DEVELOPMENT AND EVALUATION OF RAW AND PRE-COOKED VACUUM PACKAGED GOAT MEAT PRODUCTS

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
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Production of value added raw and heat and serve goat meat products could increase demand, consumption, acceptability, and marketability of goat meat. The objectives of this study were to develop and evaluate proximate composition, pH, sensory and microbiological characteristics of refrigerated value-added vacuum packaged raw, and heat and serve goat rib products. Four goat rib formulations were evaluated for each product. The formulations were evaluated for each product. The formulations included control (goat ribs, no additives), goat ribs in apple cider vinegar marinade, goat ribs with external only spice rub, and goat ribs in apple cider vinegar plus external spice rub. After formulation, all goat ribs are vacuum packaged and stored at $4 \pm 1^{o}C$ for 21 days (raw goat rib products), and 42 days (heat and serve goat rib products). The products were analyzed for proximate composition, pH, microbiology (fecal coliforms, aerobic plate counts, psychrotroph counts, anaerobic plate counts), cost analysis for both products. Thiobarbituric acid reactive substances and lactic acid bacteria analysis were conducted for the heat and serve products only. Trained and consumer panelists evaluation were performed. Overall tenderness and goat flavor intensity was evaluated for both products (raw and heat and serve goat ribs). Consumer panelists evaluated goat flavor intensity, overall flavor, texture, overall acceptance, and the purchase intent as sensory characteristics.

The trained panelists found differences among the four treatments regarding overall tenderness (vacuum packaged raw goat ribs). Overall tenderness varied from slightly tender to moderately tender. The ribs were rated slightly tender, and the marinated- spice rub ribs were rated moderately tender. The pH values varied between 5.79 and 6.40. pH values for treatments with goat ribs plus marinade and goat ribs plus marinade with externally applied spice rub were significantly lower ($P < 0.05$) than values for control, and goat ribs plus externally applied spice rub. Moisture values varied between 65.37% and 67.64% and were not significantly different between treatments. No significant increase ($P > 0.05$) in aerobic plate counts was revealed over time, through 21 days storage, for the goat ribs that were marinated or marinated and rubbed with spice. A similar trend was observed for psychrotrophic microorganisms. The addition of marinade with and without the spice rub resulted in significantly lower ($P > 0.05$) anaerobic counts.

CHAPTER 1
INTRODUCTION

Goat meat is one of the most consumed red meats worldwide, except for the United States. According to the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS, 2006), the dairy, fiber, meat, 4-H, industrial, and biotech goat inventory in the United States accounted for 2.93 million head in 2007, a boost of 5 percent when compared to 2006. In addition, meat and all other goats (meat, 4-H, industrial, and biotech) accounted for 2.40 million head (5% increase from 2006). The demand for goat meat is on the rise. This trend was extensively researched and documented in Florida (Degner and Locascio, 1988, Johnson, 1989). The increase was mainly due to the growth of ethnic populations and also the awareness of health conscious consumers of lower fat in chevon compared to other red meats. In addition, consumers also demand convenient products that will require the least time in the kitchen.

This research project had for goal to add value to goat meat by either vacuum packaging a marinated raw goat rib product, or vacuum packaging a marinated heat and serve goat product rib. The consumer will only have to bake and microwave or boil the value-added goat rib products. The objectives of this study were to develop refrigerated value-added vacuum packaged raw goat ribs, evaluate proximate, pH, sensory and microbiological characteristics of four different formulations of raw goat ribs, develop a convenient and marketable refrigerated vacuum packaged heat and serve goat meat rib product, and evaluate proximate, pH, TBARS, sensory and microbiological characteristics of the heat and serve products. Cost analysis was performed on the vacuum packaged raw and heat and serve goat ribs to determine affordability for the consumers.

CHAPTER 2
LITERATURE REVIEW

Meat Goats

Capra aegagrus hircus (domestic goat) is a member of the bovine family and is closely related to the sheep. *Capra aegagrus hircus* is one of the oldest domesticated species. Cave art 10,000 to 20,000 years ago indicates that goats were common and important (USDA FSIS, 2006). For thousands of years, they have been utilized for their milk, meat, hair, and skin all over the world. Goat meat, called chevon (from the French word for the animal chèvre), is said to be similar in taste to veal or venison, depending on the age of the goat (Wikipedia Foundation, 2006).

Except for the United States, goat is one of the most consumed red meats worldwide. However, it is being gradually introduced to consumers in the United States. Chevon has become an established term for goat meat, originally applied to Angora goat meat and emanates from the United States. Cabrito, a term derived from Spanish refers to goat kid, and is a delicacy in Central and South Americas (Casey, 1992). Religious preferences, social customs and dietary considerations shape the consumption patterns in the U.S.A. Immigrants from Asia and Africa consume more goat meat than immigrants from Europe, especially developed Europe. (USDA, APHIS, 2005). Native African-American and Caucasian populations tend to consume goat meat on special occasions such as 4th of July, Easter, and Muslim holidays (Fraser, 2004). The demand for goat meat peaks during Easter, according to the National Agricultural Statistics Service (NASS) weekly data (Gipson, 1999). According to the Food and Agriculture Organization (2003), goat population worldwide accounted for 743,374,300 head, with 440,291,400 produced by developing countries. The state of Florida produced 65, 000 meat and other goats at the end of 2006. There was an increase of 8.33% in the Florida meat and other goat

production between 2005 and 2006 (USDA NASS, 2007). The patterns of consumption also vary by ethnic and cultural preferences. Muslims and Jews require their meat slaughtered to religious standards. Most prefer their meat fresh but many are willing to accept frozen imported meat (Fraser, 2004). The weight and gender of the goat is determined by the holiday (Agricultural Marketing Resource Center, 2006). Milk-fed kid weighing 13.60 kilograms is ideal for Easter, while male or female kids weighing 27.21 kilograms are desired for Ramadan (Muslim holiday). Weights between 20.41 and 54.43 kilograms are also accepted for Ramadan. Goats weighing 27.21 to 36.28 kilograms are marketed during Caribbean, and Chinese holiday, while the Latino market desires a suckling kid (cabrito) weighing 9.07 to 15.87 kilograms. (Agricultural Marketing Resource Center, 2006). There are various ways to prepare goat meat all around the world. Goat meat could be stewed, baked, grilled, barbecued, minced, canned or transformed into sausage, or jerky. (Wikipedia Foundation, 2007).

The value of goat meat in the United States is affected by the seasonal availability of live goats, with the price per pound of goat meat being highest in late winter and early spring (Pinkerton and McMillin, 2005). The highest price also coincide with religious and ethnic holiday dates (Pinkerton, 2002) whereas the lowest prices are in the summer when the demand is least and supply is greatest (Farris, 2003).

Availability and Demand

The growing meat goat industry has found a perfect environment in the Southeastern United States. The demand is on the rise. According to the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS, 2006), the dairy, fiber, meat, 4-H, industrial, and biotech goat inventory in the United States accounted for 2.93 million head in 2007, a boost of 5% when compared to 2006. In addition, meat goats used for 4-H, industrial, and biotechnology accounted for 2.40 million head (5% increase from 2006). According to the

2002 USDA NASS Agricultural Census, Texas had the largest population of goats (47%) reported in the U.S. inventory (USDA NASS, 2006). The IBISWorld (2005) industry report revealed that there are four segments that form the goat industry: goat meat (meat processors), mohair and cashmere (textile mills), breeding goats (other farmers), and goat milk sale. The major segment is constituted by goats sold for slaughter purposes.

The goat industry is located in two major regions in the United States: South West region (52.6% of the goat population), and the South East region (23.1% of the goat population) (IBISWorld, 2005). According to Gipson (1999), the Southeastern United States is well positioned geographically to supply goats to Florida and urban Northeast states (area of high demand). Texas is by far the major state for goat farming (47.2% of all goats in the U.S.). Texas' suitability to raising goats (mild dry climate, mountain terrain, low average cost of land) allowed the production of meat, dairy, and fiber goats (IBISWorld, 2005)

In 1977, the first year that USDA began keeping statistics for goats slaughtered at federally inspected plants, approximately 35,000 goats were slaughtered nationwide. Total federally inspected goats have increased from 81,000 head in 1983 to 666,000 head in 2004. Growth has been steady since 1983, with Texas and New Jersey leading the federally inspected slaughter capacity (USDA APHIS, 2005). Between 1997 and 2002, the meat and other goats (4-H, Industrial, Biotech) segments grew 87% in inventory, while the total growth in population for the entire goat industry was 23% (USDA NASS, 2002). 4-H goats are used for youth education in animal health, care and constructive self-image. Industrial goats are used for ground cover management, as pack animals to control weeds and allow access in remote areas of wilderness. Biotech goats are used for the production of biotechnological products (USDA APHIS, 2005). Meat and other goats accounted for 51,500 head in 2005, and increased to 55,000 the following

year in the state of Florida (USDA NASS, 2006). USDA APHIS (2005) estimated the total goat slaughter in 2003 to be 666 thousand head. Federally inspected goat slaughter has been dominated by Texas (18%) and New Jersey (30%). In Florida (2004 fiscal year), 15,093 head of goats were slaughtered in federally inspected facilities (USDA APHIS, 2005).

This increasing demand for goat meat was made known in a national benchmark study funded by Winrock International (1986) in "Strategies for Expanding Goat Meat Production, Processing, and Marketing in the Southeastern U.S.". This trend was extensively researched and documented in Florida (Degner and Locascio, 1988, Johnson, 1989). The increase was mainly due to the growth of ethnic populations and also the awareness of health conscious consumers of lower fat in chevon compared to other red meats. The three largest goat consuming ethnic populations are Hispanics, Muslims and the peoples from the Caribbean. The strongest demand for goat meat is along the eastern coast, Southern California, Florida, Detroit, and the northeast region stretching from Washington, D.C. to Boston (McKenzie-Jakes, 2004). The demand for goat meat in the United States is concentrated in areas with ethnic populations that use goat as a traditional staple (Hansen, 2003). Urban demographic growth is proportionally related to the urban consumption of goat meat. However, because of low innovation, urban inhabitants prepare goat meat with difficulty. The ability of manufacturers to process goats into products, and the capability of the farmers to supply goats consistently influence the availability of products (IBISWorld, 2005).

Nutritional Comparison of Meat Goats and Red Meat

Goat meat is a high quality protein source, and is considered red meat. A study conducted by University of Florida and Florida Agricultural and Mechanical University (Johnson , 1995) employed three meat goat breeds of six to eight months of age: Florida natives, Nubian x Florida natives,and Spanish x Florida natives. There was no significant effect from the sex or the breed

type on carcass yield. Even though breed did not have an effect on fat-free yield, sex class did influence fat-free lean deposition where intact male goat carcass had 3 percent more fat-free muscle mass than castrated and female goat carcasess (Johnson, 1995). Breed type and sex class affected the total fat deposition on the goat carcasses (Johnson,1995; Mahgoub et al., 2004). Colomer-Rocher et al. (1992) reported goat carcasses from intact males to have higher contents of muscle and lower contents of fat than carcasses from females. A nutrient profile analysis of the goat meat carcass composites suggested a similarity to chicken in total grams of fat, percent of calories from fat, and cholesterol. Iron content was 2.2mg for broiled goat meat and beef, and 1.1mg for chicken. (Johnson,1995).

