convenience food and food service industry as it ensures proper cooking and reduces the potential for foodborne illness (Katsanidis et al., 2001). However, oxidative rancidity becomes an issue. Precooked meats are challenged with warmed over flavor (WOF) caused by lipid oxidation (Sato and Hegarty, 1971; Pearson et al., 1977). Disruption of cell membranes occurs during cooking (Karpinska et al., 2001) and exposes unsaturated fatty acids to oxygen and iron, promoting oxidation during storage and reheating (Sato and Hegarty, 1971). In cooked beef patties, lipid oxidation increased over refrigerator storage of 21 (Alakali et al., 2010) and 30 days (Dzudie et al., 2004).

Oxidative reactions are further cultivated through meat grinding, a process that exposes unsaturated fatty acids of the lipid membrane to metal ionic pro-oxidants (Devatkal and Naveena, 2010). Grinding also leads to increased oxygen consumption rate (Madhavi et al. 1993), which correlates to metmyoglobin formation (Ledward, 1985). Salt is added to processed meat to improve flavor, extract myofibrillar proteins, and reduce water activity. However, salt also accelerates oxidation in raw goat meat patties (Devatkal and Naveena, 2010), frozen ground pork (Lee et al., 1997), cooked chicken patties (O’Neill et al., 1999), and fresh ground beef (Torres et al., 1988). Two and 4% salt in ground beef increases lipid oxidation after 96 hr of refrigerator storage from 0.11 and 0.12 mg MDA/kg in 0 and 0.5% salt ground beef, respectively, to 0.49 and 0.51 mg MDA/kg, respectively. Over 96 hr storage, salt levels of 0.5, 2, and 4% increased metmyoglobin from 23.22% in control ground beef to 32.53, 36.07, and 39.17, respectively (Torres et al., 1988). Lee et al. (1997) showed antioxidant enzyme activity is reduced in ground pork in the presence of salt. In addition, sodium chloride inhibits free iron from binding heme pigments, leaving more iron to promote lipid oxidation (Kanner et al., 1991).

Antioxidants are often added to meat products to limit oxidative damage. Synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisol (BHA) act as free-radical scavengers by contributing hydrogen from the phenolic hydroxyl group to the fat free radical (Giese, 1996). Although lipid oxidation is deterred by BHA and BHT (Naveena et al., 2008; Shahidi et al., 1987), BHA possesses a weak carcinogenic effect (Hirose et al., 1997). In addition to free radical scavengers, antioxidants, such as vitamin C, can act as reducing agents by transferring hydrogen atoms to oxygen radicals. Chelating agents can be used along with antioxidants to bind pro-oxidative metal ions. Phosphate and citric acid are two examples of chelating agents used in meat products (Giese 1996). Interest in natural antioxidants has triggered effective use in processed meats of vitamin E and C (Mitsumoto et al., 1991), tea catechins (Tang et al., 2001), rosemary extract, mustard (McCarthy et al., 2001), pomegranate, (Naveena et al., 2008) and several other plant and spice extracts. Vitamin E, a natural phenolic compound, and vitamin C reduce both lipid oxidation and metmyoglobin formation in ground beef (Mitsumoto et al., 1991). Ground beef was mixed with 6 mg/kg d-α-tocopherol, 500 mg/kg sodium ascorbate, or a combination of the two and displayed for 7 days. Control ground beef increased in TBARS from 1.18 mg MDA/kg on day 1 to 4.34 mg MDA/kg on day 7 and in surface metmyoglobin from 24.2 to 57.6%, respectively. Mitsumoto et al. (1991) stated the Vitamin E concentration in the ground beef was low compared with 50 to 800 ppm seen in similar studies. However, it was still enough to reduce lipid oxidation and surface metmyoglobin to 42.2% on day 7 compared to the control. Vitamin C in ground beef is even more effective than vitamin E by further limiting day 7 TBARS and metmyoglobin percentage to 1.52 and 26.7%, respectively. Patties with vitamin E and C hindered oxidation throughout refrigeration with day 7 TBARS of 0.26 mg MDA/kg (Mitsumoto, 1991).

Mustard, which contains phenolic compounds, reduced TBARS in raw pork patties on days 3 and 6 of retail display at 4°C, with day 6 TBARS at 0.65 mg MDA/kg compared to 1.54 mg MDA/kg in the control. However, TBARS in cooked patties were greater in mustard patties on day 9 of storage compared to control patties (McCarthy et al., 2001). Of the 11 antioxidants tested by McCarthy et al. (2001), only 0.25% tea catechins decreased day 9 TBARS in both frozen and raw pork patties from control patties.

Vitamin E reduced lipid oxidation in ground beef to a greater extent when added in the steer diet compared to addition postmortem into the ground beef. Mitsumoto et al. (1993) evaluated beef patties with similar vitamin E levels from either endogenous or exogenous addition. Patties with endogenous vitamin E reduced day 9 TBARS from 6.91 to 0.58 mg MDA/kg and decreased day 9 metmyoblobin formation from 86.8% to 40.4% compared to patties without added dietary vitamin E (Mitsumoto et al., 1993).

Nitrite is used in cured meat products in order to extend shelf life by suppressing lipid oxidation. Nitrite acts as an antioxidant by forming nitric oxide which reacts with heme proteins to form nitriso- and nitrosyl compounds, which act as free radical scavengers. Nitric oxide also chelates non-heme iron (Sindelar and Milkowski, 2011). After 21 days of refrigerator storage, cooked ground beef with nitrite had lower TBARS than control ground beef (0.42 to 0.54 mg MDA/kg versus 2.83 mg MDA/kg, respectively) (Igene et al., 1985).

Myoglobin is an iron containing heme protein in meat that is the major contributor to meat color. The iron forms six bonds, including four with the nearby pyrrole nitrogen and one with the proximal histidine, leaving one for the ligand. The bound ligand determines meat color (Mancini and Hunt, 2005). The three main chemical forms for meat color are oxymyoglobin, deoxymyoglobin, and metmyoglobin. Oxymyoglobin results in a bright cherry red color when oxygen is the bound ligand. When no ligand is bound, the form is deoxymyoglobin and a purple color results. Metmyoglobin is caused by the oxidation of ferrous iron (+2) to the ferric state (+3). The result is a brown color that is unappealing to consumers (Faustman and Cassens, 1990). In addition to the use of antioxidants, a method used to combat metmyoglobin formation utilizes low levels of carbon monoxide packaging to ensure the sixth iron bond is bound to CO, resulting in carboxymyoglobin and a bright cherry red color (Mancini and Hunt, 2005).

There are two methods used for color evaluation as recognized by the AMSA Guidelines for Meat Color Evaluation (2012). Visual appraisal is the method used by consumers and it sets the standard for instrumental measurement. Despite variation in color perception among individuals, color standards are used to assure consistency and validity of visual appraisal. A colorimeter or spectrophotometer is the instrument used to provide objective color measurements, and is effective at tracking color changes over time. The instrument converts reflected light to Commission Internationale de l’Eclairage (CIE) L* (lightness), a* (redness), and b* (yellowness) values. L* values make up a spectrum of black to white ranging from 0 to 100, respectively. Values for a*, red to green, and b*, yellow to blue, range from -100 to +100, respectively (AMSA, 2012).

Binders act as antioxidants to improve shelf stability

Proteins used as binders, such as soy, are reported to have antioxidant properties in addition to water binding capabilities (Wu and Brewer, 1994). Wu and Brewer (1994) extracted the phenols from soy protein isolate and incorporated the soy protein isolate antioxidant (SPIA) solution into ground beef at 300 and 900 ppm. The metal ionic pro-oxidant, Fe^{+2}/ Fe^{+3}, was added to the ground beef to catalyze lipid oxidation over the 24 hr storage period at 4°C. Sensory rancid odor scores increased in ground beef with 0 and 300 ppm SPIA from 0 to 16 hr. Odor scores for ground beef with 900 ppm SPIA did not change over the 24 hr storage. Rancid odor scores positively correlated with TBARS. Ground beef with 900 ppm SPIA had lower TBARS at 16 and 24 hr than control and 300 ppm ground beef (Wu and Brewer, 1994). When used in raw pork patties at inclusion rates similar to those of natural antioxidants such as mustard and rosemary, 0.1% soy protein isolate does not decrease TBARS relative to control patties over 9 days retail display at 4°C (McCarthy et al., 2001). In a similar preliminary study, McCarthy et al. (2001a) found soy protein does reduce TBARS from 0.514 mg MDA/kg in raw control pork patties to 0.320 mg MDA/kg.

Beef patties were stored at 0°C for 10 days and no difference in lipid oxidation over time from day 0 to 10 was observed. However, patties with any level of hydrated soy (10-26%) reduced TBARS values relative to patties containing no soy (Ray et al., 1981). Pena-Ramos and Xiong (2003) incorporated soy protein isolate and whey protein isolate, as well as enzyme hydrolysates of these protein isolates into pork patties. TBARS were reduced by both of the intact proteins as well as each protein hydrolysate over 7 days of refrigerator storage compared to control patties. Soy patties exhibit greater antioxidant activity than whey patties, which likely is due to the phenolic compounds present in soy (Pena-Ramos and Xiong, 2003). Four percent whey protein reduced TBARS from 2.44 mg MDA/kg in raw control patties to 0.76 mg MDA/kg. Additionally, whey increased a* values throughout 9 day display (McCarthy et al. 2001). McCarthy et al. (2001a) contradicted these findings, reporting no difference in TBARS or a* values between patties with whey protein and control patties.

A number of plant extracts are being studied for their antimicrobial and antioxidant strength in precooked and fresh meats. Bambara groundnut seed flour at 5% inclusion reduces microbial growth of cooked beef patties over 21 day refrigerator storage from 4.82 in control patties to 3.84 log CFU/g (Alakali et al., 2010). The reduction in microbial growth may be due to the decrease in day 21 pH from 6.11 in control patties to 5.70 in patties with bambara groundnut (Alakali et al., 2010). Five, 10, and 15% plum puree (34.29% dry matter), when incorporated into low (5.6 to 5.9%) fat beef patties, increases a* values from 10.5 in control patties to 12.7, 11.9, and 14.4%, respectively (Yildiz-Turp and Serdaroglu, 2010). Over a 45 day storage period at -18°C, plum puree patties reduced TBARS from 0.75 mg MDA/kg in control patties to 0.66 mg MDA/kg or less. Although free radical scavenging activity exists due to the presence of polyphenols, plum puree is not a water binder. Addition of plum puree negatively affects cooking yield in beef patties, reducing it from 79.6 to 76.6% or less (Yildiz-Turp and Serdaroglu, 2010). Dehydrated potato extract possess phenolic compounds, which contribute to a strong antioxidant system. Precooked beef patties containing potato extract with mustard were measured for TBARS on day 7 of storage at 1°C. Patties with no potato extract measured 5.93 mg MDA/kg, which is greater than patties containing 0.6, 1.2, and 1.8% potato extract, which had TBARS values of 2.09, 1.05, and 0.86 mg MDA/kg, respectively (Katsanidas et al. 2001).

Non-allergen plant-based protein or carbohydrate sources that act as binders and antioxidants need to be evaluated for their ability to enhance water binding and storage stability in processed meat products. Potato extracts, in particular, have yet to be evaluated in frankfurters and fresh patties.

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CHAPTER 2: DRY POTATO EXTRACTS IMPROVE WATER HOLDING CAPACITY, SHELF LIFE, AND SENSORY CHARACTERISTICS OF FRESH AND PRE-COOKED BEEF PATTIES

Abstract

The objective was to examine shelf stability, cooked product yield, and sensory characteristics of beef patties that had no binder (Control) or incorporated soy flour (TVP) or one of three dry potato extracts: X-TEND™ (potato extract), X-TEND™ M (potato extract with mustard), or X-TEND™ S (potato extract with sodium acid pyrophosphate). In retail display patties, all binders decreased discoloration and lipid oxidation compared to Control, and X-TEND™ M was superior ($P < 0.0001$) to all other treatments. Cooking yield was higher ($P < 0.0001$) in patties containing potato extracts compared with patties containing TVP, which had higher yield than Control patties. Beef patties with potato extracts were juicier ($P < 0.001$) than Control and TVP patties, and had higher ($P < 0.001$) overall acceptability than Control patties. We conclude that potato extracts are effective binders for use in fresh or pre-cooked beef patties because they improve retail shelf life, cooked product yield, and sensory characteristics.

Introduction

Binders are utilized in processed meat products to improve yield, shelf stability, and sensory characteristics (Ray et al., 1981; Pena-Ramos and Xiong, 2003; Yang et al., 2001; Raut et al. 2011). Binders generally improve product yield (Ray et al., 1981; Pena-Ramos and Xiong, 2003), and consequently reduce product cost as well as improve the meat’s consistency and texture or mouth-feel. Water levels are often maximized in products such as pre-cooked beef patties to further minimize product cost. Binding agents are especially common in these products in order to maintain acceptable product juiciness and texture (Yang et al., 2001; Chang and Carpenter, 1997).

Processing and pre-cooking meat increases lipid oxidation in the product (Sato and Hegarty, 1971). Oxidation continues through refrigerator storage of 21 (Alakali et al., 2010) and 30 days (Dzudie et al., 2004) in precooked beef patties. Soy protein, often referred to as textured vegetable protein (TVP), is commonly used as a binder in precooked beef patties (Ngadi et al., 2001). Soy is also effective at reducing lipid oxidation in raw beef patties (Ray et al., 1981) and cooked pork patties (Pena-Ramos and Xiong, 2003). In addition, soy improves cooking yield in beef (Ray et al., 1981), chicken (Raut et al., 2011), and pork (Pena-Ramos and Xiong, 2003) patties. USDA FSIS classifies soy as an allergen. Non-allergenic binding agents that provide desirable product attributes would be beneficial for the meat processing industry and consumers.

Research is continually being conducted on non-allergen plant-based protein or carbohydrate sources that act as binders and/or antioxidants to improve yield, shelf stability, and sensory characteristics of the meat product (Yang et al., 2001; Naveena et al. 2008; Katsanidis et al., 2001). Katsanidis et al. (2001) reported significant improvements in cooking yield when potato extract is used as a binder at 1.8% in beef patties. Moreover, potato extract is effective in preventing lipid oxidation and therefore, can improve shelf life (Katsanidis et. al. 2001). Faustman et al. (2010) reported a link between lipid oxidation and reduced shelf life. A consumer’s decision when purchasing meat is heavily influenced by the color of fresh meat, and discolored meat is seen as old and less wholesome (Faustman and Cassens, 1990).

The objectives of this study were to evaluate the water holding capacity, shelf stability, and sensory characteristics of fresh and cooked beef patties that incorporated TVP or one of three dry potato extracts.

Materials and Methods

Preparation of product

Beef shoulder clod was coarse ground through a 0.9525 cm plate and subsequently fine ground through a 0.3175 cm plate. The ground product was ~15% fat as determined by a Hobart ground beef portable fat percentage measuring kit (Hobart Corporation, Troy, OH). Ground beef was divided into five treatments: Control, TVP (Uncolored ¼, Legacy (2000-10N), Product Code: 0500140, Lot Number: 043350, Excalibur Seasoning, Perkin, IL), X-TEND™ ((X) potato extract, Item 207085, Basic American Foods (BAF), Blackfoot, ID), X-TEND™ M ((M) potato extract with mustard, Item 207087, BAF), or X-TEND™ S ((S) potato extract with sodium acid pyrophosphate, Item 207086, BAF). Treatments consisted of 10 lb ground beef, and 1% salt, 15% water, 0.2% onion granules, and 2% of the designated binder. Ingredients were added as a percentage of the meat block. Each treatment batch was mixed for two and a half minutes in a DMX 50 mixer (Daniels Food Equipment, Parkers Prairie, MN) and then formed using a Patty-O-Matic 220A patty former (Patty-O-Matic Inc., Farmingdale, NJ) into 1.5875 cm-thick patties weighing 151.2 g each. Batches were the experimental units. Two trials were conducted with three batches of each treatment per trial. Three patties from each batch were analyzed for all parameters.

Patties were designated for fresh retail display for four days or were cooked on the day of formulation and frozen for 21 to 52 days. Patties designated for fresh retail display were placed in white Styrofoam trays, overwrapped with oxygen permeable PVC film (Koch Industries, Inc. #7500-3815; Wichita, KS), and displayed in a glass-fronted retail display case (Model GDM-69, True Manufacturing Co., O'Fallon, MO) at 2°C for 4 days. The display case was equipped with natural white Hg 40W lights, and the average light intensity was 409 lux. The beef patties designated for frozen storage were cooked on a clam shell grill (Model QS12, Taylor Company, Rockton, IL) set at a depth of 14 mm with the bottom plate at 143°C and the top plate at 154°C for 155 seconds to an average endpoint temperature of 74.4°C as monitored by hypodermic temperature probes (Omega Engineering Co., Stamford, CT) coupled with a 12-channel scanning thermocouple thermometer (Digi-Sense, Cole-Parmer Instrument Co., Vernon Hills, IL). Patties were frozen individually on trays at -20°C and stored in Great Value resealable freezer bags. After frozen storage, patties were reheated for 20 minutes in a conventional oven at 176.7°C. See Table 2.1 for final internal temperature. During cooking and reheating, patties from each treatment were placed in different grill and oven locations to account for potential differences in temperature.

Water holding capacity

Patty weights were recorded before and after cooking and storage to determine percent cook yield (percent cook yield = cooked weight / raw weight * 100) and percent storage loss, respectively. Additionally, weights were taken before and after reheating to establish percent reheated yield.

Retail Color

At least two hours after patty formation, two objective color measurements per patty were taken using a Hunter MiniScan EZ (Restin, VA). This represented day 0 of retail display, and subsequent color measurements were taken on days 1, 2, 3, and 4. The Hunter MiniScan was equipped with a 25 mm-diameter measuring area and a 10° standard observer. The instrument was set to illuminant A and Commission Internationale de l'Eclairage (CIE) a* (redness) values were recorded. Calibration of the machine was carried out each day by measuring against black and white calibration tiles. Subjective discoloration was scored by two evaluators on each day of retail display following American Meat Science Association (AMSA) Meat Color Measurement Guidelines (AMSA, 2012). To avoid potential effects due to display case location, patties were rotated after each measurement.

Lipid oxidation

Thiobarbituric acid reactive substances (TBARS) were analyzed on days 0 and 4 of retail display and day 0 after cooking and day 21 of frozen storage following the protocol provided in Appendix D (AMSA, 2012).

pH

Patty pH was measured on day 0 after patty formation. A portable pH meter (Model SevenGo, Mettler Toledo, Woburn, MA) equipped with an InLab SolidsPro puncture-type electrode was used to measure pH. The pH meter was calibrated each day using standard pH 4.0 and 7.0 buffers.

Sensory analysis

With regard to human subject participation in the consumer panel, the University of Idaho Institutional Review Board certified this project as Exempt.

Patties designated for sensory analysis were cooked and frozen for 51 or 52 days. Immediately prior to being served, patties were reheated in a conventional oven at 177.7°C to an internal temperature of 71.1°C. A panel of 60 consumers rated patties for overall acceptability, texture, juiciness, and flavor using a 9-point scale (9 = like extremely, like texture extremely, extremely juicy, and like flavor extremely, respectively; 1= dislike extremely, dislike texture extremely, extremely dry, and dislike flavor extremely, respectively). Each panelist evaluated one 2.54 cm x 2.54 cm x patty thickness (~1.27 cm) sample from each of five experimental treatments.

Statistical analysis

Data were analyzed using the Mixed Model procedure of the Statistical Analysis System. Batches served as the experimental units ($n = 3$). Color measurements were analyzed as repeated measures. Differences in least squares means (LSM) were compared by the DIFF option. P-values of ≤ 0.05 were considered statistically significant and p-values ≤ 0.10 were considered trends in the data. Data for trials 1 and 2 were combined when no difference in trial was observed.

Results

Binders improve water holding capacity

Beef patties made with potato extracts had greater percent cook yield than those made with TVP ($P < 0.0001$), which were superior to Control patties in both experiments ($P < 0.01$)

(Figure 2.1). In Trial 1, S patties had a greater cook yield than M patties ($P < 0.05$), whereas in Trial 2, both X and S patties had a greater cook yield than M patties ($P < 0.05$). Endpoint cooking temperatures were not different between treatments (data not shown). Differences in percent cook yield of patties after 4 days of retail display ($P < 0.0001$) were consistent with day 0 percent cook yield (Table 2.1). Fluid loss during 21 days of frozen storage of cooked patties as well as during 4 days of retail display for fresh patties did not differ among treatments (Table 2.1). Percent reheated yield of patties made with X and M was greater than TVP and Control patties ($P < 0.05$) (Table 2.1). Patties made with TVP reached a higher endpoint temperature than the three potato extract treatments ($P < 0.05$) (Table 2.1) though patties from all treatments were reheated for the same time and temperature, and were represented equally in all oven locations. There was a negative correlation ($r = -0.87$) between reheated yield and temperature ($P < 0.0001$).

Binders improve retail color

Discoloration scores did not differ on day 0 among treatments (Figure 2.2). On day 1, patties made with S discolored less than Control patties ($P < 0.05$), and the remaining treatments were not different from either patties made with Control or S. On day 2, patties made with M, S, or TVP showed less discoloration than Control patties ($P < 0.001$); patties made with TVP did not differ from potato treatments. On day 3, Control patties discolored to a greater extent than all other treatments ($P < 0.0001$), and discoloration of patties made with X was greater than the other two potato extract treatments ($P < 0.01$), but was no different than patties made with TVP. TVP patties discolored to a greater extent than M patties ($P < 0.01$), while S patties were not different from either TVP or M. Discoloration on day 4 was least in M patties ($P < 0.0001$). S and TVP patties were less discolored than X ($P < 0.01$), which showed less discoloration than Control patties ($P < 0.0001$). Trial 2 differences were similar (data not shown). Representative patties on day 4 of display are illustrated in Figure 2.3.

In objective measurement of beef color, positive a* values are associated with product redness. Day 0 a* values of S patties were greater than those of the Control and X patties ($P < 0.05$) (Figure 2.4). S patties also had higher a* values than X, Control, and TVP patties on day 1 of retail display ($P < 0.05$). M patties had higher a* values than Control patties on day 1 ($P < 0.05$) and Control, X, and S patties on day 2 ($P < 0.05$). By days 3 and 4 of retail display, patties made with M had higher a* values than all other treatments ($P < 0.001$) and Control patties were less red (lower a*) than all treatments ($P < 0.0001$). Trial 2 differences were similar (data not shown).

Binders reduce lipid oxidation

On day 0 of retail display, TBARS were less for patties made with M than patties made with Control, TVP, or X ($P < 0.05$) (Table 2.2). M remained lower than all other treatments on day 4 ($P < 0.001$). In fact, TBARS of patties made with M on day 4 did not differ from day 0 TBARS of the other four treatments. After 4 days of retail display, TBARS in S and TVP patties were not different from each other, but were less than X patties ($P < 0.01$), which was less than Control patties ($P < 0.01$). All binder treatments provided a reduction in lipid oxidation compared with Control patties.

Cooked patties made with M and S had lower initial TBARS values than Control patties ($P < 0.05$) (Table 2.3). X and TVP patties also had lower TBARS than Control on day

0 in Trial 1 ($P < 0.05$), but were not different than other treatments in Trial 2. After 21 days of frozen storage, M and S had the lowest TBARS ($P < 0.05$). TBARS values for M and S patties on day 21 were not different than those of Control and X patties on day 0 and did not increase from day 0 in Trial 2. While TVP and X patties did not differ from each other, both treatments had lower TBARS values than Control patties after 21 days of storage.

pH

Patties made with TVP had a higher pH than all other treatments in each Trial ($P < 0.01$) (Table 2.1), while patties made with S were lower in pH than Control patties in Trial 2 ($P < 0.05$).

Potato extracts improve consumer panel scores

Consumer acceptability was greater in all potato extract treatments versus Control patties ($P < 0.001$) (Table 2.4). Acceptability of patties made with M was also greater than that of TVP patties ($P < 0.001$), while X patties tended to have greater acceptability than TVP patties ($P = 0.09$). Patties made with TVP also trended towards greater acceptability than Control patties ($P = 0.08$). Texture was more desirable in M patties than TVP and Control patties. S patties also exhibited more desirable texture than Control patties ($P < 0.05$) and tended to be more desirable than TVP patties ($P = 0.06$). Texture of X patties did not differ from other treatments. Juiciness scores were superior in all patties made with potato extracts compared to patties made with TVP or no binder ($P < 0.0001$). The latter two did not differ from each other. No difference among treatments existed for consumer perception of flavor. Table 2.5 shows at least 79% of consumer panelists were willing to purchase pre-cooked patties made with potato extracts. Only 63.8 and 55.9% of consumer panelists were willing to purchase TVP and control patties, respectively. The trait least liked in control and TVP patties was juiciness. The most commonly consumed form of beef as voted by 68.2% of the panelists was ground (Table 2.6). Of the 60 panelists, 33 eat beef between two and four meals a week and 19 eat beef between five and seven meals a week.

Discussion

Incorporation of potato extracts into beef patties resulted in greater cooked product yield compared with Control and TVP patties. Katsanidis et al. (2001) found similar improvements in cooking yield compared to control patties when potato extract with mustard is incorporated at 1.8% into lower fat (9.3%) comminuted beef patties. Potato starch consists of mainly amylopectin with ranges of amylose reported from 17 to 27% (Waterschoot et al., 2015). In a water to starch ratio of at least 2:1, swelling of amylopectin during cooking opens up the structure of starch to interact with water through hydrogen bonding. Potato starch gelatinizes at 58-66°C, which is below the endpoint cooking temperature (Waterschoot et al., 2015) Moreover, long amylose polymers of potato starch make the incidence of gel retrogradation low in potato starch (deMan, 1999).

In the current study, TVP patties improved cooking yield relative to control patties. Similar increases in yield were found with 2.5% soy protein in beef patties (Ray et al. (1981) and 2% soy protein isolate in pork patties (Pena-Ramos and Xiong, 2003). Pena-Ramos and Xiong (2003) noted enzyme hydrolysis of soy further improves water binding ability and cooking yield by exposing more charged, polar amino and carboxylic groups to interact with water. No previous study has compared potato extract to TVP in meat patties. However, Raut et al. (2010) found soy flour improves cooking yields compared to rice and lentil flour.

Ngadi et al. (2001) found finer TVP binders such as soy protein flour increase porosity in cooked patties, which can affect heat transfer. The use of fine textured soy flour in the current experiment may have contributed to increased porosity and faster reheating rates.

Color stability is essential for retailers to market fresh meat products to consumers (Faustman and Cassens, 1990). Patties with potato extracts or TVP outperformed control patties in both visual and objective color. Little research has been done evaluating binder effects on raw meat patty color over a period of refrigerator storage or retail display, and no research was found on visual discoloration scoring of such products. McCarthy et al. (2001) found 4% whey protein improves redness of raw pork patties throughout refrigerator storage of nine days. The improvement in redness scores may be due to free radical scavenging activity of whey peptides (Peng et al. 2009). In a similar study, McCarthy et al. (2001a) noted no difference in a* values between patties made with whey protein or 0.1% soy protein and control patties over 6 days of refrigerator storage, although soy numerically improved redness. The current study used 20 times the TVP used by McCarthy et al (2001 and 2001a), so any positive effect soy has on redness during retail display was elevated.

In the current experiment, S and TVP reduced lipid oxidation to a similar extent in patties during retail display. TVP at 2.5% was previously shown by Ray et al. (1981) to reduce oxidation of raw beef patties when stored for ten days at 0°C. Wu and Brewer (1994) used the phenol extracts from soy protein isolate at 900 ppm to reduce 24 hr oxidation in ground beef challenged with the pro-oxidant, Fe^{+2}/ Fe^{+3}. Oxidation in ground meat with TVP is limited by oxidative free radical scavenging activity of the phenolic compounds in TVP and possibly by TVP chelating Fe^{+2} and Fe^{+3}(Wu and Brewer, 1994). Pena-Ramos and Xiong

(2003) also show TVP is an effective antioxidant during seven days of refrigerator storage of pre-cooked pork patties.

In the present study, M reduced lipid oxidation more than all other treatments. Discoloration is related to lipid oxidation (Faustman et al., 2010). As a result, M was also superior to all treatments in improving redness and reducing discoloration. Katsanidis et al. (2001) also reports a decrease in TBARS of precooked beef patties made with potato extract and mustard over one week of refrigerator storage. The reduction in lipid oxidation of patties made with M compared to X patties can be attributed to the antioxidant properties of mustard, which contain a variety of phenolic acids and hence, free radical scavenging activity (Fang et al. 2008). McCarthy et al. (2001) observed a decrease in lipid oxidation in pork patties made with mustard compared to control patties over 9 days of retail display. However, under the same display conditions, mustard-containing pre-cooked patties had greater TBARS than control patties and days 3 and 9, a result that contrasts the current results. Sodium acid pyrophosphate contributes the strong antioxidant activity to S. Phosphates act as chelating agents that bind pro-oxidative metal ions, limiting catalysis of oxidation (Giese, 1996). In the current study, the base potato product, X, performed as well as TVP in reducing lipid oxidation of frozen patties; an indication that phenols are active in potatoes as well (Katsanidis et al., 2001). The lower TBARS values in precooked, frozen patties versus fresh patties can be attributed to reactions induced by cooking that convert malondialdehyde into other oxidative substances (Utrera et al., 2014).