Kids (goats under a year of age) are often slaughtered at 3 to 5 months of age and weighing from 25 to 50 pounds. Kids do not store significant body fat until they are about a year old. The meat of older goats is darker and less tender, but juicier and full of flavor when compared to kids' meat.

Goat tend to have lower dresssing percentage and different carcass proportions when compared to sheep (Webb et al., 2005). Goat meat from Angora (no age) was found to be less tender, have more residues, shear force resistance, collagen content than Boer goats (no age) (Schönfeldt et al., 1993a,b). In contrast, Smith et al. (1978) found that loin chops and leg roasts from Angora and Spanish goats from the same age had the same juiciness. He also suggested that conformation and breed may have a consequence on the effect of age on meat properties. Low conformation leg slices from yearling goats and kids were less tender than leg meat from kid goats with medium or high conformation (Phelps et al., 1999). "Mestiço" or hybrid goat age varying from 175 to 310 days decreased organoleptic properties such as tenderness, appearance, aroma, flavor, juiciness, and overall palatability (Madruga et al., 2000).

Sen et al. (2004) also reported that goat meat was less tender than sheep meat, although juiciness, and overall palatability were not different. Casey et al. (2003) reported preferential order in the deposition of adipose tissue in goat with visceral fat first, followed by intermuscular, subcutaneous and intramuscular fat. The highly variable fat content is being influenced by factors such as age, sex, nutrition, body weight growth rate, physiological condition, and physical actvity (Owen et al., 1978; Kirton, 1988).

Microbiology of Goat Meat

Meat is defined as "the part of the muscle of any cattle, sheep, swine, or goats which is skeletal or which is found in the tongue, diaphragm, heart, or esophagus, with or without the accompanying and overlying fat, and portions of bone (in bone-in product such as T-bone or porterhouse steak), skin, sinew, nerve, and blood vessels which normally accompany the muscle tissue and that are not separated from it in the process of dressing" (Code of Federal Regulations 9CFR301.2, 2006). It is animal tissues that are suitable for use as food and it includes processed foods prepared from those tissues (Aberle et al., 2001). Meat and meat products are very perishable. Deterioration begins soon after exsanguination, resulting in microbial, chemical and physical changes. The initial microbial load plays a role in the determination of the food product's shelf-life. Three major microorganisms found in meat are fungi, mold, and bacteria (being a major source of contamination). The molds and yeast growing on meat are aerobic. Bacteria thriving in meat could be aerobic, anaerobic or facultative. During refrigerated storage some genera of bacteria found on meat and poultry are mainly *Pseudomonas, Moraxella, Psychrobacter* and *Acinetobacter* on the surface, followed by *Aeromonas, Shewanella, Micrococcus, Lactobacillus, Streptococcus, Leuconostoc, Pedicoccus, Flavobacterium*, and *Proteus* (Aberle et al., 2001). The process of freezing decreases the number of microorganisms during storage. Species of the above genera can survive this process and resume growth

following thawing (Forrest et. al, 1975). Some additional organisms of concern associated with meat in general are *Salmonella, Escherichia coli, Campylobacter jejuni, Listeria monocytogenes, Staphylococcus aureus* (Romans et al., 1994). Srivastava et al. (1981) analyzed frozen goat meat for microbes and toxin production by *Bacillus cereus*. No *Salmonella, Staphylococci,* yeast nor mold was found. There was an increase in psychrophiles as a function of storage. A surprising increase of mesophiles (*Streptococci*) was detected. *Enterobacter* sp., *Escherichia coli, Klebsiella* sp. and *Bacillus cereus* were isolated from the frozen goat meat (Srivastava et al., 1981; Sinha and Mandal, 1977). Cooked goat meat was then served to six human volunteers to study toxin production. Fourteen hours after the ingestion of the meat, only one person developed stomach ache, nausea and mild diarrhea. Those results support "in vivo" study performed on mice (Srivastava et al., 1981).

Production of Meat Goats

Meat goat production is increasing because of the goat's economic value as efficient converter of low quality forages into quality meat, milk, and hide products for specialty markets (The Pennsylvania State University, 2000). Goats are also very efficient regarding the conversion of browse pasture to lean tissue because of their inclination to browse on bushes, brushes, and weeds (Small Farms Research Center Alabama A & M University, 2005). Casey (1988) and Wheaton (1993) reported an average daily weight gain to be 300gm for lambs and 227 gm for goats during pre-weaning period on grass with some supplementation.

There are around eleven breeds of goats raised within the U.S. for meat (USDA APHIS, 2005). Except for the South African Boer goat imported from New Zealand, there are no true meat goat breeds in the U.S. (Luginbuhl, 1998; Pinkerton et al. 1991). Spanish goats are one of the breeds that stand out as more specialized for meat production. The Spanish goat is originally from Spain via Mexico to the U.S. It is now the predominant meat type goat found in Central

Texas around the Edwards Plateau. It has the ability to breed out of season and is an excellent range animal. It has recently been bred intensively to improve meat characteristics (Luginbuhl, 2000). The Boer goat of South Africa owes its name to the Dutch word “boer” meaning “farm” and was introduced to the United States in 1993 (Coffey, 2002; USDA APHIS, 2005). The present Boer goat emerged in the 20th century, when South African farmers began breeding for a meat goat with good conformation, high growth rate and fertility, short white hair and red markings on the head and neck. Other types of goats bred for meat are Myotonic or “Fainting goat”, Nubian (dairy and meat), and Kiko (Luginbuhl, 1998).

Meat goat production requires following good husbandry practices in the areas of sanitation, health, feed, water, and shelter. Female goats are referred to as “does”, doelings”, or “nannies”. Males are “bucks”, “billies” or “bucklings”. Castrated males are identified as wethers. Young goats are called “kids”. Goats adapt well to hot environments because of their small size and higher ratio of body surface area to body weight. In addition, their ability to conserve body water, their limited subcutaneous fat cover, and their hairy coats are good survival traits under desert like conditions. Goats are inclined to forage or browse from the top of a plant downward. Their plant diet is extremely varied and includes some species which are toxic or detrimental to cattle and sheep. This makes them valuable for controlling noxious weeds and clearing brush and undergrowth. They will seldom eat soiled food or water unless facing starvation (Wikipedia Foundation, 2006).

Breeding occurs from September to November for spring kidding (Stanton, 2005). Goats are seasonally polyestrous with estrous cycles every 20 to 21 days from July through January. Tropical breeds of goats may cycle year-round. Goats reach sexual maturity at five to nine months, but it is not recommended to breed them until they have reached 60 percent of their

adult weight, or one year of age. With proper nutrition and management, three kid crops every two years are possible. An ideal management scheme would be to breed in February, then again in September. A buck may breed 50 to 200 does in a single breeding season, but it is recommended that three or four bucks be put with 100 does. Bucks should be changed often to prevent inbreeding in the flock (at least every two years) (Alford et al., 1998). The gestation period varies from 147 to 155 days, the average being 149 days, but five months on average. Does generally deliver two kids averaging four to six pounds each with one or three kids not uncommon. The best mating system consists of exposing the does during February and March, removing them, and placing them with the males (bucks) in September, October.

Marketing of Goat Meat

A marketing channel describes the movement of a product or commodity from the site of production to the place of consumption. It may include transportation, handling and storage, ownership transfers, processing, and distribution (Pinkerton et al., 1991). Consumer demands are met through different marketing channels that include: direct sales, wholesale and retail markets, or restaurants, specialty markets (freezer market, ethnic/religious market, gourmet market).

Some ethnic or religious groups such as Africans and Muslims prefer to slaughter goats themselves. Most consumers obtain their goat meat from wholesalers and retailers, who in turn purchase their meat from USDA inspected processing facilities or importers. Goat meat is served in ethnic restaurants but is a rare delicacy in mainstream restaurants (Fraser, 2004).

One of the greatest challenges to the meat goat industry is reaching mainstream consumers rather than only ethnic groups. There are few places where goat meat is sold wholesale or retail. Because of a lack of familiarity, goat is difficult to sell in supermarkets because consumers lack cooking preparation knowledge (Alford et al., 1998). A promising strategy to implement is to target the foodservice sector (restaurants). If this is to be done, it is

imperative to ensure a constant, high quality supply of goat meat at a stable price. Marketing goat meat in restaurants, could also encourage consumers to purchase goat for home preparation (Alford et al., 1998).

The percentage of fat in meat depends on many factors such as the animal specie, the diet, the meat cut, the degree of trimming of fat, the cooking or processing technique (Jimenez-Colmenero et al., 2001). The amount of cholesterol in lean red meat, where fat had been trimmed, is low when compared to the amount produced by the human body each day (Swize et al., 1992; Chizzolini et al., 1999; Jimenez-Colmenero et al., 2001).

Acceptability of Goat Meat

Individuals consume meat in order to obtain some satisfaction that is influenced by psychological and sensory responses (product appearance, price, aroma, flavor, tenderness, juiciness, nutritive value) (Aberle, 2001). Flavor has a great influence on the sensory quality of muscle foods, consequently on its overall acceptability (Shahidi, 1994).

Smith et al. (1974) compared sensory characteristics of goat meat with meat from pork, beef and lamb. Goat meat had the same juiciness, but less tenderness and less overall satisfaction, when compared to pork, beef, and lamb at comparable maturity and fatness. Goat meat has a distinct flavour and aroma when compared to lamb and muttons studies on chemical composition and meat quality revealed that goat meat was not inferior to lamb (Schönfeldt et al., 1993a, 1993b; Casey et al., 2003; Sheradin et al., 2003a, b; Webb et al., 2005). Smith et al. (1974) reported that goat meat was not significantly different from beef or lamb in flavor desirability when oven-baked rib or loin samples were evaluated by untrained panelists. Meat that is cooked and then stored refrigerated is susceptible to oxidation of lipids and phospholipids, known as warmed-over flavor (Cross et al., 1987). A major quality spoiler of stored foods is attributed to off-odors and –flavors of oxidative rancidity (chemical change in an unsaturated

bond of a fat or oil). The cooking yield and shear of goat leg chops were similar for broiling and microwaving, but broiled chevon chops were darker and lower in fat (James and Berry, 1997). By observation, higher surface temperature in broiling may have been responsible for the significantly darker surface color (the electric oven was pre-heated to 191°C, with the meat products being cooked to an internal temperature of 75°C). No significant difference was observed in the shearing of the samples, suggesting no differences between broiled and microwaved samples (James and Berry, 1997). Cooking losses were highest in leg cuts, intermediate in shoulder/arm cuts, and lowest in loin/rib cuts (Kannan et al., 2001).

Goats and sheep belong to the family of Bovidae and the subfamily of Caprinae. Extensive work has been done on sheep meat and its chemistry and flavor. Shahidi (1998) determined that sheep meat has a inherent characteristic odor and flavor associated with it. Hornstein and Crowe (1963) suggested that fat was responsible for the species flavor. (Brennand and Lindsay, 1982) determined fatty tissues were the most significant source of mutton flavors. Panelists were able to differentiate lamb from beef and from pork. In addition, Melton (1990) determined that meat flavor is influenced by fatty acid composition. Jacobson and Koehler (1963) named carbonyls as important contributors to mutton odor. Factors such as age, diet, breed, and sex may also influence the odor and flavor of sheep or goat meat (Shahidi, 1994). Flavor and odor can be masked by technologies such as marination, cooking, and curing. These technologies can be combined and their use can add value to meat products.

Value-added Product Technology

Value-added is defined as adding economic value to a product by changing its current place, time and from one set of characteristics to other characteristics that are more preferred in the marketplace (Boland and Bosse, 2006). Adding value is the process of changing or transforming a product from its original state to a more valuable state. Value-added refers to

products that have been changed in form, function, or grouping to increase their economic value and/or consumption appeal (USDA, 2004). Consumer food trends include convenience requirements, more meat, innovative dairy products, growth in ethnic foods and one-dish meals which include sandwiches, bowls, or cups as the entrees (Sloan, 2003). Convenience means less time for shopping, speed or ease of preparation, speed or ease of consumption, ready-to-eat or no preparation, or portability (McMillin and Brock, 2005). Consumers often are willing to pay higher prices for convenient versions of their favorite products (Information Resources Inc, 2002).

Value-added products are a means to provide convenience and economic profitability. Primary processing operations include tenderization, grinding, flaking, freezing, case ready fabrication and packaging, whereas examples of further processing are curing, smoking, marinating, injection, emulsifying, forming, and cooking (Pearson and Gillette, 1996). Some other additional processes include grinding, chopping, seasoning, heat treatment, water reduction and modified atmosphere packaging. Value-added product areas also would include irradiated products for microbial safety, precooked products for convenience, portioned and institutional items for uniformity, and nutritionally enhanced meat for healthfulness (McMillin and Brock, 2005).

Goat meat is usually sold as a whole carcass or in primal cuts (Kannan et al., 2001) to ethnic consumers (Degner and Locascio, 1988; Pinkerton, 2002). Adding value to goat meat through production and processing practices will increase the price of the meat (McMillin and Brock, 2005). The USDA Agricultural Marketing Service (AMS) Institutional Meat Purchase Specifications (IMPS) for Fresh Goat Series 11 Meat illustrates five cutting styles targeting institutional and retail buyers. The different cuts from the cutting styles consist of foreshank,

hindshank, neck, foresaddle, shoulder, outside shoulder, inside shoulder, rack, ribs, breast, back, loin, sirloin, and legs. (USDA AMS, 2006).

According to McMillin and Brock (2005), the potential for value-added goat meat items can be identified, but increasing the value to specific producers, processors, or consumers requires identification and communication with the target consumers. There are opportunities for direct marketing of live animals or meat to customers or increasing the availability of traditional fresh raw chilled meat for the growing ethnic population.

Rhee et al. (2003) developed plain meat loaves and chili prepared with ground goat or beef at 15% fat. Goat meat was differentiated from beef in samples containing the same amount of fat by consumer panelists because of the distinct taste of goat meat. James and Berry (1997) designed patties containing different percentages of chevon and beef. The most tender samples evaluated by the consumer panelists contained a combination of both meat types. Panelists (untrained and trained) found 20/80 chevon/ beef patties most flavorful, and the 100% chevon patties less flavorful. These findings suggest that in making a ground product containing chevon, a combination with beef will produce a desirable product for the consumers. Cosenza et al. (2003) developed a cabrito smoked sausage using goat meat alone, and combinations with soy protein concentrate. Fermented goat snack sticks were made using goat meat alone and in combinations with soy protein concentrate to reduce cost (Cosenza, 2003). Trained panelists and consumer panelists detected no differences between the products. All products were acceptable.

Gadiyaram and Kannan (2004) manufactured batches of chevon, beef, pork, and mixed-meat sausages with no added fat under identical conditions using a commercial sausage seasoning. Spanish goat carcasses, beef chuck, and pork leg cuts from different animals were used. All sausages were prepared in a conventional oven to internal temperature of 75°C. It was

suggested that chevon could be used to manufacture low fat sausages without influencing texture (Gadiyaram and Kannan, 2004). Kahan et al. (2006) evaluated five marinated goat meat products using apple cider vinegar, lime juice and water. The four different treatments were similar in goat flavor intensity and tenderness. Panelists rated the goat formulated with the lime juice marinade significantly lower in off-flavor when compared to the control meat without apple cider vinegar or lime juice. The main goals of marination have been considered to be tenderizing, flavoring, and enhancing the shelf life and safety of meat products (Björkroth, 2005). Meat flavor is improved when vinegar, oils, or both, in combination with spices are used. Water is chemically bound within the muscle tissue. Higher water holding capacity is equivalent to juicier, and more palatable sensory perceptions. Additional benefits include flavor enhancement through the addition of spices and flavorings (Sams, 2001).

Treatment of meat with spices and curing agent (nitrate, nitrite, sugar, sodium erythorbate, and salt) has been known since the mid-1920s (Tompkins, 1986). Marination, a method to increase shelf-life and improve flavor, texture and juiciness, is a process for infusing meat with savory ingredients (Toledo, 2001). It is the process of soaking foods in a seasoned, often acidic solution before cooking. “Marinate” may have originated from the Latin word “marine” and means soaking or pickling in salt brine (Björkroth, 2005). According to Toledo (2001), marination is a process for infusing meat with savory ingredients to improve flavor, texture and juiciness. The whole objective of the marination process is to uniformly disperse the functional ingredients throughout the muscle in the marinade. Marinades must be effectively incorporated and retained in the muscle in order to impart the desired effects of tenderness, juiciness and flavor impact in the cooked product. With time, this definition has been modified. In industrial systems, marination is accomplished by injection, tumbling or massaging. It can also contain

herbs and spices (Toledo, 2001). Sodium Chloride (NaCl) and Calcium Chloride (CaCl2) are substances commonly used in meat technology and meat marination to help bind water. According to Hamm (1960), Sodium Chloride moves the isoelectric point of meat proteins towards lower pH values, enhancing its water binding properties. A similar effect can be achieved by the addition of substances, which are capable of increasing pH value (phosphates, carbonates) and by the application of food acids (lactic, citric, ascorbic, tartaric and acetic acids) (Calhoun et al., 1996). The primary reason for using phosphates is to improve water-holding capacity which is the amount of moisture a piece of meat can maintain. The water-holding capacity varies with the muscle pH. Post-slaughter muscle pH drops from around 7.2 to between 5.3 to 5.7, right around the isoelectric point of the meat (about 5.4). In this state of neutral charge, muscle fibers are very close together, squeezing out moisture and leaving no room for added moisture. Adding positive or negative charges creates repulsion of the muscle fibers, sometimes referred to as “protein swelling”, that creates space in which water can be held (Foster, 2004).

McKenna et al. (2003) investigated sheep and goat meat production and utilization. Lamb loin chops were marinated by injection with water, cranberry juice, salt, black pepper- oleoresin, onion- oleoresin, marjoram- oleoresin, and rosemary- oleoresin, and applying a topical butter garlic spice rub (#144; A.C. Legg, Inc.). The chops were then packaged, retail displayed, consumer evaluated, microbiologically tested, and evaluated for lipid oxidation. Marination improved palatability characteristics of lamb chops and extended shelf life during retail display; but consumers preferred the appearance of non-marinated chops to those that were marinated.

Packaging Systems for Value-added Goat Products

Packaging is a coordinated system to prepare food products for transport, distribution, storage, retailing and consumption (Soroka, 2002). Its purpose is to protect, extend shelf-life,

provide convenience and communicate information. According to Rourke (2005), manufacturers of cooked meat products select packaging for two major reasons: preservation of product quality (appearance, flavor, odor and texture) and inhibition of microbial growth. In addition, customers are demanding consumer-friendly packaging such as easy open, recloseable, dual-ovenable and microwaveable. Mize and Kelly (2004) audited and reported the trends in fresh meat packaging at the retail level. In 2002, 69% of the linear footage of the self-service meat case was occupied by fresh meat and poultry. This figure declined to 63% in 2004, reflecting a growing conversion of meat items to products with greater consumer convenience such as fully cooked entrees, marinated meats, as well as hams and sausages. In 2004, 60% of the packages audited were case ready, which increased from 49% in 2002. Although literature was available on specific packaging systems for goat meat products, it will be expected that the majority of packages in the category of value-added meat packaging were still in a flexible film, and vacuum sealed state (Eilert, 2005). Fully cooked entrees are a category of products that have grown over the last five years. The majority of these products are packaged and cooked in a flexible heat stable film, with a variety of secondary packages around the product. Consumers are demanding foods with greater convenience Meal kits category sales are expected to increase from $11 million in sales (1998) to $50 million by 2008 (Eilert, 2005). Factors that contribute to this increase include the number of young people with minimal cooking skills, employment and lifestyle that do not allow time for meal preparation, the baby boom generation is reaching retirement age, and the willingness to prepare complete meals is diminishing.

However, Food Saver® bags are an example of a commercially available “cook-in bag”. Food Saver® bags are patented therefore limited information is available on the properties of the systems. These bags are made of polyethylene (a combination of high density, and low density),

one of the most versatile and economical polymers with low processing energy costs, and coated with nylon for strength. High-density polyethylene (HDPE) is inexpensive, easily processed, and a good moisture barrier. The film also has low oxygen-, hydrocarbon-, and flavor – barrier properties, a low softening point, and opacity (Soroka, 2002). Low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE) are low cost, easy processibility, and good moisture barriers similar to HDPE. LDPE and LLDPE have good heat sealability at temperatures from 106°C to 112°C. Instructions for microwaving, boiling are recommended for frozen foods. Food Saver® bags have a melting point of 127°C. The packaging material consists of two sides: one smooth, and one rough side. The smooth side allows a better seal, while the rough side permits air to be channeled out during the vacuuming process. Packaging systems such as Food Saver® exist for consumer convenience.

Consumers demand for convenient foods steered the industry toward ready-to-eat, fully cooked, or heat and serve products, and packaging plays an important role in maintaining shelf-life.