Higher pH typically correlates to improved water holding capacity (Huff-Lonergan, 2002). In the present study, TVP patties had a higher pH but lower cook yield than patties made with potato extracts. Furthermore, sodium acid pyrophosphate contributed to a lower pH in patties made with S, but maintained the highest cook yield due to phosphates hydrophilic negatively charged oxygen atoms interacting with water. Yildiz-Turp and Serdaroglu (2010) found a reduction in both pH and cooking yield when plum puree was incorporated in beef patties. Likewise, an increase in pH correlated to an increase in cooking yield when the protein binder, bambara groundnut seed flour, is added to beef patties (Alakali et al. 2010). On the other hand, Naveena et al. (2006) found another protein binder, finger millet flour, to reduce pH, but improve water holding capacity. These findings, along with the current findings, demonstrate changes in pH are not a prerequisite for binders to improve water holding capacity.

As expected with improved water holding capacity, potato patties were rated higher for juiciness than TVP and control patties, and were also generally rated higher in texture and overall acceptability by consumer panelists. Soy flour incorporated in into chicken patties was found to improve cooking yield, juiciness, and overall acceptability relative to rice and lentil flour patties and improve texture over rice, lentil, and control patties (Raut et al., 2011).

Oxidative rancidity is first detectable at approximately 1 mgMDA/kg (Baker et al., 1972). An increase in lipid oxidation correlates to detectable rancid flavors in beef sensory analysis (Campo et al. 2006). However, the current study found lipid oxidation did not lead to differences in consumer perception of flavor. Onion’s antioxidant properties (Park et al., 2008) could have limited oxidation enough to prevent prevalent off-flavor of the control. Also, the flavor contributed to the patties by the onion granules may have masked off-flavors.

Overall, beef patties containing potato extracts were rated similarly for sensory characteristics.

Conclusion

Binders, including potato extracts and TVP, can be used to improve water holding capacity and retail shelf life of fresh and precooked beef patties. Potato extracts can also improve juiciness, texture, and overall acceptability of precooked patties. All three potato extracts were similar for sensory attributes of beef patties. Likewise, all potato extracts tested increased cooking yield relative to TVP, a traditional industry binder. M exhibited the most persistent antioxidant activity for maintenance of desirable fresh meat color. Use of non-allergenic potato extracts as binders in fresh and precooked beef patties has obvious benefits relative to TVP.

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Tables and Figures

Table 2.1

Characteristics of beef patties

Treatment	Control	TVP[5]	X[6]	M[7]	S[8]	SEM
Percent retail fluid loss[1]	0.94	1.11	1.07	1.04	1.11	0.04
Percent cook yield day 4[2]						
Trial 1	68.3^{a}	70.4^{b}	73.1^{d}	71.6^{c}	72.0^{c}	0.3
Trial 2	69.0^{a}	71.0^{b}	73.3^{cd}	72.5^{c}	73.6^{d}	0.3
Percent fluid loss day 21[3]						
Trial 1	1.54	1.8	1.79	1.53	1.58	0.1
Trial 2	2.09	2.03	2.11	1.99	2.11	0.1
Percent reheated yield[4]						
Trial 1	90.5^{a}	91.5^{ab}	93.0^{c}	92.8^{c}	92.4^{bc}	0.4
Trial 2	88.9^{a}	89.5^{a}	90.2^{b}	90.6^{b}	89.4^{a}	0.4
Reheated temperature (°C)						
Trial 1	67.2^{ab}	68.6^{a}	61.5^{c}	59.3^{c}	62.9^{bc}	0.17
Trial 2	71.7^{b}	76.9^{a}	70.7^{b}	71.4^{b}	71.5^{b}	0.17
pH						
Trial 1	5.71^{a}	5.77^{b}	5.72^{a}	5.70^{a}	5.69^{a}	0.01
Trial 2	5.74^{b}	5.77^{c}	5.73^{ab}	5.73^{ab}	5.71^{a}	0.01

[1] Percent retail fluid loss = (1 - Day 4 Weight/Day 0 Weight)*100

[2] Percent cook yield day 4 = Cooked Weight/Raw Weight*100

[3] Percent fluid loss day 21 = (1 - Day 21 Weight/Day 0 Weight)*100

[4] Percent reheated yield = Reheated Weight/Cooked Weight*100

[5] Textured vegetable protein (soy flour)

[6] X-TEND™ (Potato extract)

[7] X-TEND™ M (Potato extract with mustard)

[8] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

[a-d] Means with different superscripts within a row differ ($P < 0.05$)

Table 2.2

Lipid oxidation (TBARS[1]) of fresh beef patties

Treatment	Day 0	Day 4
Control	0.62^{b}	1.66^{e}
TVP[2]	0.48^{b}	0.85^{c}
X[3]	0.51^{b}	1.33^{d}
M[4]	0.27^{a}	0.56^{b}
S[5]	0.41^{ab}	0.98^{c}
SEM	0.07	0.07

[1] TBARS = mg malondialdehyde/kg meat

[2] Textured vegetable protein (soy flour)

[3] X-TEND™ (Potato extract)

[4] X-TEND™ M (Potato extract with mustard)

[5] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

$^{a\text{-}d}$Means with different superscripts differ ($P < 0.05$)

Table 2.3

Lipid oxidation (TBARS[1]) of cooked beef patties subjected to frozen storage

	Trial 1		Trial 2	
Treatment	Day 0	Day 21	Day 0	Day 21
Control	0.54^{c}	1.07^{e}	0.42^{bc}	0.89^{d}
TVP[2]	0.33^{a}	0.76^{d}	0.30^{ab}	0.43^{bc}
X[3]	0.40^{ab}	0.78^{d}	0.32^{ab}	0.52^{c}
M[4]	0.33^{a}	0.47^{bc}	0.26^{a}	0.31^{ab}
S[5]	0.29^{a}	0.46^{bc}	0.26^{a}	0.30^{ab}
SEM	0.04	0.04	0.04	0.04

[1] TBARS = mg malondialdehyde/kg meat

[2] Textured vegetable protein (soy flour)

[3] X-TEND™ (Potato extract)

[4] X-TEND™ M (Potato extract with mustard)

[5] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

[a-d] Means within a Trial with different superscripts differ ($P < 0.05$)

Table 2.4

Sensory analysis by consumer panelists[1] of beef patties

Treatment	Acceptability	Texture	Juiciness	Flavor
Control	5.5^{a}	5.7^{a}	4.9^{a}	5.7
TVP[2]	6.1^{ab}	5.9^{ab}	5.3^{a}	6.1
X[3]	6.6^{bc}	6.2^{abc}	6.5^{b}	6.2
M[4]	6.8^{c}	6.6^{c}	6.4^{b}	6.5
S[5]	6.6^{bc}	6.5^{bc}	6.6^{b}	6.4
SEM	0.2	0.3	0.2	0.2

[1] n=60. Scale, 9 = like extremely, extremely juicy, and like flavor extremely, respectively; 1= dislike extremely, extremely dry, and dislike flavor extremely, respectively.

[2] Textured vegetable protein (soy flour)

[3] X-TEND™ (Potato extract)

[4] X-TEND™ M (Potato extract with mustard)

[5] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

[a-c] Means within columns with different superscripts differ ($P < 0.05$)

Table 2.5
Consumer preferences of beef patties

	Control		TVP		X		M		S	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Like most[1]										
Flavor	22	44.9	29	55.8	17	35.4	26	46.4	25	47.2
Juiciness	12	24.5	12	23.1	22	45.8	21	37.5	23	43.4
Texture	15	30.6	11	21.2	9	18.8	9	16.1	5	9.4
Like least[2]										
Flavor	14	25.9	14	25.5	18	41.9	15	30.6	18	36.7
Juiciness	25	46.3	22	40.0	5	11.6	8	16.3	13	26.5
Texture	15	27.8	19	34.5	20	46.5	26	53.1	18	36.7
Off flavor[3]										
Yes	17	28.3	16	27.1	15	25.9	15	25.0	15	25.4
No	43	71.7	43	72.9	43	74.1	45	75.0	44	74.6
Purchase[4]										
Yes	33	55.9	37	63.8	46	79.3	49	81.7	47	79.7
No	26	44.1	21	36.2	12	20.7	11	18.3	12	20.3

For 1 to 4, consumers were asked:

1. IF APPLICABLE, please circle the trait you liked most about this product. flavor, juiciness, or texture/mouth feel
2. IF APPLICABLE, please circle the trait you liked least about this product. flavor, juiciness, or texture/mouth feel
3. OFF-FLAVOR: This is based on your ability to detect an off-flavor of the sample: NO/YES
4. CONSUMER SATISFACTION: Would you be willing to purchase this product? NO/YES

Table 2.6
Demographics of beef patty consumer panelists

	n	%
Age		
18-19	8	13.3
20-29	31	51.7
30-39	6	10.0
40-49	8	13.3
50+	7	11.7
Gender		
Male	27	45.0
Female	33	55.0
Beef meals/wk[1]		
0 to 1	5	8.2
2 to 4	33	54.1
5 to 7	19	31.2
8+	4	6.6
Most consumed[2]		
Ground	45	68.2
Roast	1	1.5
Steak	18	27.3
Other	2	3.0

For 1 and 2, consumers were asked:
1. Please indicate the number of meals a week in which you consume beef: 0-1, 2-4, 5-7, or 8+
2. Please indicate the form in which you most commonly consume beef: ground, roast, steak, or other

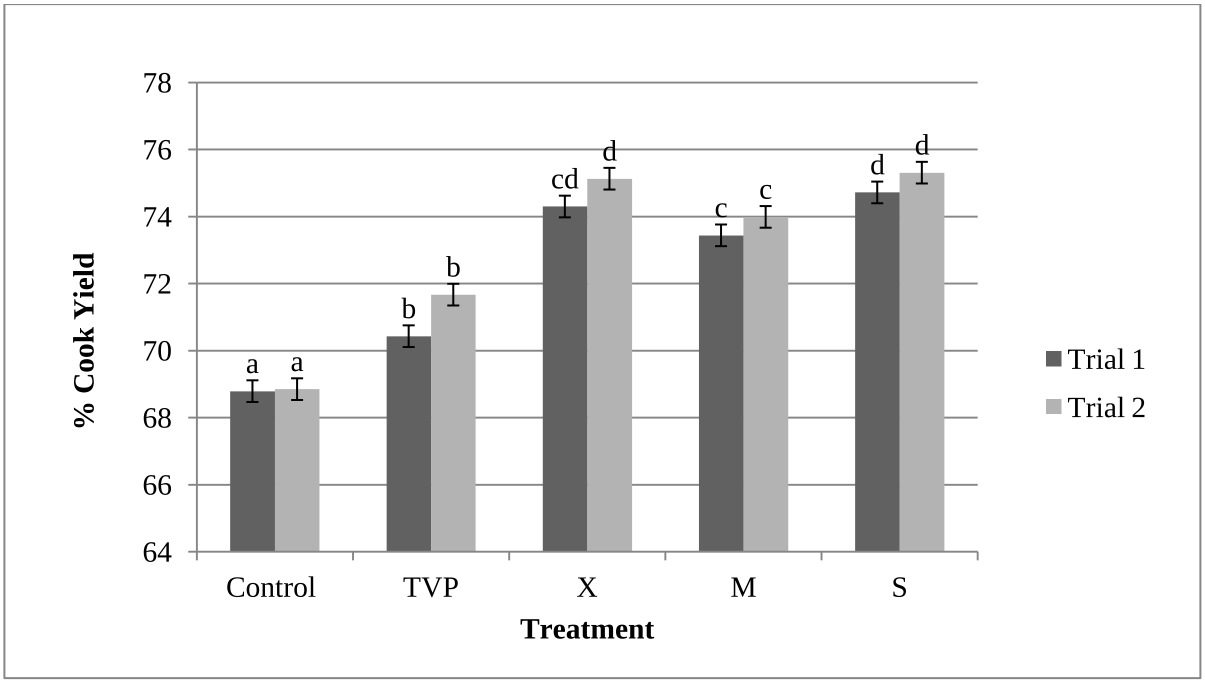

Figure 2.1. Binders increase percent cook yield in beef patties. Patties were made with Control (no binder) or 2% TVP (soy flour), X ((X-TEND™) potato extract), M ((X-TEND™ M) potato extract with mustard), or S ((X-TEND™ S) potato extract with sodium acid pyrophosphate). Trial 1 and 2 each included three batches per treatment, and three patties from each batch were weighed before and after cooking to 71.1°C on a clam shell grill (percent cook yield = cooked weight / raw weight X 100). The least squares means of percent cook yield are shown for each treatment. Data from trial 1 and 2 are shown separately because a difference in trial was observed. Values within experiments with different superscripts differ ($P < 0.05$). The error bars indicate ± standard error of the mean.

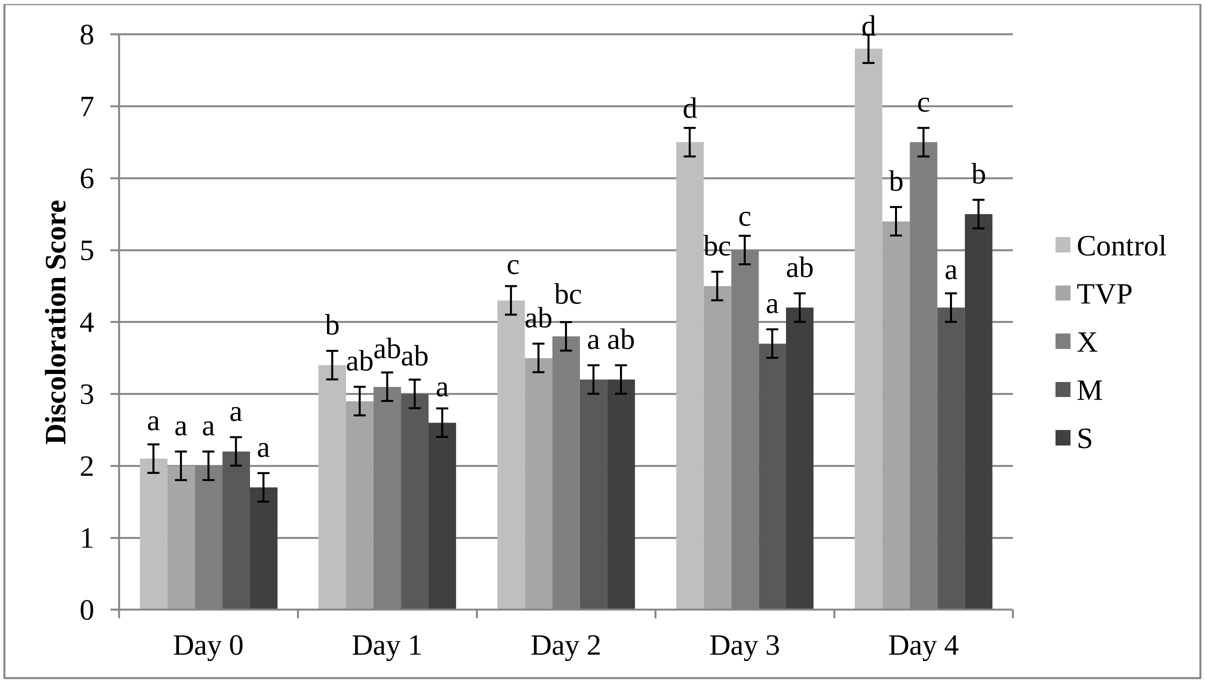

Figure 2.2. Binders decrease beef patty discoloration. Patties were made with Control (no binder) or 2% TVP (soy flour), X ((X-TEND™) potato extract), M ((X-TEND™ M) potato extract with mustard), or S ((X-TEND™ S) potato extract with sodium acid pyrophosphate). The experiment was done in two trials. Each trial included three batches per treatment, and three patties from each batch were scored subjectively for discoloration by two individuals following American Meat Science Association (AMSA) Meat Color Measurement Guidelines (AMSA, 2012) (1 = very bright red, 2 = bright red, 3 = dull red, 4 = slightly dark red, 5 = moderately dark red, 6 = dark red, 7 = dark reddish-tan, 8 = tan to brown). The least squares means of discoloration are shown for each treatment. Values within the same day with different superscripts differ ($P < 0.05$). The error bars indicate ± standard error of the mean.