CHAPTER 3
MATERIALS AND METHODS

This study was conducted in three phases. Phase 1 consisted of research and development to determine the appropriate amount for the marinade and the spice blend ingredients. Phase 2 involved the production and evaluation of a value-added uncooked vacuum packaged marinated goat meat product. Phase 3 involved the production and evaluation of a value-added heat and serve vacuum packaged goat meat product.

Phase 1: Formulation of Marinade and Topical Spice Rub

Sample Preparation

Meat goats were purchased from a local producer in Jasper, Florida (Eunice Cornelius farm) (Table 3-1). Among the eleven animals, were ten males (castrated by 3 weeks of age), and one female. The animals weighed on average 28.78 kg. The animals were slaughtered, and processed at the University of Florida Animal Sciences USDA inspected processing facility. The carcasses were washed, rinsed with a lactic acid antimicrobial solution and chilled for 24 hours. After the chilling process, the carcasses were fabricated into primal cuts: leg, loin, rack (ribs) and shoulder. The ribs were cut according to the USDA Institutional Meat Purchase Specifications (USDA AMS, 2006) for Fresh Goat, barbeque style (approved in October 2001). The ribs were separated from the carcass by a straight cut posterior to the last rib on the posterior end. The neck and the breast were removed. The ribs were split. All the meat was vacuum packaged and frozen at -20ºC until used. Only the rib racks with loin muscle attached were used in this study. The racks were cut into three equal longitudinal portions, vacuum packaged and frozen at -20°C until used (approximately 2 weeks).

Sample Treatment

Various ingredients were evaluated in an effort to develop a marinade (Table 3-2). In all formulation, the goat meat samples were marinated for 1 hour in individual containers (30 minutes for each side of the loin chops) at 4 ± 1°C. Following marination of the loin chops, the products were baked in a conventional oven (General Electric Model: JGRS14 Built-In Gas Oven) at 163°C to an internal temperature of 74°C using copper--constantan thermocouples attached to a potentiometer. Goat meat formulation with or without 2.0% apple cider vinegar or lime juice were prepared by sensory panel. Based on the results of this evaluation, the decision was made to marinate with apple cider vinegar to limit the cost. (Recipe 1) (Table 3-3). Four formulations were developed and consisted of Control or 1 (goat meat), 2 (goat meat + marinade), 3 (goat meat + spice rub), and 4 (goat meat + marinade + spice rub). For each formulation, the goat loin chops were placed in a vacuum tumbler, and tumbled for 25 minutes. After tumbling, the product was either packaged immediately, or subjected to a topical spice blend (Table 3-4) before packaging. The evaluation of the goat loin chops involved baking in a conventional oven (General Electric Model: JGRS14 Built-In Gas Oven) at 163°C to an internal temperature of 74°C, and tasted by panelists in a formal sensory panel.

Preparation of the Marinate and Spice Rub for application to the Goat Loin Chops

Step 1: Spice rub preparation

1- Combine all ingredients in the spice rub formulation. Mix well.

Step 2: Preparation of marinade

1- Dissolve sodium tripolyphosphate in water.
2- Add salt and dissolve.
3- Add apple cider vinegar and blend well.
4- Place meat in tumbler.

5- Add marinade solution.

6- Vacuum tumble for 25 minutes.

Step 3: Application of spice rub

1- Manually apply spice rub on the outside of the loin chops uniformly.

Step 4: Cooking process

1- Preheat conventional electric oven to 163°C.

2- Insert thermocouples in the thickest portion of the loin chops.

3- Cook the meat to an internal temperature of 74°C.

4- Remove the baked ribs from the oven and allowed to stand at room temperature for 30 minutes.

5- Vacuum package the meat in commercially available cooking bags, and store in walk-in cooler.

Phase 2: Production and Evaluation of Vacuum packaged Raw Goat Ribs

Sample Preparation

Boer Crossbred Spanish meat goats (about 7 months old) were purchased from a local producer from White Springs, Florida (Norma Tillman) (Table 3-5). Ten animals including eight castrated males, and two females weighing on average 20.63 kg were utilized. The animals were slaughtered, and processed at the University of Florida Animal Sciences USDA inspected processing facility in the same manner as discussed in Phase One.

Sample Treatment

The frozen goat ribs were thawed for 18 ± 2 hours in a 4 ± 1°C walk-in cooler. The racks from the goats were cut in three longitudinally proportional cuts, using an electric band saw (Biro 44 Band Saw, The Biro Manufacturing Company, Marblehead, OH, 43440-2099). The rib units were divided into four groups and combined with either 1) No treatment, control, 2) apple cider vinegar only, 3) Spice rub only, and 4) Spice rub plus apple cider vinegar (Table 2). Except

for the control treatment and treatment 3 (spice rub only), the ribs were placed into a vacuum tumbler (Lyco vacuum tumbler, model 40, Columbus, WI) along with water, salt, apple cider vinegar, sodium tripolyphosphate, and tumbled for 25 minutes. After marination, the meat in treatment 4 was coated with the spice rub. All meat was vacuum packaged in Cryovac B4770 9 x 18 (Simpsonville, SC) vacuum bags, and stored at 4 ± 1°C for 21 days. The specifications for the Cryovac B4770 9 x 18 are 0.5- 0.6 g/100 in2/24 hrs@100°F, 100% Relative Humidity for water vapor transmission rate, and 1cm^{3} /m2/24hr atm @ 40°F at 0% Relative Humidity. A total of four packages were produced for each treatment, and for each day. Two of the packages, (each containing approximately 300g of goat ribs) were used for sensory panel. The other two packages containing approximately 25g of goat meat, each were utilized for microbiological analysis. The ribs were evaluated after 0, 7, 14, and 21 days storage for sensory characteristics, microbiology, proximate composition, and pH.

Microbiological Analysis and pH

The goat meat samples were analyzed for *Staphylococcus aureus, Salmonella,* fecal coliforms, *E. Coli* 0157:H7, *Listeria monocytogenes,* total anaerobes, total psychrotrophs, and total aerobes. All media (Difco Laboratories, Detroit, MI 48232-7058) and materials used for the cultivation and maintenance of the bacteria were purchased from Fisher Scientific (Pittsburgh, PA 15238).Twenty-five grams of goat meat from each formulation were placed in sterile 18 x30 cm Fisherbrand stomacher bags (400 ml, Fisher Scientific, Pittsburgh, PA 15238) along with 225 ml of sterile 0.1% peptone water (Cat. No. DF01897-17-4). The stomacher bags were massaged by hand for two minutes to loosen any surface bacteria. The use of the stomacher spilled the mixture. 1 ml of the sample rinse was transferred to a test tube containing 9 mL of sterile 0.1% peptone water from which 10-1 to 10-6 serial dilutions were prepared for each treatment. 1µl from the dilutions was pipetted and spread (using a glass hockey stick which was flame sterilized before

spreading) onto the plates. 0.1 ml aliquot of each dilution was spread onto Xylose Lysine Desoxycholate Agar (XLD, Cat. No. DF0788-17-9) for Salmonella colonies, Plate Count Agar (PCA, Cat. No. DF0479-17-3) for total psychrotrophs counts, Anaerobic Agar (Cat. No. DF0536-17-4) for total anaerobes, Tryptic Soy Agar (TSA, Cat. No. DF0369-17-6) for total aerobes, m FC Agar (Cat. No. DF0677-17-3) for fecal coliforms, Oxford Agar (Cat. No. DF0225-17-0) for Listeria monocytogenes, Oxford media Supplement (Cat. No. DF0214-60-9), Remel Mannitol Salt Agar (Cat. No. 453902) for Staphylococcus aureus, MacConkey Sorbitol Agar (Cat. No. DF0075-17-1) for Escherichia coli 0157:H7, AnaeroGenTM 3.5L packets from Remel (Cat. No. 6535) were used in plastic anaerobic jars for the generation of anaerobic conditions. All plates were done in duplicate. The mFC plates were incubated for 18- 24 hrs at 44 ± 1°C. The PCA plates were stored at 25 ± 1°C for 5 days. The TSA plates, Mannitol Salt Agar, and Modified Oxford Agar plates, MacConkey Sorbitol Agar plates were incubated for 48 hrs at 35 ± 1°C. The XLD, and Anaerobic Agar plates were stored for 24 ± 2 hrs at 37 ± 1°C. After incubation, suspected colony forming units (CFU) from each plate were counted, recorded and averaged. Immediately after the plates were spread, pH values were measured using Fisher Scientific pH meter, (Accumet, AB15, Vernonhills, IL), and recorded for all treatments immediately after the microbiological analyses were completed. The probe was placed inside the sample homogenate and allowed to equilibrate for one minute before the reading was taken. All pH readings were performed in duplicates followed by an average of the results.

Sensory Evaluation

Training for the goat meat sensory panels was accomplished in a one-hour session. Most panelists were already familiar with goat meat and had previously participated in trained panels involving goat meat. Goat meat was purchased from a local supermarket, and utilized in the training session. Panelists were trained to identify goat meat flavor and overall tenderness.

The panelists were presented with roasted goat meat without any additives, roasted goat meat that was treated with apple cider vinegar, and roasted beef. The panelists were asked to rate the characteristic goat flavor in goat meat with and without apple cider vinegar added. Beef was presented as a typical meat control, and as a comparison to goat meat flavor. Goat flavor intensity was evaluated using an 8 - point scale, where 8 = extremely intense, 7 = very intense, 6 = moderately intense, 5 = slightly intense, 4 = slightly bland, 3 = moderately intense, 2 = very bland, 1 = extremely bland. Overall tenderness was evaluated using an 8 - point scale, where 8 = extremely tender, 7 = very tender, 6 = moderately tender, 5 = slightly tender, 4 = slightly tough, 3 = moderately tough, 2 = very tough, 1 = extremely tough.

On the day of evaluation, the samples intended for sensory analysis (2 packages per treatment) were weighed and then roasted at 163ºC, until the meat reached an internal temperature of 74ºC in a conventional gas fired oven. Following the cooking process, the samples were weighed to determine the cooking yield and cut into 1.25 cm^2 pieces for sensory evaluation. All samples were coded, and served on paper plates with unsalted crackers and ambient temperature water. Panelists were instructed to pause for 20 seconds between samples, drink water and eat crackers to cleanse their palates**.** The panels were conducted in sensory booths illuminated with red filtered lights to create objectivity.

Proximate Analysis

Proximate analysis was performed on each of the goat rib formulations for the two trials. All analyses were conducted in duplicate samples per treatment on the day of analysis (0, 7, 14, 21). Duplicate samples of each rib formulation were analyzed for moisture using the oven drying technique (method 985.14 AOAC, 2000), and ash using the muffle oven technique (method 920.153 AOAC, 2000), fat (method 960.39 AOAC, 2000), and protein following the Kjeldahl procedure (method 928.08 AOAC, 2000).