Figure 2.3. Representative beef patties after 4 days of fresh retail display. From left to right: Control (no binder), 2% TVP (soy flour), X ((X-TEND™) potato extract), M ((X-TEND™ M) potato extract with mustard), and S ((X-TEND™ S) potato extract with sodium acid pyrophosphate).

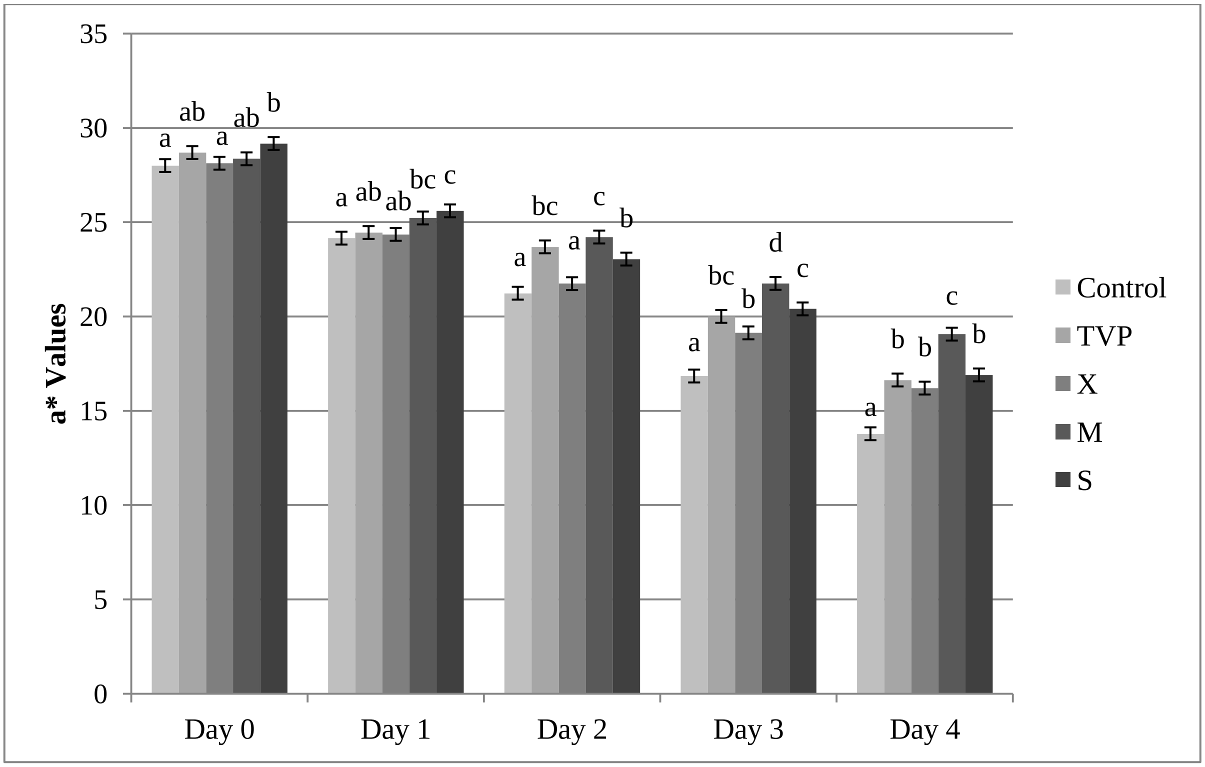

Figure 2.4. Binders increase beef patty a* (redness) values. Patties were made with Control (no binder) or 2% TVP (soy flour), X ((X-TEND™) potato extract), M ((X-TEND™ M) potato extract with mustard), or S ((X-TEND™ S) potato extract with sodium acid pyrophosphate). The experiment was done in two trials. Each trial included three batches per treatment, and three patties from each batch had two objective color measurements taken using a Hunter MiniScan EZ (Restin, VA) on days 0, 1, 2, 3, and 4. The least squares means of a* values are shown for each treatment. Values within the same day with different superscripts differ ($P < 0.05$). The error bars indicate ± standard error of the mean.

CHAPTER 3: EFFECTS OF DRY POTATO EXTRACTS, TEXTURED VEGETABLE PROTEIN, AND CORN SYRUP SOLIDS ON PROCESSING YIELD, TEXTURE, AND SENSORY CHARACTERISTICS OF CHICKEN FRANKFURTERS

Abstract

Binders are commonly incorporated into frankfurters to enhance textural and sensory characteristics. The objective was to evaluate the processing yield, texture, and sensory characteristics of chicken frankfurters that had no binder (Control) or incorporated TVP, corn syrup solids (CSS), or one of three dry potato extracts: (X-TEND™ (potato extract), X-TEND™ M (potato extract with mustard), or X-TEND™ S (potato extract with sodium acid pyrophosphate). No differences in processing yields or lipid oxidation among treatments were observed. This is likely due to the presence of nitrite and phosphate, which are common frankfurter ingredients. All treatments were generally no different in mechanical parameters as measured by Texture Profile Analysis. However, consumer taste panelists (n=90) rated frankfurters with X-TEND™ M higher for texture than Control, TVP, and CSS frankfurters. Juiciness was scored higher for Control and CSS frankfurters compared to X-TEND™ frankfurters ($P < 0.05$). We conclude that potato extracts effectively bind water resulting in improved texture and reduced juiciness during chewing.

Introduction

Since nitrite is used in cured meat products to increase shelf stability (Sindelar and Milkowski, 2011) and phosphate is added to improve water holding capacity (Whiting, 1984), the main purpose for binders is to improve the texture of emulsified products (Yang et al., 2001). USDA regulations allow fat and water to be substituted for one another so long as their total does not exceed 40% in cooked sausages (USDA, 1988). Water levels are often maximized in comminuted products, such as chicken frankfurters, to minimize product cost. Increased water from 10 to 30% leads to decreased hardness in frankfurters (Chang and Carpenter, 1997). Lower fat levels, less saturated fat, and hence, increased moisture also leads to decreased product hardness (Sams and Diez, 1991). Binding agents are commonly added to these products to improve texture, and ultimately, consumer satisfaction (Yang et al., 2001). Soy protein, often referred to as textured vegetable protein (TVP), is commonly used as a binder in frankfurters (Lacomte et al., 1993). FSIS classifies soy as an allergen. Non-allergenic binding agents that provide desirable product attributes would be beneficial for the meat processing industry and consumers. The objective was to evaluate the processing yield, texture, and sensory characteristics of chicken frankfurters that had no binder (Control), TVP, corn syrup solids (CSS), or one of three dry potato extracts.

Materials and Methods

Preparation of product

Boneless, skinless chicken thighs (~13% fat) were comminuted using a bowl chopper and the ingredients in Table 3.1 were added during chopping to form a frankfurter batter. The emulsified batter was then vacuum stuffed into 30 mm cellulose casings (Viscofan, Danville, IL) to form 75.6 g frankfurters. Frankfurters were cooked in a smokehouse (Alkar Model 700, Alkar-RapidPak, Inc., Lodi, WI) following the processing schedule shown in Table 3.2, then cooled to 2°C. Each treatment was represented equally in oven locations. Casing removal, vacuum packaging, and refrigerator storage followed. Batches (n = 3) were the experimental units.

Water holding capacity

Frankfurter batch weights were recorded before and after cooking to determine percent cook yield. Frankfurters were weighed and vacuum packaged in groups of four, stored for 18 days, and reweighed to determine percent storage loss.

Internal color

Objective internal color measurements were taken using a Hunter MiniScan EZ (Restin, VA) on day 4. Frankfurters were split lengthwise to provide enough area for measurement. The Hunter MiniScan was equipped with a 25 mm-diameter measuring area and a 10° standard observer. The instrument was set to illuminant A and Commission Internationale de l'Eclairage (CIE) L* (lightness), a* (redness), and b* (yellowness) values were recorded. Calibration of the machine was carried out by measuring against black and white calibration tiles.

Lipid oxidation

Thiobarbituric acid reactive substances (TBARS) were measured on raw batter and on day 1 after cooking. The protocol used for quantification of TBARS is provided in Appendix D (AMSA, 2012).

Mechanical texture analysis

On day 5 of refrigerated storage, frankfurter texture was analyzed using a TA.XT Plus Texture Analyser (Stable Micro Systems, UK). Force needed to fracture (break force) a core (diameter = 2.54 cm; height = 3.175 cm) compressed axially was determined as an indicator of emulsion strength. Additionally, cores were compressed to 50% of original height in a two compression cycle at a speed of 1.67 mm per sec and force was plotted against time as shown in Figure 3.1. Texture profile analysis (TPA) produced addition mechanical parameters: hardness (N) = peak force (2), adhesiveness (N) = negative area under curve (area 3-4), resilience (%) = area 2-3/area 1-2 * 100, cohesiveness = area 4-6/area 1-3, springiness = spring (time 4-5/time 1-2) * 100, gumminess = hardness * cohesiveness, and chewiness = gumminess * spring.

Sensory analysis

After four days of refrigerator storage, frankfurters were reheated to 60°C in boiling water and immediately served to consumer panelists (n=90) for sensory analysis. Each panelist evaluated 1.27 cm long x 2.54 cm diameter samples from four different treatments for overall acceptability, texture, juiciness, and flavor using a 9-point scale (9 = like extremely, like texture extremely, extremely juicy, and like flavor extremely, respectively; 1= dislike extremely, dislike texture extremely, extremely dry, and dislike flavor extremely, respectively).

Statistical Analysis

Data were analyzed using the Mixed Model procedure of the Statistical Analysis System. Differences in least squares means (LSM) were compared by the DIFF option. Batches (n = 3) served as the experimental units. P-values of ≤ 0.05 were considered statistically significant and p-values ≤ 0.10 were considered trends in the data.

Results

Product yield

There were no differences in percent cook yield among treatments as shown in Table 3.3. Storage loss after 18 days of refrigeration was < 0.9% in all treatments and did not differ among treatments (data not shown).

Internal color

Objective color scores for lightness (L*) were higher for all three potato extract treatments compared to frankfurters made with CSS or TVP ($P < 0.001$) (Table 3.4). Frankfurters made with CSS had lower L* values than all other treatments and higher redness (a*) values than Control, M, and S frankfurters ($P < 0.05$).

Lipid oxidation

No difference in TBARS was observed among treatments for either raw batter or cooked frankfurters (Table 3.5).

Mechanical texture analysis

Treatments were similar for all mechanical texture categories except adhesiveness, signifying similarities in emulsion strength among all treatments (Tables 3.6 and 3.7). Adhesiveness represents the product of negative force and time needed for the plunger to pull away from the sample core. X frankfurters had greater adhesiveness than all other treatments, while S frankfurters were more adhesive than frankfurters made with CSS ($P < 0.01$).

Sensory analysis

Consumer panelists found texture more desirable in M frankfurters compared to Control, CSS, and TVP frankfurters ($P < 0.05$) (Table 3.8), while X frankfurters tended to have higher texture scores than those without a binder ($P = 0.052$). Juiciness of CSS frankfurters was similar to Control and higher than all other binder treatments ($P < 0.05$). Control frankfurters were also juicier than X frankfurters ($P < 0.05$). Flavor and overall acceptability did not differ among treatments. Consumer preferences of chicken frankfurters are shown in Table 3.9. Only 30 of the 59 panelists to respond would be willing to purchase TVP frankfurters. At least 70% of panelists would purchase frankfurters made with M or S. Over 60% of respondents liked texture least in CSS and control frankfurters. No treatment had more than 30% of respondents detect off-flavor. As seen in Table 3.10, 69 of the 90 panelists eat zero to one hot dog meals per week, while 20 panelists eat two to four and one panelist eats five to seven hot dog meals per week.

Discussion

As anticipated, cooking yield did not differ among treatments. These findings are similar to results of Yang et al. (2001), who found no difference between frankfurters with varying binders and levels of fat. In Yang et al. (2001) and the present study, phosphate was added to all treatments. Phosphate has been shown to improve water binding in frankfurters (Whiting, 1984), and therefore may have limited variation in processing yield between treatments. Beef, pork, and lamb frankfurters with 10 or 22% fat yielded over 20% higher at 96.9 to 98.4% (Yang et al., 2001) than the chicken frankfurters in the current study. Although yields in the mid to upper 90s are common in high (25%) fat chicken frankfurters (Tan et al.

2006), addition of water at 30% in the current study may have resulted in lower yield. Crehan et al. (2000) reported an increase in cook loss from 3.6 to 6.7% when fat was decreased from 30 to 5% in frankfurters. Water binding also worsens when water levels increase from 10 to 30% (Chang and Carpenter, 1997). In addition, over-filling the smokehouse in the current study may have led to poorer air movement and slower cooking of frankfurters on the center racks relative to frankfurters on the end racks and hence, overcooking of the outside frankfurters. In the preliminary experiment, where product spacing and therefore, air flow were increased, average cook yield was 82%.

In beef and pork frankfurters, higher lightness and yellowness values and lower redness values are indicative of higher fat content (Crehan et al. 2000). Beef, pork, and lamb frankfurters with TVP have lower L* values than wheat gluten frankfurters (Yang et al., 2001). Likewise, both TVP and CSS reduced L* values compared to potato extracts in the current experiment. In the present study, CSS reduced lightness to the greatest extent, and CSS frankfurters were lighter than control frankfurters. CSS frankfurters were generally more red as well.

TBARS development throughout processing was minimal. Igene et al. (1985) saw a reduction in TBARS after 21 days of refrigerator storage of nitrite cured ground beef. This indicates a strong, prolonged antioxidant effect due to nitrites ability to form free radical scavenging nitriso- and nitrosyl compounds, and its ability chelate pro-oxidants and free radicals through nitric oxide formation (Sindelar and Milkowski, 2011).