Cost Analysis

A cost analysis of the goat ribs was performed in order to determine the production cost and the approximate end price of the goat meat products. The information will be useful in determining the economical feasibility of the production of the different formulations of goat ribs. Cost analysis consisted of expenses for goat meat, the processing of the goat carcasses, the added of the ingredients, and labor.

Statistical Analysis

The statistical analysis for this project was performed using SAS Windows (SAS Institute, 2002). A block design with four formulations and two replications was used for evaluating proximate, pH, microbiological analysis. A total of 64 samples were analyzed for the microbiology and sensory panel. The analysis of variance of the General Linear Model Procedures (PROC GLM) of SAS® software, and the LSMEANS procedure for generating standard errors of the mean (SEM) were used to analyze trial, day, treatment, and treatment by day interaction. Variations in data were accounted for by four treatment effects: trial, treatment, day, and treatment*day. Any significant differences were analyzed by the multiple comparison procedure of Duncan's Multiple range test, using a level of significance of alpha = 0.05.

Phase 3: Production and Evaluation of Cook-in-Bag Heat and Serve Barbecue Goat Ribs

Sample Preparation

Goat racks were purchased from a Florida goat meat processor in Orlando, Florida. The ribs were cut according to the USDA Institutional Meat Purchase Specifications (IMPS, 2006) for Fresh Goat, barbeque style (approved in October, 2001). The ribs were separated from the carcass by a straight cut posterior to the last rib on the posterior end. The outside shoulder was separated by cutting through the natural seam. The neck and the breast were removed. The ribs were split. The meat was stored at 4 ± 1°C for 2 days, prior to being used in this study.

Sample Treatment

Goat meat racks were cut into approximately 12 cm by 10 cm pieces with a Biro 44 Band Saw (The Biro Manufacturing Company, Marblehead, OH 43440- 2099). The racks from the goats were cut in three longitudinally proportional cuts in the Meats Laboratory of the Department of Animal Sciences at the University of Florida. The slabs were divided into four groups and treated with either 1). No treatment, control, 2) apple cider vinegar only, 3) Spice rub application, and 4) Spice rub application in addition to Apple Cider Vinegar (Table 3-2). Except for the control treatment and treatment 3 (with spice rub only), the ribs were placed into a vacuum tumbler (Lyco vacuum tumbler, model 40, Columbus, WI) along with water, salt, apple cider vinegar, sodium tripolyphosphate, and tumbled for 25 minutes. After marination, the meat in treatment 3 was coated with the spice rub. The goat meat from each treatment was baked in a conventional gas fired oven at 163ºC until the meat reached an internal temperature of 74ºC. Following the cooking process, the meat was allowed to cool and then vacuum packaged with a commercially available FoodSaver® Pro Sport Model Vacuum Packager (Jarden Corporation. Rye, N.Y.) FoodSaver® rolls material. This packaging material was composed of two different sides: one was rough and bumpy, while the other side was smooth. The specifications for the FoodSaver® bags are 164.232 cc/m^2/24 hrs @ 23ºC on the rough side, and 0.334 cc/m^2/24 hrs @ 23ºC. Custom-sized bags (12 in x 11 in) were cut with the FoodSaver® Store ‹n Cut device and filled with approximately 300g of goat ribs per bag, and sealed. FoodSaver® packaging roll stock film was used to make 112 bags with the aid of FoodSaver® Store ‹n Cut device. The FoodSaver® packaging according to the manufacturer was designed for use in refrigerator, freezer, microwave, for boiling water; and for reuse after proper cleaning. The products were stored in a 4 ± 1°C walk-in cooler for 42 days total. The experiment was repeated two times, using goat meat from the same source for each repetition to ensure product consistency.

Microbiological Analysis and pH

The goat meat samples were analyzed for *Staphylococcus aureus, Salmonella,* fecal coliforms, *E. Coli* 0157:H7, *Listeria monocytogenes,* total anaerobes, total psychrotrophs, lactic acid bacteria and total aerobes. All media (Difco Laboratories, Detroit, MI 48232-7058) and materials used for the cultivation and maintenance of the bacteria were purchased from Fisher Scientific (Pittsburgh, PA 15238).Twenty-five grams of goat meat from each formulation were placed in sterile 18 x30 cm Fisherbrand stomacher bags (400 ml, Fisher Scientific, Pittsburgh, PA 15238) along with 225 ml of sterile 0.1% peptone water (Cat. No. DF01897-17-4). The stomacher bags were massaged by hand for two minutes to loosen any surface bacteria. The use of the stomacher spilled the mixture. 1 ml of the sample rinse was transferred to a test tube containing 9 mL of sterile 0.1% peptone water from which 10^{-1} to 10^{-6} serial dilutions were prepared for each treatment. 1µl from the dilutions was pipetted and spread (using a glass hockey stick which was flame sterilized before spreading) onto the plates. 0.1 ml aliquot of each dilution was spread onto Xylose Lysine Desoxycholate Agar (XLD, Cat. No. DF0788-17-9) for *Salmonella* colonies, Plate Count Agar (PCA, Cat. No. DF0479-17-3) for total psychrotrophs counts, Anaerobic Agar (Cat. No. DF0536-17-4) for total anaerobes, Tryptic Soy Agar (TSA, Cat. No. DF0369-17-6) for total aerobes, m FC Agar (Cat. No. DF0677-17-3) for fecal coliforms, Oxford Agar (Cat. No. DF0225-17-0) for *Listeria monocytogenes*, Oxford media Supplement (Cat. No. DF0214-60-9), Remel Mannitol Salt Agar (Cat. No. 453902) for *Staphylococcus aureus*, MacConkey Sorbitol Agar (Cat. No. DF0075-17-1) for *Escherichia coli* 0157:H7, APT Agar (Cat. No. DF0654-17-0) for lactic acid bacteria, and AnaeroGen™ 3.5L packets from Remel (Cat. No. 6535) were used in plastic anaerobic jars for the generation of anaerobic conditions. All plates were done in duplicate. The mFC plates were incubated for 18-24 hrs at 44 ± 1°C. The PCA plates were stored at 25 ± 1°C for 5 days. The TSA plates, Mannitol

Salt Agar, and Modified Oxford Agar plates, MacConkey Sorbitol Agar plates, and APT plates were incubated for 48 hrs at 35 ± 1°C. The XLD, and Anaerobic Agar plates were stored for 24 ± 2 hrs at 37 ± 1°C. After incubation, suspected colony forming units (CFU) from each plate were counted, recorded and averaged. Immediately after the plates were spread, pH values were measured using Fisher Scientific pH meter, (Accumet, AB15, Vernonhills, IL), and recorded for all treatments immediately after the microbiological analyses were completed. The probe was placed inside the sample homogenate and allowed to equilibrate for one minute before the reading was taken. All pH readings were performed in duplicates followed by an average of the results.

Sensory Panel Analysis

Training for the goat meat sensory panels was accomplished in a one-hour session. Most panelists were already familiar with goat meat and had previously participated in trained panels involving goat meat. Goat meat was purchased from a local supermarket, and utilized in the training session. Panelists were trained to identify goat meat flavor and overall tenderness. The panelists were presented with roasted goat meat without any additives, roasted goat meat that was treated with apple cider vinegar, and roasted beef. The panelists were trained to detect the characteristic goat flavor in goat meat with and without apple cider vinegar added. Beef was presented as a typical meat control, and as a comparison to goat meat flavor. Goat flavor intensity was evaluated using an 8 - point scale, where 8 = extremely intense, 7 = very intense, 6 = moderately intense, 5 = slightly intense, 4 = slightly bland, 3 = moderately intense, 2 = very bland, 1 = extremely bland. Overall tenderness was evaluated using an 8 - point scale, where 8 = extremely tender, 7 = very tender, 6 = moderately tender, 5 = slightly tender, 4 = slightly tough, 3 = moderately tough, 2 = very tough, 1 = extremely tough. Off-flavor was evaluated using a 6 - point scale, where 6 = none detected, 5 = threshold; barely detected, 4 = slight off-flavor, 3 =

moderate off-flavor, 2 = strong off-flavor, 1 = extreme off-flavor. If an off-flavor was detected by the panelist, they were asked to identify the off-flavor.

The panels were conducted in sensory booths illuminated with red filtered lights to create objectivity. Before each taste panel, one package (300g) from each treatment was placed in a 1.5L stainless steel utensil filled to approximately ¾ of its capacity with cold tap water. The conventional gas fired stove (General Electric Model: JGRS14 Built-in Gas Oven) was then turned on and set at 7 on a 9 point dial, until the water boiled (for thirty minutes). The ribs were immersed in the boiling water for approximately 20 minutes, and reached an internal temperature of 81°C. There exist alternative cooking processes. The vacuum packaged ribs could be reconstituted either by using a microwave, or an oven. When reconstituting the goat ribs using a microwave (Panasonic the Genius 1300W), the bag was punctured first. Secondly, the vacuum packaged meat product was inserted in the microwave for 3 minutes at high setting to an internal temperature of 72°C. Reconstitution in a conventional electric oven (General Electric Model: JGRS14 Built-in Gas Oven) was done by moist cooking. An Ovenware Casserole (9 in diameter, 2QT) was used. At first, the oven was preheated to a temperature of 135°C. Secondly, a wire top was placed inside the dish. Thirdly, the product was placed on top of the wire, and a cup of water poured at the bottom of the casserole. The Ovenware Casserole containing the meat was finally inserted in the oven for 1.5 hours to an internal temperature of 71°C. Temperatures were monitored with using copper--constantan thermocouples attached to a potentiometer.

Following the cooking process, the meat was trimmed of all bones and epimysial connective tissue as suggested by Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat published by the American Meat Science Association (AMSA) in cooperation with the National Live Stock and Meat Board (1995). The

meat was placed in a plexiglass container of dimensions 14 cm long x 12 cm wide x 4 cm deep. Each sample was prepared for sensory using separate cutting boards and knives. The purpose for this separation was to avoid any cross-contamination (flavors, juices). The ribs were cut into 1cm x 1cm pieces and served in a thermostat controlled yogurt warmer (Salton Inc., Bronx, N.Y., Automatic Yogurt Maker). Prior to serving the samples, the glass jars used in the yogurt warmer were pre-heated at 135°C for 1 hour in a conventional electric oven (General Electric Model: JGRS14 Built-in Gas Oven)

Consumer Sensory Panel Analysis

In order to evaluate the goat products and the purchase intent by consumers, an untrained consumer panel consisting of 84 individuals was conducted using the sensory facilities at the Food Science and Human Nutrition Department at the University of Florida. The booths were equipped with a computerized system (Compusense *five*, Compusense®, Ontario, Canada) in a room illuminated with white light. All the instructions were given in detail on the computer for the panelists. There were pass-through hatches to provide samples to panelists. Compusense *five* program, a sensory and consumer research data collection program from Compusense® was used during the consumer panel.