Hutchings and Lillford (1988) describe texture as a dynamic process that takes place in the mouth, therefore requiring consumer sensory analysis. Still, Yang et al. (2001) noted a positive correlation between trained panelist scores for firmness, springiness, and cohesiveness and texture profile analysis values for hardness, springiness, gumminess, and chewiness. In the current study, X frankfurters were the most adhesive, but no other treatment effects on mechanical texture were observed.

Consumer texture scores in the current study were higher for frankfurters made with M than control or those made with CSS or TVP, although frankfurters made with M were also less juicy than frankfurters made with CSS. These results are consistent with previous research that demonstrates an inverse relationship between juiciness and texture of frankfurters. Yang et al. (2001) noted that frankfurters made with a combination of 1% isolated soy protein and 4% potato starch increased texture and decreased juiciness scores compared to control frankfurters. Softness or excessive juiciness are the main qualities that lead to reduced overall consumer acceptability (Yang et al. 2001). Perception of juiciness does not correlate with water holding capacity in frankfurters (Chang and Carpenter, 1997). Schnell et al. (1972) notes a decrease in frankfurter juiciness is accompanied by an increase in viscosity. Increased water from 10 to 30% led to increased expressible moisture and decreased sensory hardness (Chang and Carpenter, 1997). In the present experiment, reduction of taste panel juiciness scores in frankfurters made with X *vs* control and CSS frankfurters is likely due to an increase in bound water. All frankfurters made with potato extracts were less juicy than CSS frankfurters.

Conclusion

Maximizing water levels in low fat chicken frankfurters is not ideal, even in the presence of binders, since it leads to significant Processing loss. CCS produced the darkest frankfurters, and both CSS and TVP frankfurters were darker than those made with potato extracts. Consumers preferred the texture of frankfurters made with M over two common industry binders used in manufacturing frankfurters. M and X also reduced juiciness scores compared to CSS; possibly an indication frankfurters with M and X potato extracts have improved water binding ability.

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Tables and Figures

Table 3.1

Chicken frankfurter ingredients as a percentage of product finished weight

Ingredient	%PFW[1]
Chicken Thighs	
Potato Extract and CSS Treatments	64.5
TVP	65.5
Control	67.5
All Treatments	
Curing salt (6.25% nitrite)	0.17
Sodium erythorbate	0.04
Phosphate (Brifisol 512)	0.04
Water	30.0
Salt	1.7
Spices	0.5
Ground White Pepper	0.21
Coriander	0.12
Nutmeg	0.09
Garlic Granules	0.04
Ground Mustard	0.03
Binders	
Control	0.0
CSS[2]	3.0
TVP[3]	2.0
X[4]	3.0
M[5]	3.0
S[6]	3.0
PFW	100

[1] %PFW = Ingredient Weight/Raw Product Finished Weight*100

[2] Corn syrup solids (Tate and Lyle Ingredients Americas, Inc., Decatur, IL)

[3] Textured vegetable protein (soy flour; Uncolored ¼, Legacy (2000-10N), Product Code: 0500140, Lot Number: 043350, Excalibur Seasoning, Perkin, IL)

[4] X-TEND™ (potato extract, Item 207085, BAF, Blackfoot, ID)

[5] X-TEND™ M (Potato extract with mustard, Item 207087, BAF)

[6] X-TEND™ S (Potato extract with sodium acid pyrophosphate, Item 207086, BAF)

Table 3.2
Smokehouse processing schedule for chicken frankfurters

Stage	Dry Bulb (°C)	Wet Bulb (°C)	Dampers	Smoke	Time (min)
1	43.3	37.8	closed	off	30
2	48.9	-----	open	off	10
3	60.0	-----	closed	on	45
4	68.3	53.3	open	off	20
5	76.7	60.0	closed	off	20
6	82.2	71.1	closed	off	To 71°C internal
7	-----	-----	open	off	15 min shower

Table 3.3

Percent cook yield of chicken frankfurters

Treatment	% Cook Yield[1]
Control	72.0
CSS[2]	71.9
TVP[3]	73.2
X[4]	73.0
M[5]	74.3
S[6]	73.2
SEM	1.5

[1] % Cook Yield = Cooked Weight/Raw Weight*100

[2] Corn syrup solids

[3] Textured vegetable protein (soy flour)

[4] X-TEND™ (Potato extract)

[5] X-TEND™ M (Potato extract with mustard)

[6] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

Table 3.4

Internal color[1] of cooked chicken frankfurters

Treatment	L*	a*	b*
Control	66.7^{bc}	13.0^{a}	15.5^{a}
CSS[2]	65.0^{a}	13.7^{b}	15.7^{a}
TVP[3]	66.1^{b}	13.2^{ab}	17.2^{b}
X [4]	67.4^{c}	13.4^{ab}	17.1^{b}
M[5]	67.5^{c}	12.7^{a}	16.5^{ab}
S[6]	67.4^{c}	12.9^{a}	16.6^{ab}
SEM	0.3	0.2	0.4

[1] L* (lightness), a* (redness), and b* (yellowness)

[2] Corn syrup solids

[3] Textured vegetable protein (soy flour)

[4] X-TEND™ (Potato extract)

[5] X-TEND™ M (Potato extract with mustard)

[6] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

[a-c] Means within columns with different superscripts differ ($P < 0.05$)

Table 3.5

Lipid oxidation (TBARS[1]) of chicken frankfurters

Treatment	Raw	Cooked
Control	0.12	0.23
CSS[2]	0.14	0.23
TVP[3]	0.13	0.23
X[4]	0.12	0.23
M[5]	0.12	0.22
S[6]	0.13	0.22
SEM	0.02	0.02

[1] TBARS = mg malondialdehyde/kg meat

[2] Corn syrup solids

[3] Textured vegetable protein (soy flour)

[4] X-TEND™ (Potato extract)

[5] X-TEND™ M (Potato extract with mustard)

[6] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

Table 3.6

TPA of chicken frankfurters

Treatment	Hardness (N)	Adhesiveness (g. sec.)	Resilience (%)	Cohesiveness (ratio)	Springiness (%)	Gumminess (N)	Chewiness (N)
Control	51.82	-0.18^{ab}	39.72	0.68	90.67	35.35	32.05
CSS[1]	50.08	-0.06^{a}	39.08	0.67	88.93	33.61	29.94
TVP[2]	52.95	-0.17^{ab}	39.15	0.67	88.87	35.46	31.55
X [3]	55.28	-0.61^{c}	37.83	0.66	87.34	36.41	31.78
M[4]	54.42	-0.21^{ab}	37.72	0.66	88.83	35.99	31.98
S[5]	50.85	-0.35^{b}	38.07	0.66	87.93	33.68	29.64
SEM	2.77	0.07	1.16	0.01	1.53	1.56	1.71

[1] Corn syrup solids

[2] Textured vegetable protein (soy flour)

[3] X-TEND™ (Potato extract)

[4] X-TEND™ M (Potato extract with mustard)

[5] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

[a-c] Means within columns with different superscripts differ ($P < 0.05$)

Table 3.7

Break force of chicken frankfurters

Treatment	Force (N)
Control	81.87
CSS[1]	76.24
TVP[2]	79.13
X [3]	83.58
M[4]	79.67
S[5]	78.30
SEM	4.18

[1] Corn syrup solids

[2] Textured vegetable protein (soy flour)

[3] X-TEND™ (Potato extract)

[4] X-TEND™ M (Potato extract with mustard)

[5] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

Table 3.8

Sensory analysis by consumer panelists[1] of chicken frankfurters

Treatment	Acceptability	Texture	Juiciness	Flavor
Control	5.8	5.2^{a}	6.1^{bc}	5.9
CSS[2]	5.9	5.4^{a}	6.4^{c}	5.6
TVP[3]	5.6	5.5^{a}	5.8^{ab}	5.3
X[4]	5.8	5.8^{ab}	5.5^{a}	5.9
M[5]	6.1	6.2^{b}	5.9^{ab}	6.0
S[6]	6.0	5.6^{ab}	5.7^{ab}	6.0
SEM	0.2	0.2	0.2	0.2

[1] n=90. Scale, 9 = like extremely, like texture extremely, extremely juicy, and like flavor extremely, respectively; 1= dislike extremely, dislike texture extremely, extremely dry, and dislike flavor extremely, respectively.

[2] Corn syrup solids

[3] Textured vegetable protein (soy flour)

[4] X-TEND™ (Potato extract)

[5] X-TEND™ M (Potato extract with mustard)

[6] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

$^{a\text{-}c}$Means within columns with different superscripts differ (*P* < 0.05)

Table 3.9
Consumer preferences of chicken frankfurters

	Control		CSS		TVP		X		M		S	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Like most[1]												
Flavor	24	47.1	22	40.0	21	40.4	24	52.2	25	47.2	30	54.5
Juiciness	17	33.3	25	45.5	15	28.8	11	23.9	12	22.6	11	20.0
Texture	10	19.6	8	14.5	16	30.8	11	23.9	16	30.2	14	25.5
Like least[2]												
Flavor	12	21.8	16	31.4	22	38.6	16	35.6	13	27.1	19	36.5
Juiciness	8	14.5	4	7.8	14	24.6	13	28.9	13	27.1	13	25.0
Texture	35	63.6	31	60.8	21	36.8	16	35.6	22	45.8	20	38.5
Off flavor[3]												
Yes	17	28.3	11	18.3	14	24.1	14	23.3	11	18.0	12	20.0
No	43	71.7	49	81.7	44	75.9	46	76.7	50	82.0	48	80.0
Purchase[4]												
Yes	38	64.4	37	63.8	30	50.8	35	58.3	45	73.8	42	70.0
No	21	35.6	21	36.2	29	49.2	25	41.7	16	26.2	18	30.0

For 1 to 4, consumers were asked:

1. IF APPLICABLE, please circle the trait you liked most about this product. flavor, juiciness, or texture/mouth feel
2. IF APPLICABLE, please circle the trait you liked least about this product. flavor, juiciness, or texture/mouth feel
3. OFF-FLAVOR: This is based on your ability to detect an off-flavor of the sample: NO/YES
4. CONSUMER SATISFACTION: Would you be willing to purchase this product? NO/YES

Table 3.10
Demographics of chicken frankfurter consumer panelists

	n	%
Age		
18-19	13	14.4
20-29	51	56.7
30-39	8	8.9
40-49	10	11.1
50+	8	8.9
Gender		
Male	37	41.1
Female	53	58.9
Hotdog meals/wk[1]		
0 to 1	69	76.7
2 to 4	20	22.2
5 to 7	1	1.1
8+	0	0.0

1. Consumers were asked: Please indicate the number of meals a week in which you consume hot dogs: 0-1, 2-4, 5-7, or 8+

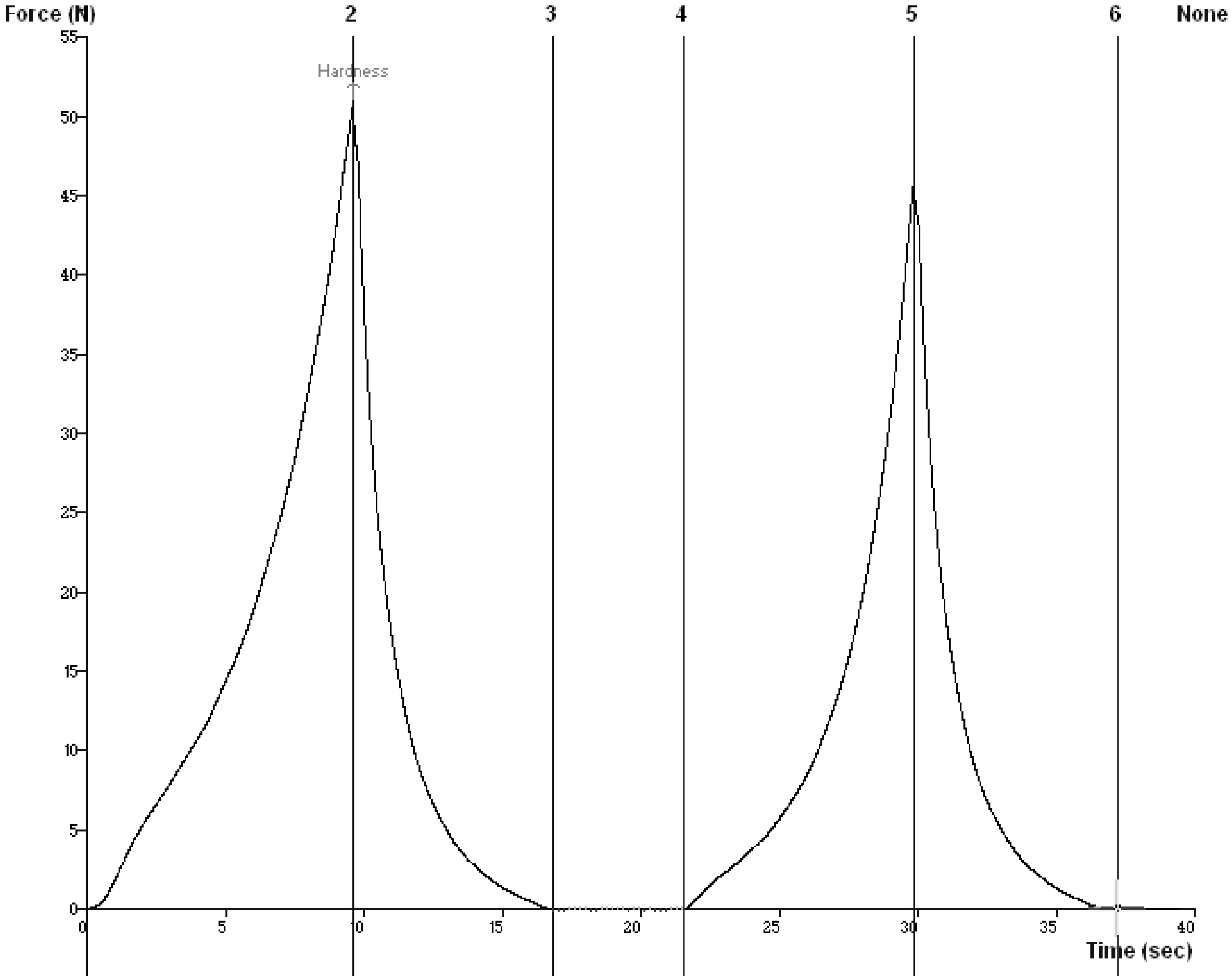

Figure 3.1. Force versus time plot produced by a TA.XT plus texture analyser (Stable Micro Systems, UK) upon double compression axially of chicken frankfurter cores (diameter = 2.54 in; height = 3.175 in) with different binders to 50% of original height at a cross-speed of 1.67 mm/sec. Texture profile analysis (TPA) produced results: Hardness (N) = peak force (2), adhesiveness (g. sec.) = negative area under curve, resilience (%) = area 2-3/area 1-2 * 100, cohesiveness = area 4-6/area 1-3, springiness = spring (time 4-5/time 1-2) * 100, gumminess = hardness * cohesiveness, and chewiness = gumminess * spring.