As a result of the trained panel, it was determined that the goat meat samples formulated with spice rub only, and marinade plus spice rub be evaluated in the consumer panel. The samples (Goat meat + Spice rub, and Goat meat + Marinade + Spice rub) were served randomly to the panelists. Each panelist was given crackers, water, a number (panelist number) to input in the computer, and instructed to lift the hatch' door completely once finished. The panelists were instructed to evaluate the two products for meat flavor intensity, overall flavor, and texture, and overall acceptability using a hedonic scale where 1= dislike extremely, 5= neither like or dislike and 9= like extremely. A hedonic scale is a rating scale method that measures the level of liking

or disliking of food products (O'Mahony, 1986). A score of 5 and over would indicate that the product was acceptable. The panelists were also asked to identify their sex, age group, and whether he/ she would buy the products. The data were collected automatically at the end of the sensory session and printed for analysis.

Proximate Analysis

Proximate analysis was performed on each of the goat rib formulations for the two trials. All analyses were conducted in duplicate samples per treatment on the day of analysis (0, 7, 14, 21). Duplicate samples of each rib formulation were analyzed for moisture using the oven drying technique (method 985.14 AOAC, 2000), and ash using the muffle oven technique (method 920.153 AOAC, 2000), fat (method 960.39 AOAC, 2000), and protein following the Kjeldahl procedure (method 928.08 AOAC, 2000).

Cost Analysis

A cost analysis of the goat ribs was performed in order to determine the production cost and the approximate end price of the goat meat products. The information will be useful in determining the economical feasibility of the production of the different formulations of goat ribs. Cost analysis consisted of expenses for goat meat, the processing of the goat carcasses, the added of the ingredients, and labor.

Statistical Analysis

The statistical analysis for this project was performed using SAS Windows (SAS Institute, 2002). A block design with four formulations and two replications was used for evaluating proximate, pH, TBARS, sensory and microbiological analysis. A total of 112 samples were analyzed for the microbiology and sensory panel. The analysis of variance of the General Linear Model Procedures (PROC GLM) of SAS® software, and the LSMEANS procedure for generating standard errors of the mean (SEM) were used to analyze trial, day, treatment, and

treatment by day interaction. Variations in data were accounted for by four treatment effects: trial, treatment, day, and treatment*day. Any significant differences were analyzed by the multiple comparison procedure of Duncan's Multiple range test, using a level of significance of alpha = 0.05.

Thiobarbituric Acid Reactive Substances Analysis

Thiobarbituric Acid Reactive Substances (TBARS) distillation procedure for meat and poultry was adapted using procedures from Tarladgis et al. (1960), Rhee (1978) and Ke et al. (1984). In the adapted procedure, the sample was read against the blank at the optical wavelength of 535nm. In addition, 66% recovery was obtained, compared to 69% in Tarladgis et al. (1960), resulting in a variation in the K (distillation) value.

Table 3-1. Weight and sex data for Spanish, Boer Crossbred Meat Goats purchased from Eunice Cornelius farm

Tag #	Sex	Live Weight (lbs)	Live Weight (kg)	Carcass Weight (lbs)	Carcass Yield (%)
10	M	61	27.66	30	49.18
11	M	65	29.48	30	46.15
09	M	76	34.47	35	46.05
12	M	51	23.13	24	47.06
15	M	68	30.84	31	45.59
16	M	70	31.75	33	47.14
17	M	45	20.41	22	48.89
14	M	70	31.75	33	47.14
61	M	68	30.84	34	50.00
18	M	60	27.21	28	57.13
62	F	64	29.02	30	46.88
Mean		64	28.77	30	48.29

Table 3-2. Goat Meat Marinade

	Formulation			
Ingredients	1	2	3	4
	%	%	%	%
Fajita[a]	2.0	0.0	0.0	0.0
Water	8.0	8.6	9.0	11.0
Salt	0.0	1.0	1.0	1.0
Apple Cider Vinegar[b]	2.0	2.0	1.0	0.0
Sodium Tripolyphosphate[c]	0.0	0.4	0.4	0.4
Goat Meat	88.0	88.0	86.6	86.6
Lime juice[d]	-	-	2.0	1.0

[a]: A.C. Legg Packing Co., Inc, Birmingham, AL
[b]: Albertson's Inc., Boise ID
[c]: Budenheim Gallard-Schlesinger, Plainview, NY

Table 3-3. Marinade formulations for Goat meat ribs: Phase 1

Ingredients	Recipe 1 (%)	Recipe 2 (%)	Recipe 3 (%)	Recipe 4 (%)
Water	10.00	10.00	10.00	12.00
Salt	1.00	1.00	1.00	1.00
Apple Cider Vinegar	2.00	0.00	1.00	0.00
Sodium Tripolyphosphate	0.40	0.40	0.40	0.40
Meat	86.60	86.60	86.60	86.60
Lime Juice	0.00	2.00	1.00	0.00

Table 3-4. Spice Blend Rub for Goat meat ribs

Ingredients	Grams/ 25 lbs of meat	Source
Salt	25.00	
Black Pepper	18.75	Badia Spices, Miami FL
Cayenne pepper	6.25	Zatarain's, New Orleans FL
Dried Thyme	18.75	Badia Spices, Miami FL
Garlic Powder	25.00	Badia Spices, Miami FL
Onion Powder	25.00	Badia Spices, Miami FL
Paprika	25.00	Badia Spices, Miami FL

Table 3-5. Weight and sex data for Spanish Boer Crossbred Meat Goats purchased from Norma Tillman farm

Tag #	Sex	Live Weight (lbs)	Live Weight (kg)	Carcass Weight (lbs)	Carcass Yield (%)
32	M	42	19.05	20	47.62
08	F	55	24.94	28	50.91
037	M	53	24.04	26	49.06
16	M	46	20.86	22	47.83
10	M	38	17.23	17	44.74
25	M	45	20.41	22	48.89
30	F	46	20.86	24	52.17
11	M	50	22.67	19	38.00
05	M	40	18.14	17	42.50
04	M	40	18.14	25	62.50

CHAPTER 4
RESULTS AND DISCUSSION

The objectives of this study were to (1) develop refrigerated value-added vacuum packaged raw goat ribs, (2) evaluate proximate composition, pH, sensory and microbiological characteristics of four formulations on the raw goat rib formulations, (3) develop a convenient and marketable refrigerated vacuum packaged heat and serve goat meat rib product, and (4) evaluate proximate composition, pH, Thiobarbituric Acid Reactive Substances (TBARS), cost sensory and microbiological characteristics of four heat and serve goat rib formulations.

Marinated Vacuum Packaged Raw Goat Ribs refrigerated for 21 days at 4 ± 1°C

Microbiological Analysis

Fecal coliforms

Fecal coliforms remained less than 2 log CFU/g through 21 days storage (Table 4-1). Although fecal coliforms were less than 2 log CFU/g for all treatments, the spice rub alone and in combination with marinade resulted in higher microbial counts ($P > 0.05$). In contrast, no fecal coliforms were detected after 7 and through 21 days storage for the control and samples treated with marinade only. This observation suggested that low levels of fecal coliforms might have been present in the dry spice rub ingredients.

Aerobic plate counts

Aerobic microorganisms (Table 4-2) were less than 6 log CFU/g, for all treatments through 21 days storage. In general, aerobic plate counts (APC) increased for all treatments as storage time increased. The control (plain goat meat) had the least amount of aerobic counts on Day 0 (when compared to other treatments). Initially on Day 0, APCs for the control were significantly lower ($P < 0.05$) when compared to treatment 4. On Day 7, APCs were significantly lower ($P < 0.05$) when compared to treatment 3. A similar finding was observed on Day 14,

when APCs were significantly lower ((P < 0.05) for treatment 2, when compared to all other treatments. This could be due to the presence of marinade in treatments 2 and 4. There were no significant differences (P > 0.05) in APCs among treatments for Day 21. No significant increase in APCs was revealed over time, through 21 days storage, for the goat ribs that were marinated or marinated and rubbed with spice. APCs for the control ribs increased significantly (P < 0.05) after 14 and 21 days storage. This finding suggested a continuous antimicrobial effect of the marinade against the aerobic microorganisms. The growth of aerobic microorganisms in the vacuum packaged system suggested the existence of facultative anaerobes.

Psychrotroph counts

In general, psychrotrophic counts increased as storage time increased (Table 4-3) for all treatments. Psychrotrophs counts were less than 4 log and not significantly different (P > 0.05) from each other at Day 0. After Day 0, significant differences (P < 0.05) were noted between treatments. A similar trend was observed for psychrotrophic and APCs, wherein the marinade with and without the spice rub displayed antimicrobial properties. Treatment 3 (Goat + Spice Rub) had the highest count, followed by the control (plain goat meat). The significant increase (P < 0.05) between Day 0 and Day 7 and the significant decrease between Day 7 and 14 of treatment 4 could be due to contamination of the media. Microbial growth is stimulated by a rich medium such as fresh meat.

Anaerobic plate counts

Anaerobic microorganisms were present in all the treatments, at the end of the storage time (Table 4-4). There was no significant increase (P > 0.05) in anaerobic counts over storage days. Anaerobic counts for treatment 3 were initially significantly different (P < 0.05) from the other three treatments. The presence of anaerobes on Day 0 suggested that they may be facultative, and the spice may have contained microorganisms. During Days 7 and 14, the control had

significantly higher ($P < 0.05$) anaerobes counts, when compared to all other treatments. The addition of marinade with and without the spice rub resulted in significantly lower ($P > 0.05$) anaerobic counts. This observation revealed antimicrobial properties in the marinade plus spice rub.

Product Analysis

The pH analysis

The pH values varied between 5.79 and 6.40 (Table 4-5). On Day 0, pH values for treatments 2 (goat + marinade), and 4 (goat meat with marinade and spice rub) were significantly lower ($P < 0.05$) than the other two treatments. The pH values for Days 7, 14, 21 were significantly lower ($P < 0.05$) for treatments 3 and 4, when compared to treatments 1 and 2. Normal meat pH (beef) with good keeping qualities in refrigerated state has values between 5.4 and 5.7 (Gill & Newton, 1981). At the isoelectric point of proteins the pH value ranges from 5.0 to 5.4, and the water holding capacity (WHC) is at its lowest. On either side of the isoelectric point, WHC increases steadily with pH (Young et al., 2005). Because alkaline polyphosphates (pH of 9.8) were used in this study, a higher pH value and WHC are to be expected. Salt interferes with this phenomenon by shifting from the isoelectric point to a more acidic pH. Hamm (1982) found that WHC improved with pH up to 7.5 at least. pH values never reached 7.5 in this study, but were less than 6.5. Values of pH closest to the neutral point (pH 7.0) may promote microbial growth: spoilage bacteria multiply rapidly at high meat pH, consequently shortening shelf life.

Proximate analysis

The moisture values were similar ($P > 0.05$) for all treatments (Table 4-6). The mean moisture value reported by the USDA SR 19 (2006) is 75.84%. This result is a mean for edible portions.

Moisture analysis performed for Boer goats by Webb et al. (2005) and Tshabalala et al. (2003) revealed 69.4%. The moisture values reported by the researchers are similar to the values obtained in this study. Boer goat has an average of 10.5% fat (Tshabalala et al., 2003; Webb et al., 2005). Differences observed when comparisons are done among data imply other sources of variation (sex, age, nutrition, breed, weight). There was no significant difference ($P > 0.05$) among treatments regarding protein percentage. Ash values of Treatment 3 were significantly different ($P < 0.05$) from those of Treatment 1 and 2 (Table 4-6). This disparity may be due to the existence of variability in the loin muscles, and the presence of the spice rub.

Cost analysis

A comparative cost analysis was performed to determine the production costs and retail values for the formulated four treatments applied to the goat ribs (Table 4-8). The price of the goat carcass was calculated based on purchasing price $8.59/ kg, processing fees $1.10/ kg, and boning price $0.44/ kg. The non meat ingredients costs were calculated using the percentages in the formulations for the production of 100 kg batch of goat ribs. A mark up of 30% was used as an average for a processed meat product being sold. A serving of vacuum packaged seasoned raw goat ribs would cost the consumer $11.74/kg. All uncooked beef steaks retail for $11.92/kg, all pork chops for $6.94/kg, and USDA-ERS retail chicken composite for $3.63/kg. The calculated retail price for the goat ribs is not excessive, and is slightly higher than pork price.

Trained Sensory Evaluation

The trained panelists found differences among the four treatments regarding overall tenderness (Table 4-7). Overall tenderness varied from slightly tender to moderately tender. On Days 0, 14, and 21 there was no significant difference ($P > 0.05$) among treatments. On Day 7, panelists rated overall tenderness in the control significantly lower ($P < 0.05$) than ribs that were marinated and treated with the spice rub. The ribs were rated slightly tender, and the marinated-

spice rub ribs were rated moderately tender. This observation suggested that the marinade- spice rub functioned to increase tenderness in the ribs. In addition, storage time had no significant effect ($P > 0.05$) on overall tenderness through 21 days. These results may be due to the use of young goats (6 months of age). In general, meat from young goats is more tender than older goats (Gaili et al.,1972, Riley et al., 1989). Kannan (2001) also found that vacuum packaged leg, shoulder, and loin cuts in were slightly more tender than those in air-permeable film.

Goat flavor intensity was similar ($P > 0.05$) for all treatments through 14 days storage. After 21 days storage, goat meat treated with spice rub and a combination of spice rub and marinade had significantly lower ($P < 0.05$) goat flavor intensity than the control ribs. The data suggested that the spice rub functioned to minimize goat flavor intensity in presence and absence of marinade. Except for the control sample, storage time had no effect ($P > 0.05$) on goat flavor intensity. Goat flavor intensity in the control sample increased significantly ($P < 0.05$) after 21 days storage from moderately bland (3.89) to slightly intense (5.50). Panelists detected a sour and sulfur-like odor in the control samples after 21 days, which was attributed primarily to microbial degradation.

Marinated Vacuum Packaged Heat and Serve Goat Ribs refrigerated for 42 days at 4 ± 1°C

Microbiological Analysis

Aerobic plate counts

There was no significant difference ($P > 0.05$) among the four treatments on Day 0 (Table 4-9). On Day 7, only the treatment containing marinade only had no detectable microbial growth. On Day 28, no microorganisms were detected in all treatments. Possible sources of errors were methodology, aerobes reaching the death phase, limited oxygen in the package, and presence of *Bacillus cereus*. Because the goat ribs were cooked before vacuum packaging, no strict aerobic microorganisms should have been present. The existence of these specific microbes suggests either a contamination from the air during the cooling process, or the oxygen permeability of the package. Overall there were variations among all treatments. Treatments 2 and 4 showed the least microbial counts. The vacuum packaged cooked marinated goat ribs with a spice rub applied (treatment 4) were acceptable. All the other treatments developed either a rancid off-flavor, or an off odor.

Psychrotroph counts

Psychrotrophic organisms counts varied from 0 to 5.95 log CFU/g. (Table 4-10) Psychrotrophic counts for treatments 1 and 2 were significantly lower ($P < 0.05$) on Day 0 when compared to treatments 3 and 4. Except for the spice rub, the data had a decrease in psychrotrophic organisms after 21 days and through 42 days for all treatments. This observation suggested that the spice blend might have contributed to microbial contamination of the meat. The psychrotrophic counts remained less than 6 log CFU/g for all treatment.

Anaerobic counts

No total anaerobic counts were detected on Day 0 (Table 4-11). However, after Day 7, total anaerobes were detected in all samples except for treatment 2. The values for total anaerobes through the shelf life study were between 0 and 6.05 log. There was an almost 3 log increase from Day 14 to Day 21. This sharp increase could be attributed to the packaging not being oxygen free. Another suggestion would be the presence of facultative anaerobes. On Day 28, there was 2.65 log of anaerobe bacteria in treatment 2 which so far had 0 microbial count. A methodology error may have caused the 0 bacterial counts for treatment 2 through time, with the exception of Day 28. The package may also have had oxygen present inside it. For the control, there was no significant difference ($P > 0.05$) between Days 7, 14, 21, 28, and 35. Days 0 and 42 microbial counts (0 log) were significantly different ($P < 0.05$) from days 7, 14, 21, 28, and 35 for all treatments. There was an increase on Day 21 for treatment 3 (spice rub) followed by a slide decrease at Day 28. The microorganisms needed time to grow after Day 0, but reached a peak between Day 21 and 28. At Day 42, no anaerobes microorganisms were detected suggesting a passage from the stationary phase to the death phase.

Lactic Acid Bacteria counts

The presence of lactic acid bacteria in meat products is less damaging because of the slow growth, leading to a longer shelf-life of meat in vacuum package (Blickstad, 1983). Because the shelf life of lamb has been found to be shorter than beef and pork (Shaw et al., 1980; Egan and Shay, 1984), goat meat should follow the same path. Vacuum packaging has the role of inhibiting spoilage microbes (pseudomonads) and allowing the dominance by low spoilage lactic acid bacteria (Babji et al., 2000). Initial flora, pH of meat, prevalence or absence of facultative anaerobes will however influence the dominance of lactic acid bacteria (Grau, 1980, 1981). In Table 4-12, the bacteria were either absent or present at very low levels in the meat on Day 0.

There was a significant increase in the microbial counts from Day 14 to Day 21, except for treatment 2. The highest ($P < 0.05$) counts occurred in the treatment containing a combination of apple cider vinegar and spice rub on Day 21. The lactic acid data demonstrated that the marinade was effective in controlling the growth of lactic acid bacteria. The microorganisms may have reached their stationary phase during Days 21 and 28, and their death phase during Day 35 (for treatment 2) and Day 42 (treatments 1, 3 and 4). The application of the spice rub and the meat itself may have been sources of "contamination" even though the control also registered high microbial counts.

Spice blend analysis

Analysis of spices revealed a slimy mucoidal off-white colony. The colonies were identified as *Bacillus cereus*. This bacterium was isolated primarily from the spice rub blend, and sporadically on the goat meat. Common sources of infection of this specific microorganism are: raw, dried or processed foods, spices, soil, air, water, dust, animals, meat products, starchy foods, vegetables. This organism was also found on the goat meat (raw, and cooked). Srivastava et al. (1981) and Sinha and Mandal,(1977) isolated *Enterobacter* sp., *Escherichia coli* and *Klebsiella* sp. and *Bacillus cereus* from frozen goat meat. This bacterium can adapt to acidic conditions, heat, ethanol, salt, and hydrogen peroxide after prior exposition (Browne and Dowds, 2002). Consequently, the shelf life study was terminated.

Product Analysis

The pH measurements

The pH values (Table 4-13) varied between 5.81 and 6.78, with the highest pH corresponding to Day 42 of the control treatment. There was no significant difference in pH values ($P < 0.05$) between Day 0 and Day 42 of the control. On all days of storage, goat meat formulated with marinade alone or in combination with spice rub had significantly lower (P <

0.05) pH values when compared to goat meat with spice rub (except for spice rub only on Day 42) and the control. The presence of lactic acid bacteria may not have contributed to the decrease in pH reported for the treatments. The data suggested that the decrease in pH was due largely to the addition of the acetic acid in the marinade.

Proximate analysis

Protein, Fat, and Ash values (Table 4-14) were similar ($P > 0.05$) for all treatments. Moisture content was significantly higher ($P < 0.05$) for the control when compared to the spice rub only treatment. Except for values for Fat and Ash, proximate in this study are similar to values reported by the USDA Nutritive Value of the Edible Part of Food. The closest animal to goat was lamb. Broiled lamb loin (3oz of lean and fat) had values of 52% moisture, 24.7% fat, and 23.5% protein.

Cost analysis

A comparative cost analysis was performed to determine the production costs and retail values for the formulated four treatments applied to the goat ribs (Table 4-15). The price of the goat meat was calculated based on purchasing price $10.09/kg, processing fees $1.10/kg, and boning price $0.44/kg. The non meat ingredients costs were calculated using the percentages in the formulations for the production of 100kg batch of goat ribs. A mark up of 30% was used as an average for a processed meat product being sold. One pound of vacuum packaged seasoned cooked goat ribs would cost the consumer $7.19, or $15.84/kg. No product of this type exists on the market for goat. Similar Heat and Serve vacuum packaged marinated products exist for pork on the market. Chili's Mesquite Smoked and Seasoned Baby Back Pork Ribs retails for $18.81/kg, while Lloyds Barbeque Seasoned & Smoked Baby Back Pork ribs and Tony Roma's Baby Back Ribs respectively sell for $16.87/kg and $12.97/kg. The cost analysis for the vacuum packaged seasoned cooked goat ribs did not include labeling, transportation, and advertising.

This Heat and Serve goat rib product has some success potential. Consumer's desire in the United States for convenience (cut up meats, marinated, ready to eat meals) will make this heat and serve goat product a success once on the market.

Thiobarbituric Acid Reactive Substances

This study (Table 4-16) shows variability in TBARS among treatments and during the storage time. A maximum increase in TBARS was observed for all samples on Day 28. Significant differences ($P < 0.05$) over time were observed for the control and treatment 4. TBARS increased significantly ($P < 0.05$) for the control on Day 0 from 0.68 to 4.10 mg malonaldehyde/ kg on Day 28. In accordance, TBARS increased significantly ($P < 0.05$) for treatment 4 on Day 0 from 0.78 to 2.52 mg malonaldehyde/ kg on Day 28. Some spices such as rosemary, garlic, spices have antioxidant properties (Bishov et al., 1977; Chang et al., 1977; Houliahan et al. 1984, 1985; Barbut et al., 1985), onions, and green peppers (Watts, 1962) improve flavor stability during storage. The presence of spices also may have counteracted the prooxidant effect of the salt.