CHAPTER 4: EFFECTS OF REHYDRATED POTATO EXTRACT ON WATER HOLDING CAPACITY, SHELF STABILITY, AND SENSORY CHARACTERISTICS OF BEEF TOP ROUND

Abstract

The objective was to evaluate the water holding capacity, shelf stability, and sensory characteristics of beef top round roasts and steaks that were not injected (Control) or injected with 10% (wt/wt) of a 10% solution (wt/wt) containing one of three potato extracts: X-TEND™ (potato extract), X-TEND™ M (potato extract with mustard), or X-TEND™ S (potato extract with sodium acid pyrophosphate). Top round sections were designated to either cooking followed by 21 day refrigerator storage or 14 day aging followed by 4 days of steak retail display. Compared to Control, all three potato extracts reduced lipid oxidation of cooked beef after 21 days of storage ($P < 0.01$). Retail display steaks from product injected with potato extracts generally had greater discoloration. Product injected with potato extracts purged more fluid than control during 14 day storage in a vacuum package, but had similar water holding capacity to Control steaks during retail display and cooking. Results indicate potato extracts improved shelf stability to a greater extent in precooked roasts than fresh steaks.

Introduction

Binders are utilized in processed meat products to improve product yield and shelf life (Ray et al., 1981; Pena-Ramos and Xiong, 2003; Raut et al. 2011). Binders also improve sensory characteristics (Yang et al., 2001). The beef top round improves in tenderness with extended aging; however, an increase in purge and a decrease in shelf stability result from aging (Colle, 2014). Top round could potentially benefit from injection with binders to reduce moisture losses and improve shelf stability. The objectives of this study were to evaluate the water holding capacity, shelf stability, and sensory characteristics of beef top round that incorporated one of three dry potato extracts.

Materials and Methods

Preparation of product

USDA Select beef top (inside) rounds (IMPS 168) (n=12) were purchased from AB Foods (Toppenish, WA) and transported to the University of Idaho Meat Science Laboratory at 48 hr post mortem (fabrication = day 0). The *semimembranosus* was removed from the wholesale cut and sectioned into thirds. The sections were strategically assigned to four treatments, Control, X-TEND™ ((X) potato extract, SKU: IQA5038, Lot: 26411A 018, Basic American Foods (BAF), Blackfoot, ID), X-TEND™ M ((M) potato extract with mustard, SKU: IQA5140, Lot: 09409A 0047, BAF), or X-TEND™ S ((S) potato extract with sodium acid pyrophosphate, SKU: IQA5039, Lot: 121514RD, BAF), in order that no treatment was applied to sections of the same muscle. Each potato extract was mixed into solution (10% wt/wt) with distilled water using an Osterizer blender (Oster; Warwick, RI). Solutions were then injected at 10% of the section's raw weight using a five needle hand pump, vacuum tumbled in a BIRO vacuum tumbler (VTS – 42; BIRO Manufacturing Co., Marblehead, Ohio) at 40.64 cm Hg for 25 min, and rested under vacuum for another 25 min. Control sections were neither injected nor tumbled. Sections were cut in half and designated for either retail display or precooking. Retail display sections were packaged in vacuum shrink bags (7 x 12 Durashrink bags, Winpak Films, Senoia, GA) and aged for 14 days at 0°C before retail display. The remaining sections were packaged in Cryovac cook-in bags (Sealed Air Global), cooked on day 1 to 71°C in a thermal processing oven (Alkar Model 700, Alkar-RapidPak, Inc., Lodi, WI) with smoke generation capabilities. After cooking, product was weighed, repackaged, and stored for 21 days at 0°C.

The sections designated for retail display were removed after the aging period and two 2.54 cm thick steaks were cut from each. Steaks were randomly assigned for taste panel analysis or retail shelf-life and Warner-Bratzler shear force (WBSF) analysis. Steaks used for retail display were weighed, swabbed (3M Quick Swab) for microbial analysis, sampled for determination of thiobarbituric acid reactive substances (TBARS), and packaged on white Styrofoam trays with an oxygen permeable overwrap (Koch Industries, Inc. #7500-3815; Wichita, KS) with the freshly cut surface exposed. The steaks were displayed in a glass-fronted retail display case (Model GDM-69, True Manufacturing Co., O'Fallon, Mo) at 3°C for 4 days. The display case was equipped with natural white Hg 40W lights, and the average light intensity was 409 lux.

After retail display, steaks were cooked on open-hearth broilers to 40°C then flipped and cooked to a final internal temperature of 71°C. Temperature was monitored with hypodermic temperature probes (Omega Engineering Co., Stamford, CT) coupled with a 12-channel scanning thermocouple thermometer (Digi-Sense, Cole-Parmer Instrument Co., Vernon Hills, IL). After cooking, steaks were weighed and refrigerated overnight for WBSF analysis.

Water holding capacity

Retail display sections were weighed prior to packaging and after 14 days of aging at 0°C to determine percent purge. Steaks were weighed before and after retail display and cooking to calculate percent retail fluid loss and percent cook yield, respectively. Cook-in bag sections were weighed prior to packaging and after cooking and cooling to determine percent cook yield.

Microbial growth

Each steak was dry swabbed (5 cm x 5 cm area) on days 0, 2, and 4 of retail display using 3M^{TM} Quick Swabs (3M, St. Paul, MN). Letheen broth contained in the top of the swab was added and the samples were plated on a 3M^{TM} Petrifilm^{TM} Aerobic Count Plates (3M, St. Paul, MN). The Aerobic Count Plates were incubated at 35°C for 48 h to examine the growth of mesophilic organisms. Plates were counted by research personnel following the 3M Interpretation Guide (http://www.3m.com/intl/kr/microbiology/p_aerobic/use3.pdf).

Lipid oxidation

Thiobarbituric acid reactive substances (TBARS) were analyzed on days 0, 2, and 4 of retail display and day 21 of refrigerator storage following the protocol provided in Appendix D (AMSA, 2012). The end (~1 cm) of the steak was discarded before samples were taken from the top half of the steak avoiding the edge.

Warner-Bratzler shear force

Six cores (1.27 cm diameter) from each steak were mechanically removed parallel with the muscle fibers using a drill press mounted coring device. A Warner-Bratzler shear machine (GR Manufacturing, Manhattan, KS) was used to determine shear force by shearing each core once in the center perpendicular to the muscle fibers.

Color stability

Steaks were allowed to bloom for at least 60 min, and two objective color measurements per steak were taken using a Hunter MiniScan EZ (Restin, VA). Each point was selected avoiding large marbling flecks, connective tissue, and the very edge of the product. This represented day 0 of retail display, and subsequent color measurements were taken on days 1, 2, 3, and 4. The Hunter MiniScan is equipped with a 25 mm-diameter measuring area and a 10° standard observer. The instrument was set to illuminant A and Commission Internationale de l'Eclairage (CIE) L* (lightness), a* (redness), and b* (yellowness) values were recorded. Calibration of the machine was carried out each day by measuring against black and white calibration tiles.

The steak surface was evaluated daily during retail display for oxygenated lean color (1 = extremely bright cherry red; 8 = extremely dark red), amount of browning (1 = no evidence of browning; 8 = dark brown), discoloration (1 = no discoloration; 5 = extreme discoloration), surface discoloration (1 = no discoloration (0%); 6 = extensive discoloration (81-100%)), and color uniformity (1 = uniform, no two-toning; 5 = extreme two-toning) by four evaluators following American Meat Science Association (AMSA) Meat Color Measurement Guidelines (AMSA, 2012). To avoid potential effects due to display case location, steaks were rotated after each measurement.

Sensory panel

Steaks designated for taste panel analysis were displayed in the retail case for 2 days, then vacuum packaged and frozen at -20°C. For the consumer taste panel, steaks were thawed overnight at 4°C and cooked as described previously. A panel of consumers (n=63) evaluated 1.27 cm x 1.27 cm x steak thickness samples for overall acceptability, tenderness, juiciness, and flavor using a 9-point scale (9 = like extremely, extremely tender, extremely juicy, and like flavor extremely, respectively; 1 = dislike extremely, extremely tough, extremely dry, and dislike flavor extremely, respectively) (Appendix F). Each consumer evaluated one sample from each of the four treatments. Seven samples were cut from each steak.

Statistical analysis

Data were analyzed using the Mixed Model procedure of the Statistical Analysis System (SAS Institute, Inc., Cary, NC). Top round sections served as the experimental units (n = 9). Individual muscle served as a random variable. Color measurements were analyzed as repeated measures. Differences in least squares means (LSM) were compared by the DIFF option. P-values of ≤ 0.05 were considered statistically significant and p-values ≤ 0.10 were considered trends in the data.

Results

Water holding capacity

Percent purge was greater ($P < 0.0001$) in all potato extract treatments, which had been injected with 10% fluid compared to uninjected Control steaks (Table 4.1). No differences were observed between treatments in retail fluid loss or cooking yield for either retail display steaks or cook-in bag roasts (Table 4.1).

Microbial growth

Aerobic counts increased with longer aging periods (data not shown). However, aerobic counts did not differ between treatments.

Lipid oxidation

TBARS increased over time of retail display ($P < 0.001$; data not shown). TBARS did not differ between treated and control steaks subjected to retail display with the exception of X steaks having greater TBARS than control and M steaks. TBARS of cooked roasts with potato extracts were only 24.3 to 52.8% of control roasts ($P < 0.01$; Table 4.1). M steaks trended towards lower TBARS values than S steaks ($P = 0.06$).

Warner-Bratzler shear force

Despite a numerical decrease in WBSF of injected steaks, there were no significant differences between treatments (Table 4.1).

Color stability

Oxygenated lean color, amount of browning, surface discoloration, and color uniformity deteriorated ($P < 0.0001$) with longer retail display (Table 4.2). Surface discoloration was greater in M and X steaks ($P < 0.01$) and tended to be greater in S steaks ($P = 0.07$) compared to Control (Table 4.3). Furthermore, discoloration had a treatment by day interaction as shown in Table 4.4 ($P < 0.05$). Discoloration of steaks injected with M was greater than all other treatments on day 1. Although discoloration increased over time for all treatments, the extent of visual discoloration on day 4 was less in Control than treated steaks ($P < 0.01$).

An interaction between treatment and day also existed for Hunter L* and a* values (Table 4.5 and 4.6, respectively). Lightness values generally decreased ($P < 0.05$) over time with the exception of M steaks, which did not change from day 0 to 4. Redness values decreased over time and were greater ($P < 0.01$) in Control steaks compared to the potato extract steaks on all days with the exception of M steaks on day 4. Both a treatment effect (Table 4.7) and a day effect (data not shown) were present for Hunter b* (yellowness) values. Yellowness values decreased ($P < 0.0001$) over retail display time and Control had greater b* values ($P < 0.0001$) than X, with M and S intermediate.

Sensory panel

Consumers found no difference between overall acceptability or juiciness of control steaks or potato extract injected steaks (Table 4.8). Control steaks were generally scored as less tender ($P < 0.05$) than M and S steaks, but had more desirable flavor ($P < 0.01$) compared to X and M steaks. Off flavor was detected by 32.3 and 42.9% of consumers that sampled X and M, respectively (Table 4.9). Only 46 and 47.6% of consumers were willing to purchase X and M steaks, respectively.

Discussion

The top round was described by Colle et al. (2014) as having relatively poor color stability and water holding capacity. Fluid loss during storage of wholesale cuts leads to decreased product weight and economic loss for retail and foodservice providers. The increased purge of top round sections injected with potato extract versus Control sections can be attributed to the injection of solution at 10% of the initial weight. After tumbling and prior to packaging, injected treatments on average weighed 6.5 to 8.0% more than their initial weight. In terms of water binding, potato extracts performed more similar to the control in cook-in bag roasts than in 14 day aged steaks, where purge from injected product was greater than control. This may be explained by the gelatinization of potato starch at 58-66°C (Waterschoot et al., 2015) resulting in greater water binding in precooked top round sections than raw sections.

Consumers base meat purchasing decisions largely on color (AMSA, 2012; Mancini and Hunt, 2005). As expected, overall color stability decreased rapidly over time. The initial light discoloration of M steaks can be attributed to injection site discoloration caused by mustard. Despite high initial discoloration, M steaks seemed to deteriorate less rapidly than the other treatments as evidenced by stagnant L* values from day 0 to 4, as well as a less rapid deterioration in b* values and discoloration scores. This phenomenon is likely due to the activity of mustard as an antioxidant.

Shelf life is affected by lipid oxidation. Oxidative products including aldehydes, ketones, alcohols, and acids result in off-odors and off-flavors of meat (Giese, 1996). Potato extracts effectively decreased lipid oxidation of roasts cooked and stored at 0°C for 21 days. Retail display steaks treated with X and M had inferior flavor to control. Although reduction in flavor of X steaks from the control may be explained by increased lipid oxidation, M steaks were no different from control steaks in TBARS after 4 days of retail display. No difference in flavor of beef patties treated with potato extract *vs* control was observed previously (Chapter 2).

Tenderness ranks as the most important palatability trait according to consumer surveys (Mackintosh et al., 1936; Morgan et al., 1991; Koohmaraie et al., 1995; Huffman et al., 1996). Despite no significant differences in shear force values, X, M, and S steaks were rated by consumers as more tender than Control steaks. The increased tenderness is likely a product of needle tenderization during injection, which causes physical disruption of muscle fibers. Pietrasik and Shand (2004) reports mechanical tenderization to increase tenderness of beef top rounds.

Conclusion

Due to its poor color stability and fluid loss, the top round is challenging to market in a retail display case. Top round may be better suited to be precooked and marketed as a convenience food. Incorporation of potato extracts into cooked top round is an effective strategy to deter lipid oxidation.

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Tables and Figures

Table 4.1

Characteristics of beef top round

Treatment	Control	X[6]	M[7]	S[8]	SEM
Retail display					
% purge[1]	2.1^{a}	5.9^{b}	5.6^{b}	5.5^{b}	0.4
% retail fluid loss[2]	0.9	1.2	1.1	1.1	0.1
% cook yield[3]	67.2	68.1	67.5	70.9	1.3
TBARS[4]	0.45^{a}	0.61^{b}	0.44^{a}	0.57^{ab}	0.05
WBSF[5]	4.14	3.92	3.97	3.73	0.18
Cook-in bag					
% cook yield[3]	69.2	67.6	67.5	67.7	1.3
TBARS[4]	1.44^{a}	0.57^{b}	0.35^{b}	0.76^{b}	0.15

[1] Percent Purge Prior to Display = (1 - Day 14 Weight/Day 0 Weight)*100

[2] Percent Retail Fluid Loss = (1 - Day 4 Weight/Day 0 Weight)*100

[3] Percent Cook Yield = Cooked Weight/Raw Weight*100

[4] Thiobarbituric acid reactive substances (mg malondialdehyde / kg meat)

[5] Warner-Bratzler shear force (kg)

[6] X-TEND™ (Potato extract)

[7] X-TEND™ M (Potato extract with mustard)

[8] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

[a-b] Means with different superscripts within a row differ ($P < 0.05$)

Table 4.2

Visual color scores[1] of retail display top round steaks

Treatment	Day 0	Day 1	Day 2	Day 3	Day 4	SEM
[2]Oxygenated lean color	3.2^a	4.4^b	5.5^c	5.9^d	6.2^e	0.1
[3]Amount of browning	1.4^a	1.9^b	2.5^c	3.2^d	3.7^e	0.1
[4]Surface Discoloration	1.5^a	2.2^b	3.0^c	3.5^d	3.8^e	0.1
[5]Color uniformity	2.2^a	2.5^b	3.0^c	3.0^c	3.4^d	0.2

[1] Mean scores of four evaluators

[2] 1 to 8 (1 = extremely bright cherry red; 8 = extremely dark red)

[3] 1 to 6 (1 = no evidence of browning; 8 = dark brown)

[4] 1 to 6 (1 = no discoloration (0%); 6 = extensive discoloration (81-100%))

[5] 1 to 5 (1 = uniform, no two-toning; 5 = extreme two-toning)

[a-e] Means with different superscripts within a row differ ($P < 0.05$)

Table 4.3

Surface discoloration[1] of retail display top round steaks

Treatment	Average
Control	2.4^{a}
X[2]	2.9^{bc}
M[3]	3.1^{c}
S[4]	2.7^{ab}
SEM	0.1

[1] Mean scores of four evaluators scoring on a scale of 1 to 6 (1 = no discoloration (0%); 6 = extensive discoloration (81-100%))

[2] X-TEND™ (Potato extract)

[3] X-TEND™ M (Potato extract with mustard)

[4] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

[a-c] Means with different superscripts differ ($P < 0.05$)

Table 4.4

Discoloration[1] of retail display top round steaks

Treatment	Day 0	Day 1	Day 2	Day 3	Day 4	SEM
Control	1.2^{az}	1.7^{ay}	2.3^{ax}	2.7^{aw}	3.1^{av}	0.1
X[2]	1.5^{abz}	2.0^{ay}	2.6^{abx}	3.4^{bw}	3.8^{bv}	0.1
M[3]	1.8^{bz}	2.4^{by}	2.8^{bx}	3.2^{bw}	3.6^{bv}	0.1
S[4]	1.3^{az}	1.9^{ay}	2.5^{abx}	3.1^{abw}	3.9^{bv}	0.1
SEM	0.1	0.1	0.1	0.1	0.1	

[1] Averages of four evaluators scoring on a scale of 1 to 5 (1 = no discoloration; 5 = extreme discoloration)

[2] X-TEND™ (Potato extract)

[3] X-TEND™ M (Potato extract with mustard)

[4] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

$^{a\text{-}b}$Means with different superscripts within a column differ ($P < 0.05$)

$^{v\text{-}z}$Means with different superscripts within a row differ ($P < 0.05$)

Table 4.5

Hunter L* values[1] of retail display top round steaks

Treatment	Day 0	Day 1	Day 2	Day 3	Day 4	SEM
Control	39.2^{z}	38.0^{axy}	38.8^{yz}	37.7^{x}	36.4^{aw}	1.3
X[2]	40.5^{z}	39.9^{abyz}	40.1^{yz}	39.2^{y}	39.2^{aby}	1.3
M[3]	41.3^{yz}	41.7^{bz}	41.4^{yz}	40.4^{y}	41.6^{bz}	1.3
S[4]	40.0^{z}	39.9^{abyz}	39.6^{xyz}	38.9^{y}	38.8^{abx}	1.3
SEM	1.3	1.3	1.3	1.3	1.3	

[1] Lightness (100) to Darkness (0)

[2] X-TEND™ (Potato extract)

[3] X-TEND™ M (Potato extract with mustard)

[4] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

$^{a\text{-}b}$Means with different superscripts within a column differ ($P < 0.05$)

$^{w\text{-}z}$Means with different superscripts within a row differ ($P < 0.05$)

Table 4.6

Hunter a* values[1] of retail display top round steaks

Treatment	Day 0	Day 1	Day 2	Day 3	Day 4	SEM
Control	36.4^{az}	36.3^{az}	31.5^{ay}	29.7^{ax}	27.6^{aw}	0.4
X[2]	34.7^{bz}	32.8^{by}	28.9^{bx}	27.4^{bcw}	25.2^{bv}	0.4
M[3]	35.2^{bz}	33.7^{by}	30.0^{bx}	28.5^{bw}	27.3^{av}	0.4
S[4]	35.2^{bz}	33.9^{by}	29.9^{bx}	27.3^{cw}	25.3^{bv}	0.4
SEM	0.4	0.4	0.4	0.4	0.4	

[1] Red (100) to Green (-100)

[2] X-TEND™ (Potato extract)

[3] X-TEND™ M (Potato extract with mustard)

[4] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

$^{a\text{-}c}$Means with different superscripts within a column differ ($P < 0.05$)

$^{v\text{-}z}$Means with different superscripts within a row differ ($P < 0.05$)

Table 4.7

Hunter b* values[1] of retail display top round steaks

Treatment	Average
Control	28.1^{a}
X[2]	26.0^{c}
M[3]	27.2^{b}
S[4]	26.8^{b}
SEM	0.3

[1] Yellow (100) to Blue (-100)

[2] X-TEND™ (Potato extract)

[3] X-TEND™ M (Potato extract with mustard)

[4] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

$^{a-c}$Means with different superscripts differ ($P < 0.05$)

Table 4.8

Sensory analysis by consumer panelists[1] of top round steaks

Treatment	Acceptability	Tenderness	Juiciness	Flavor
Control	5.4	4.6^{a}	4.9	5.8^{a}
X[2]	5.3	5.1^{ab}	5.1	4.8^{b}
M[3]	5.1	5.6^{b}	5.1	4.7^{b}
S[4]	5.5	5.3^{b}	5.4	5.5^{a}
SEM	0.2	0.2	0.2	0.2

[1] n=60. Scale, 9 = extremely acceptable, extremely tender, extremely juicy, and like flavor extremely, respectively; 1= extremely unacceptable, extremely tough, extremely dry, and dislike flavor extremely, respectively.

[2] X-TEND™ (Potato extract)

[3] X-TEND™ M (Potato extract with mustard)

[4] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

[a-b] Means with different superscripts within a column differ ($P < 0.05$)

Table 4.9

Consumer preferences of top round steaks

	Control		X		M		S	
	n	%	*n*	%	*n*	%	*n*	%
Like most[1]								
Flavor	34	57.6	16	28.6	10	18.2	21	36.2
Tenderness	3	5.1	15	26.8	23	41.8	18	31.0
Juiciness	14	23.7	16	28.6	12	21.8	11	19.0
Texture	8	13.6	9	16.1	10	18.2	8	13.8
Like least[2]								
Flavor	7	11.7	20	32.8	29	47.5	16	27.6
Tenderness	32	53.3	17	27.9	7	11.5	17	29.3
Juiciness	12	20.0	9	14.8	7	11.5	10	17.2
Texture	9	15.0	15	24.6	18	29.5	15	25.9
Off flavor[3]								
No	54	85.7	42	67.7	36	57.1	47	77.0
Yes	9	14.3	20	32.3	27	42.9	14	23.0
Purchase[4]								
No	24	39.3	34	54.0	33	52.4	20	32.3
Yes	37	60.7	29	46.0	30	47.6	42	67.7

For 1 to 4, consumers were asked:

1. IF APPLICABLE, please circle the trait you liked most about this product. flavor, tenderness, juiciness, or texture/mouth feel
2. IF APPLICABLE, please circle the trait you liked least about this product. flavor, tenderness, juiciness, or texture/mouth feel
3. OFF-FLAVOR: This is based on your ability to detect an off-flavor of the sample: NO/YES
4. CONSUMER SATISFACTION: Would you be willing to purchase this product? NO/YES

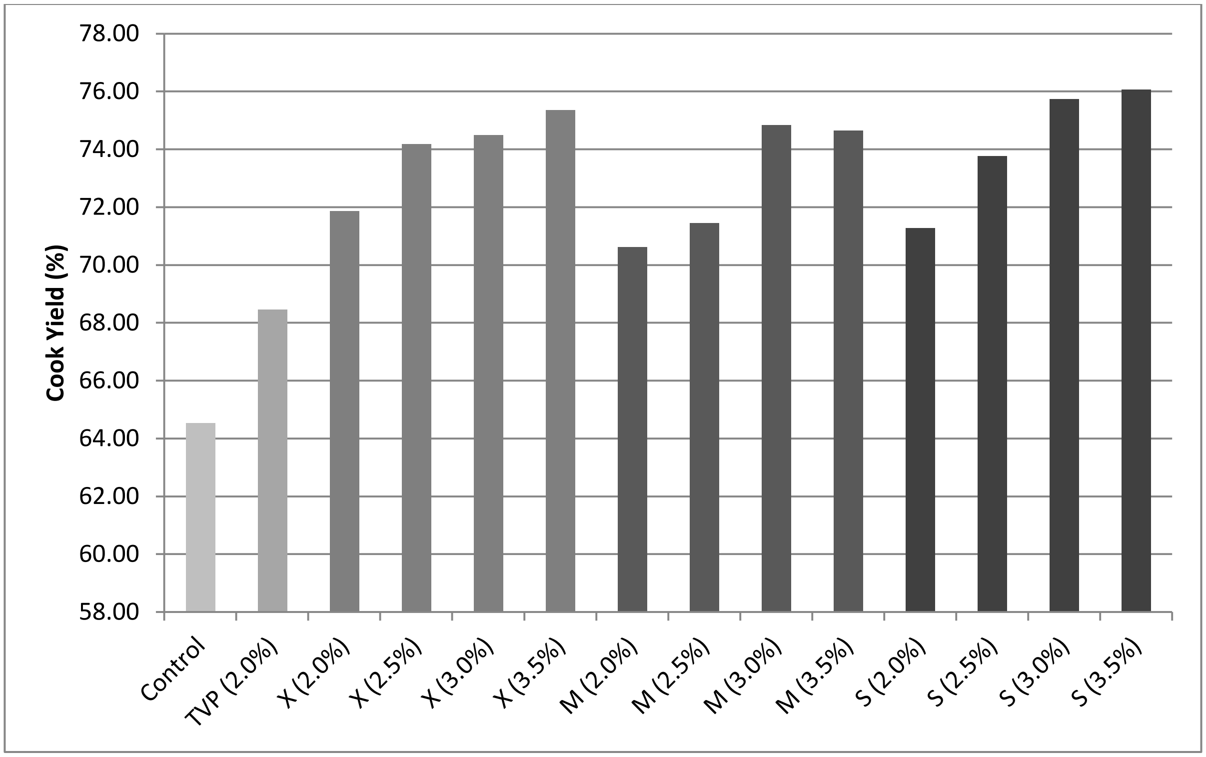
Table 4.10
Demographics of top round steak consumer panelists

	n	%
Age		
18-19	1	1.6
20-29	35	56.5
30-39	8	12.9
40-49	4	6.5
50+	14	22.6
Gender		
Male	26	41.3
Female	37	58.7
Beef meals/wk[1]		
0 to 1	15	23.8
2 to 4	37	58.7
5 to 7	9	14.3
8+	2	3.2
Most consumed[2]		
Ground	31	42.5
Roast	8	11.0
Steak	30	41.1
Other	4	5.5

For 1 and 2, consumers were asked:
1. Please indicate the number of meals a week in which you consume beef: 0-1, 2-4, 5-7, or 8+
2. Please indicate the form in which you most commonly consume beef: ground, roast, steak, or other

Appendix A

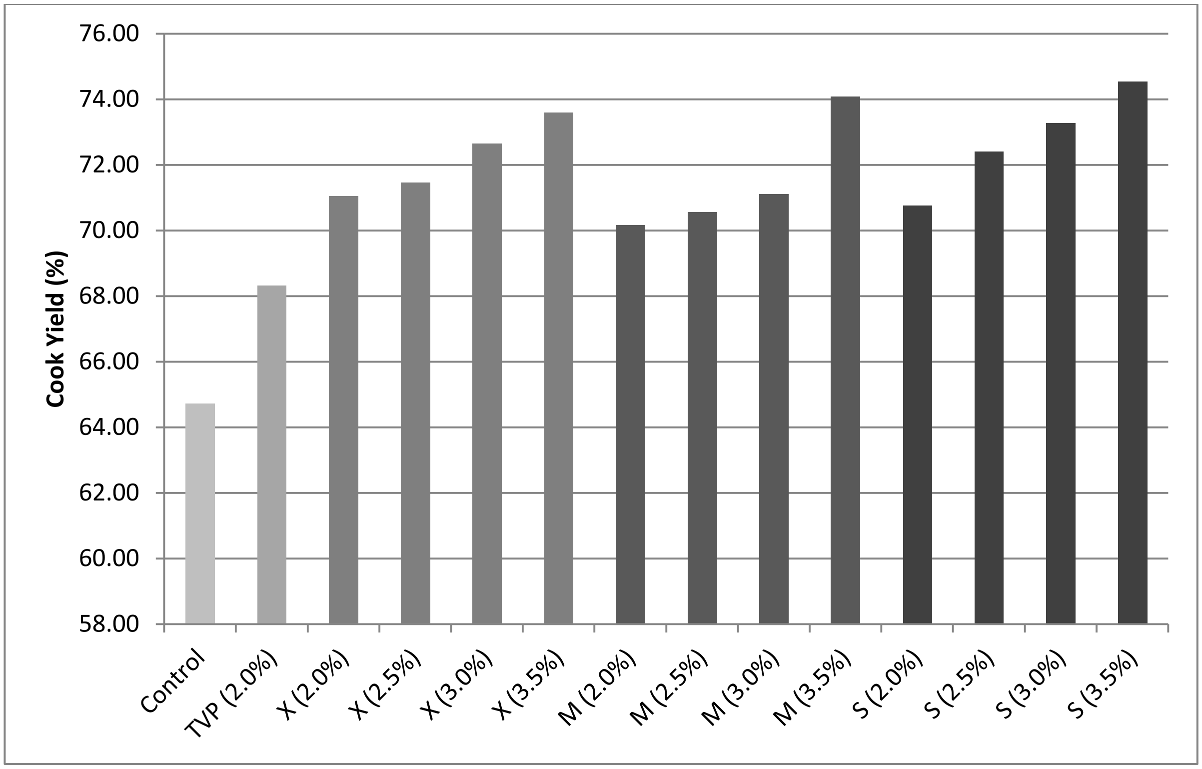
Preliminary results: effect of percent potato extract on percent cook yield of beef patties



Percent cook yield of beef patties with binders. Patties were made with Control (no binder) or 2% TVP (soy flour), or X ((X-TEND™) potato extract), M ((X-TEND™ M) potato extract with mustard), or S ((X-TEND™ S) potato extract with sodium acid pyrophosphate). Six patties were weighed from each treatment batch to determine patty weight before and after cooking. Percent cook yield was determined as cooked weight / raw weight X 100. The mean percent cook yield is shown for each treatment. No statistical analyses were conducted because data reflect measurements on one batch per treatment.

Appendix B

Preliminary results: effect of percent potato extract on day 4 retail display percent cook yield of beef patties



Percent cook yield of retail display beef patties with binders. Patties were made with Control (no binder) or 2% TVP (soy flour), or X ((X-TEND™) potato extract), M ((X-TEND™ M) potato extract with mustard), or S ((X-TEND™ S) potato extract with sodium acid pyrophosphate). Six patties were weighed from each treatment batch to determine patty weight before and after cooking. Percent cook yield was determined as cooked weight / raw weight X 100. The mean percent cook yield is shown for each treatment. No statistical analyses were conducted because data reflect measurements on one batch per treatment.

Appendix C

Preliminary results: effect of percent potato extract on TBARS

TBARS[1] of beef patties with binders

	Retail Display		Frozen Storage	
Treatment	Day 0	Day 4	Day 0	Day 21
Control	2.5	3.3	1.1	2.7
TVP[2] (2.0%)	1.2	1.4	0.8	1.4
X[3] (2.0%)	1.6	2.4	0.9	1.6
X (2.5%)	1.5	2.4	1.0	2.0
X (3.0%)	1.5	2.4	0.9	2.1
X (3.5%)	2.0	1.9	0.9	2.0
M[4] (2.0%)	0.9	0.9	0.7	1.2
M (2.5%)	0.9	0.9	0.7	1.2
M (3.0%)	0.9	1.1	0.7	0.8
M (3.5%)	0.9	0.8	0.7	0.9
S[5] (2.0%)	0.8	2.3	0.7	1.4
S (2.5%)	0.9	2.0	0.7	1.3
S (3.0%)	0.8	1.7	0.7	1.5
S (3.5%)	0.8	1.5	0.7	1.1

[1] TBARS = mg malondialdehyde/kg meat. Mean values of 6 patties from one batch

[2] Textured vegetable protein (soy flour)

[3] X-TEND™ (Potato extract)

[4] X-TEND™ M (Potato extract with mustard)

[5] X-TEND™ S (Potato extract with sodium acid pyrophosphate)

Appendix D

TBARS for oxidative rancidity - rapid, wet method

TBARS for oxidative rancidity - rapid, wet method

Adapted from Appendix O (AMSA, 2012)

Principle:

In the presence of thiobarbituric acid (TBA), malonaldehyde and other aldehyde products of lipid oxidation (TBA reactive substances; TBARS) form pink chromogens with maximum absorbance at 532-535 nm. However, in the presence of interfering sugars, a yellow chromagen forms, which can be avoided using the distillation method (Tarladgis, 1960).

Reagents:

1. TBA stock solution - 0.375% thiobarbituric acid, 15% trichloroacetic acid, and 0.25N HCl.

2. Stock solutions (100 mL) are sufficient for 20 individual tests. Stock solution may be stored at room temperature in the dark (foil-wrapped container).

Procedure:

1. Finely chop or mince a portion of the product of interest. Weigh out duplicate 0.25 g samples.

2. Add 1.25 ml TBA stock solution to each sample, giving a dilution factor of 6. Mix well.

3. Heat samples 10 min in boiling water in loosely capped 2.0 ml eppendorf tubes Caution: tightly capped tubes may burst during heating. Positive samples turn pink during heating.

4. Cool tubes in tap water.

5. Centrifuge at 5,000 × g for 10 min to obtain a clear supernatant.

6. Carefully pipette 200 µl of the supernatant to a 96 well plate. Take care that the solution remains clear.

7. Measure supernatant absorbance at 532 nm against a blank that contains all the reagents minus the meat.

8. Calculate the TBA value expressed as ppm malonaldehyde, using 1.56×10^5/M/cm as the extinction coefficient of the pink TBA chromogen (Sinnhuber and Yu, 1958), as follows:
   TBARS number (mg MDA/kg) = sample A_{532} × (1 M TBA chromagen/156,000) × [(1mole/L/M] × (0.003 L/0.5 g meat) × (72.07 g MDA/mole MDA) × 1000 mg/g) × 1000 g/kg)
   or
   TBARS value (ppm) = sample A_{532} × 2.77

References:

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Appendix E

Beef Patty Sensory Panel Consent Form

Sensory Panel Consent Form

Product May Contain Soy

1. The University of Idaho Human Assurance Committee has reviewed and found this study to be exempt.

2. The objective of this study is to evaluate the incorporation of dried potato product on the palatability of pre-cooked hamburger patties. This research could potentially improve the shelf stability, palatability and value of meat products, and also improve safety by substituting potato product for ingredients that contain allergens. The samples will be prepared under the Research Guidelines for Cookery, Sensory Evaluation, and Instrument Tenderness Measurements of Fresh Meat, as outlined by the American Meat Science Association. This taste panel is part of research supported by a gift from Basic American Foods.

3. You will be asked to evaluate 5 samples (approximately ½" x 1" x 1") per session for texture (1 = dislike extremely to 9 = like extremely), juiciness (1 = dry to 9 = juicy), and flavor (1 = bland to 9 = intense) using a 9 point scale. It is not necessary that samples be ingested. The study should take approximately 15 to 20 minutes.

4. Although there are no or minimal risks associated with the project, it is possible that some samples will have one or more qualities that may not be appealing to you (e.g. texture or juiciness or flavor that is less desirable than you would prefer).

5. With your help society can benefit from our attempt to improve the palatability of relatively inexpensive beef for consumers.

6. We anticipate that samples will be well received by panelists. However, if we find during the course of the taste panel that samples are unappealing, we will stop the evaluation process.

7. To maintain anonymity of the data collected during this evaluation, all the information you provide will be placed in a locked file with Dr. Doumit.

8. If you have questions about the taste panel, you can ask the investigator during the evaluation, when the evaluation is complete or at a time you feel is appropriate.

9. Contact information for the University of Idaho faculty member leading this research:
   Dr. Matthew E. Doumit
   University of Idaho
   Department of Animal and Veterinary Science
   Moscow, ID 83844
   208-885-6007

10. During the course of this taste panel, you may terminate participation at any time. If you choose to do so, please notify the investigator that you no longer wish to participate.

11. If you choose to terminate participation in this evaluation, there will be no penalties associated with your withdrawal.

I have reviewed this consent form and understand and agree to its contents.

Participant Name: ______________________________________ Date: _____________________

Signature: ____ Date of Birth: ______________

Appendix F

Beef Patty Sensory Panel Demographics Questionnaire

EVALUATION OF BEEF QUALITY

Panelist #:__________ Date: __________

Age: ______________ Gender: ________

Please indicate the number of meals a week in which you consume beef:

0-1 2-4 5-7 8+

Please indicate the form in which you most commonly consume beef:

Ground Roast Steak Other

Appendix G

Beef Patty Sensory Panel Questionnaire

BEEF SENSORY PANEL QUESTIONAIRE

Sample ID #:__________

1. **OVERALL ACCEPTABILITY OF SAMPLE:** This is based on your overall acceptability of the sample

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

2. **TEXTURE:** This is based on your overall opinion of the sample's texture

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

3. **JUICINESS:** This is based on your overall opinion of the sample's juiciness

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

4. **FLAVOR:** This is based on your overall opinion of the sample's flavor

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

5. **OFF-FLAVOR:** This is based on your ability to detect an off-flavor of the sample

NO YES

6. **CONSUMER SATISFACTION:** Would you be willing to purchase this product?

NO YES

7. **IF APPLICABLE,** please circle the trait you liked **least** about this product.

Flavor Juiciness Texture/Mouth Feel

8. **IF APPLICABLE,** please circle the trait you liked **most** about this product.

Flavor Juiciness Texture/Mouth Feel

9. **Overall Comments on Product:**

Thank you for taking the time to participate in this sensory panel

Appendix H

Frankfurter Sensory Panel Consent Form

Sensory Panel Consent Form

Product May Contain Soy

1. The University of Idaho Human Assurance Committee has reviewed and found this study to be exempt.

2. The objective of this study is to evaluate the incorporation of dried potato product on the palatability of chicken frankfurters. This research could potentially improve the shelf stability, palatability and value of meat products, and also improve safety by substituting potato product for ingredients that contain allergens. The samples will be prepared under the Research Guidelines for Cookery, Sensory Evaluation, and Instrument Tenderness Measurements of Fresh Meat, as outlined by the American Meat Science Association. This taste panel is part of research supported by a gift from Basic American Foods.

3. You will be asked to evaluate 4 samples (approximately ½" wide x 1" diameter) per session for texture (1 = dislike extremely to 9 = like extremely), juiciness (1 = dry to 9 = juicy), and flavor (1 = bland to 9 = intense) using a 9 point scale. It is not necessary that samples be ingested. The study should take approximately 10 to 15 minutes.

4. Although there are no or minimal risks associated with the project, it is possible that some samples will have one or more qualities that may not be appealing to you (e.g. texture or juiciness or flavor that is less desirable than you would prefer).

5. With your help society can benefit from our attempt to improve the palatability of relatively inexpensive frankfurters for consumers.

6. We anticipate that samples will be well received by panelists. However, if we find during the course of the taste panel that samples are unappealing, we will stop the evaluation process.

7. To maintain anonymity of the data collected during this evaluation, all the information you provide will be placed in a locked file with Dr. Doumit.

8. If you have questions about the taste panel, you can ask the investigator during the evaluation, when the evaluation is complete or at a time you feel is appropriate.

9. Contact information for the University of Idaho faculty member leading this research:
   Dr. Matthew E. Doumit
   University of Idaho
   Department of Animal and Veterinary Science
   Moscow, ID 83844
   208-885-6007

10. During the course of this taste panel, you may terminate participation at any time. If you choose to do so, please notify the investigator that you no longer wish to participate.

11. If you choose to terminate participation in this evaluation, there will be no penalties associated with your withdrawal.

I have reviewed this consent form and understand and agree to its contents.

Participant Name: _____________________________________ Date: _____________________

Signature: ____ Date of Birth: ______________

Appendix I

Frankfurter Sensory Panel Demographics Questionnaire

EVALUATION OF FRANKFURTER QUALITY

Panelist #:___________ Date: ___________

Age: _______________ Gender: _________

Please indicate the number of meals a week in which you consume frankfurters or sausages:

0-1	2-4	5-7	8+

Appendix J

Frankfurter Sensory Panel Questionnaire

FRANKFURTER SENSORY PANEL QUESTIONAIRE

Sample ID #:__________

6. **OVERALL ACCEPTABILITY OF SAMPLE:** This is based on your overall acceptability of the sample

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

7. **TEXTURE:** This is based on your overall opinion of the sample's texture

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

8. **JUICINESS:** This is based on your overall opinion of the sample's juiciness

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

9. **FLAVOR:** This is based on your overall opinion of the sample's flavor

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

10. **OFF-FLAVOR:** This is based on your ability to detect an off-flavor of the sample

NO YES

6. **CONSUMER SATISFACTION:** Would you be willing to purchase this product?

NO YES

7. **IF APPLICABLE,** please circle the trait you liked **least** about this product.

Flavor Juiciness Texture/Mouth Feel

8. **IF APPLICABLE,** please circle the trait you liked **most** about this product.

Flavor Juiciness Texture/Mouth Feel

9. **Overall Comments on Product:**

Thank you for taking the time to participate in this sensory panel

Appendix K

Top Round Steak Sensory Panel Consent Form

Sensory Panel Consent Form

1. The University of Idaho Human Assurance Committee has reviewed and found this study to be exempt.

2. The objective of this study is to evaluate the incorporation of dried potato product on the palatability of beef top round steak. This research could potentially improve the shelf stability, palatability and value of meat products. The samples will be prepared under the Research Guidelines for Cookery, Sensory Evaluation, and Instrument Tenderness Measurements of Fresh Meat, as outlined by the American Meat Science Association. This taste panel is part of research funded by the Idaho Beef Council and a gift from Basic American Foods.

3. You will be asked to evaluate 4 samples (approximately 1” x ½” x ½”) per session for tenderness (1 = extremely tough to 9 = extremely tender), juiciness (1 = dry to 9 = juicy), and flavor (1 = bland to 9 = intense) using a 9 point scale. It is not necessary that samples be ingested. While all samples are safe to ingest, you may evaluate the sample and then expectorate rather than ingest the sample if you choose. The study should take approximately 10 to 15 minutes.

4. Although there are no or minimal risks associated with the project, it is possible that some samples will have one or more qualities that may not be appealing to you (e.g. tenderness or juiciness that is less than you would prefer).

5. With your help, society can benefit from our attempt to improve the palatability of beef.

6. We anticipate that samples will be well received by panelists. However, if you find during the course of the taste panel that samples are unappealing, you may stop the evaluation process at any time.

7. To maintain anonymity of the data collected during this evaluation, all the information you provide will be placed in a locked file with Dr. Doumit.

8. If you have questions about the taste panel, you can ask the investigator during the evaluation, when the evaluation is complete or at a time you feel is appropriate.

9. Contact information for the University of Idaho faculty member leading this research:
   Dr. Matthew E. Doumit
   University of Idaho
   Department of Animal and Veterinary Science
   Moscow, ID 83844
   208-885-6007

10. During the course of this taste panel, you may terminate participation at any time. If you choose to do so, please notify the investigator that you no longer wish to participate.

11. If you choose to terminate participation in this evaluation, there will be no penalties associated with your withdrawal.

I have reviewed this consent form and understand and agree to its contents.

Participant Name: _____________________________________ Date: _____________________

Signature: ____ Date of Birth: ______________

Appendix L

Top Round Steak Sensory Panel Demographics Questionnaire

EVALUATION OF BEEF QUALITY

Panelist #:__________ Date: __________

Age: ______________ Gender: ________

Please indicate the number of meals a week in which you consume beef:

0-1 2-4 5-7 8+

Please indicate the form in which you most commonly consume beef:

Ground Roast Steak Other

Appendix M

Top Round Steak Sensory Panel Questionnaire

BEEF SENSORY PANEL QUESTIONAIRE

Sample ID #:__________

11. OVERALL ACCEPTABILITY OF SAMPLE: This is based on your overall acceptability of the sample

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

12. TENDERNESS: This is based on your overall opinion of the sample's tenderness

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

13. JUICINESS: This is based on your overall opinion of the sample's juiciness

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

14. FLAVOR: This is based on your overall opinion of the sample's flavor

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
(Dislike extremely) (Like extremely)

15. OFF-FLAVOR: This is based on your ability to detect an off-flavor of the sample

NO YES

6. **CONSUMER SATISFACTION:** Would you be willing to purchase this product?

NO YES

7. **IF APPLICABLE,** please circle the trait you liked **least** about this product.

Flavor Tenderness Juiciness Texture/Mouth Feel

8. **IF APPLICABLE,** please circle the trait you liked **most** about this product.

Flavor Tenderness Juiciness Texture/Mouth Feel

9. **Overall Comments on Product:**

Thank you for taking the time to participate in this sensory panel