Trained Sensory Evaluation

Except for the Control, all treatments had similar ($P > 0.05$) goat flavor intensity through 28 days storage time (Table 4-17). Sensory tasting was discontinued for the control after day 28 because of off-flavor that could be associated to rancidity. The panelists rated all samples slightly bland (4.00) to slightly intense (5.68). Because age may be a factor with flavor, Schönfeldt et al. (1993a) found that the younger the goats are (10- 30 kg), the more desirable flavor. Overall, there was no significant difference ($P > 0.05$) between treatments through the 42 days shelf life, regarding overall tenderness. Scores for all treatments varied between slightly tender and moderately tender. The different treatments did not seem to have an effect on the overall tenderness of the ribs. The product was acceptable. Using goat meat and a spicy

formulation to produce processed food, results in an acceptable sensory quality (Breukink and Casey, 1989; Tshabalala et al., 2003; Rhee et al., 2003). Smith et al. (1974) found that goat meat has the same juiciness, but less tenderness, and less overall satisfaction when compared to pork, beef, and lamb at comparable maturity and fatness. Schönfeldt et al. (1993a) found that goat meat was less tender, had more residue, shear force resistance, and collagen content than sheep meat. Sen et al. (2004) also found goat meat less tender than sheep meat.

Consumer Sensory Evaluation

A total of 82 panelists participated in the consumer sensory evaluation for goat ribs prepared with topical rub only, and ribs prepared with a combination of marinade and spice rub. Approximately 46.3% of the consumer panelists were male, while 53.7% were female. The age group varied from “under 18” and “over 60” (Table 4-18). Approximately 78.1% of the panelists were in the age range of 18 to 29, and 41.5% of all panelists had eaten goat meat before, compared to 58.5% that were tasting goat meat for the first time in their lives .Approximately 94.1% of the panelists consumed goat meat more than once a year, but not more than once a month. In addition, their demographics were diverse: the United States, the Caribbean, Canada, South America, and Asia.

Consumer Sensory Panel Analysis

Treatment 4 was rated significantly higher ($P < 0.05$) in meat flavor intensity when compared to treatment 3 (Table 4-19). The consumer panelists rated the flavor of the meat for both samples between like slightly to like moderately. Panelists rated the overall flavor of treatment 4 significantly higher ($P < 0.05$) than treatment 3. The texture of both samples was similar ($P > 0.05$). The rating for overall acceptance was significantly different between treatments (Table 4-19). The panelists scored both samples between “like slightly” and “like moderately”. The consumer panelists were also more likely to purchase the goat meat that had

been marinated and a spice rub applied over goat meat with a spice rub applied only. These two treatments were significantly different from each other ($P < 0.05$). Among the panelists (46.3% male, and 53.7% female), 50% will buy goat meat with a spice rub only versus 70.8% for marinated goat meat with a spice rub applied. These sensory results suggested the potential success of the marinated and spice rubbed goat meat.

Table 4-1. Mean fecal coliform counts for vacuum packaged raw goat ribs stored at 4 ± 1°C for 21 days

	(log CFU/g)			
Treatments*	Day 0	Day 7	Day 14	Day 21
1	$1.30^{a,w}$	0.00^{x}	$0.00^{b,x}$	$0.50^{ab,wx}$
2	$0.70^{b,w}$	0.00^{x}	$0.00^{b,x}$	$0.00^{b,x}$
3	1.20^{ab}	0.25	1.32^{a}	0.77^{a}
4	0.77^{ab}	0.37	0.65^{ab}	1.15^{a}

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-b}$ means in same column with different superscript are significantly different ($P < 0.05$).
$^{w-x}$ means in same row with different superscript are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-2. Mean aerobic plate counts for vacuum packaged raw goat ribs stored at 4 ± 1°C for 21 days

	(log CFU/g)			
Treatments*	Day 0	Day 7	Day 14	Day 21
1	$2.07^{b,w}$	$3.35^{ab,w}$	$5.70^{a,x}$	5.25^{x}
2	3.07^{ab}	3.42^{ab}	2.45^{b}	4.75
3	3.60^{ab}	3.95^{a}	5.35^{a}	4.90
4	$4.62^{a,w}$	$2.32^{b,x}$	$5.45^{a,w}$	5.35^{w}

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-b}$ means in same column with different superscript are significantly different ($P < 0.05$).
$^{w-x}$ means in same row with different superscript are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-3. Mean psychrotrophic counts on vacuum packaged raw goat ribs stored at 4 ± 1°C for 21 days

	(log CFU/g)			
Treatments*	Day 0	Day 7	Day 14	Day 21
1	3.65^{w}	$7.25^{a,x}$	$5.98^{a,x}$	$7.40^{a,x}$
2	3.80^{w}	$5.95^{c,w,x}$	$6.51^{a,x}$	$6.85^{b,x}$
3	2.60^{w}	$6.25^{b,x}$	$5.81^{a,x}$	$7.75^{a,y}$
4	2.00^{w}	$6.10^{bc,x,y}$	$3.42^{b,w,x}$	$6.65^{b,y}$

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-c}$ means in same column with different superscript are significantly different ($P < 0.05$).
$^{w-y}$ means in same row with different superscript are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-4. Mean anaerobic counts on vacuum packaged raw goat ribs stored at 4 ± 1°C for 21 days

	(log CFU/g)			
Treatments*	Day 0	Day 7	Day 14	Day 21
1	0.00^{a}	3.02^{a}	3.53^{a}	0.57
2	0.00^{a}	2.07^{b}	1.20^{b}	1.65
3	2.55^{b}	1.82^{b}	1.85^{b}	1.17
4	0.00^{a}	2.57^{ab}	1.57^{b}	1.24

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-b}$ means in same column with different superscript are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-5. Mean pH values for vacuum packaged raw goat ribs stored at 4 ± 1°C for 21 days

Treatments*	Day 0	Day 7	Day 14	Day 21
1	6.22^{ab}	6.20^{a}	6.20^{a}	6.10^{a}
2	$5.99^{b,x}$	$6.26^{a,w}$	$6.23^{a,w}$	$6.03^{ab,x}$
3	$6.40^{a,w}$	$5.99^{c,x}$	$5.98^{b,x}$	$5.95^{b,x}$
4	$6.05^{b,w}$	$6.14^{b,w}$	$6.02^{b,wx}$	$5.79^{c,x}$

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-c}$ means in same column with different superscript are significantly different ($P < 0.05$).
$^{w-x}$ means in same row with different superscript are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-6. Proximate analysis for vacuum packaged raw goat ribs stored at 4 ± 1°C for 21 days

Formulations*	Moisture (%)	Fat (%)	Protein (%)	Ash (%)
1	67.20	13.48^{b}	14.50	1.98^{b}
2	65.37	17.22^{a}	14.70	1.87^{b}
3	67.64	11.22^{b}	14.82	2.98^{a}
4	67.41	13.34^{b}	15.60	2.51^{ab}

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-b}$ means in same column with different superscript are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-7. Trained sensory evaluation scores on overall tenderness and goat flavor intensity for vacuum packaged raw goat ribs stored at 4 ± 1°C for 21 days

		Storage time			
Parameter	Treatment	Day 0	Day 7	Day 14	Day 21
Overall tenderness[1]	1	5.6	5.7[b]	6.4	5.5
	2	5.6	6.0[ab]	5.76	5.3
	3	5.8	6.2[ab]	5.9	5.4
	4	5.8	6.6[a]	6.1	5.9
Goat flavor intensity[2]	1	3.9[,x]	4.5[wx]	5.0[wx]	5.5[a,w]
	2	4.2	4.3	4.8	5.2[ab]
	3	3.8	4.1	4.4	4.0[c]
	4	3.2	4.12	4.2	4.2[bc]

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
[a-c] means in same column with different superscript are significantly different ($P < 0.05$).
[w-x] means in same row with different superscript are significantly different ($P < 0.05$). Each mean value represents four measurements.
[1]Score Scale. 8 = extremely tender, 7 = very tender, 6 = moderately tender, 5 = slightly tender, 4 = slightly tough, 3 = moderately tough, 2 = very tough, 1 = extremely tough.
[2]Score Scale. 8 = extremely intense, 7 = very intense, 6 = moderately intense, 5 = slightly intense, 4 = slightly bland, 3 = moderately bland, 2 = very bland, 1 = extremely bland.

Table 4-8. Comparative cost analysis for 100 kg batches of vacuum packaged raw goat ribs

Ingredients	Goat meat ($)
Meat	858.00
Water	0.03
Salt	0.72
Apple Cider Vinegar	13.00
Sodium Tripolyphosphate	2.48
Black pepper	5.60
Cayenne pepper	2.12
Dried Thyme	4.56
Garlic powder	2.30
Onion powder	1.20
Paprika	5.70
Vacuum pouches	7.04
Total cost/ 100 kg batch	902.75
Total cost/ 1 kg	6.27
Mark up (30%)	270.82
Total cost/ 100 kg batch	1173.57
Total cost/ 1 kg	11.74
Total cost/ 454g	5.33

Table 4-9. Mean total aerobic counts for refrigerated vacuum-packaged heat and serve goat ribs stored at 4 ± 1°C for 42 days.

	(log CFU/g)						
Treatments*	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
1	1.62^{x}	$1.71^{a,x}$	$3.71^{ab,w,x}$	$5.48^{b,w}$	0.00^{x}	$2.32^{bc,w,x}$	$3.17^{a,w,x}$
2	3.30^{x}	$0.00^{b,y}$	$1.59^{b,x,y}$	$5.17^{b,w}$	0.00^{y}	$0.00^{c,y}$	$0.00^{b,y}$
3	$2.12^{x,y}$	$1.00^{ab,x,y}$	$5.78^{a,w}$	$5.79^{ab,w}$	0.00^{y}	$6.02^{a,w}$	$3.31^{a,w,x}$
4	$2.15^{x,y}$	$1.81^{a,x,y}$	$2.72^{b,x,y}$	$6.20^{a,w}$	0.00^{y}	$3.27^{b,x}$	$0.95^{ab,x,y}$

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-b}$ means in same column with different superscripts are significantly different ($P < 0.05$).
$^{w-y}$ means in same row with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-10. Mean total psychrotrophs counts for refrigerated vacuum-packaged heat and serve goat ribs stored at 4 ± 1°C for 42 days.

	(log CFU/g)						
Treatments*	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
1	$0.00^{b,y}$	$1.76^{b,x,y}$	$5.95^{a,w}$	$1.70^{bc,x,y}$	$0.00^{b,y}$	$2.60^{x,y}$	$3.53^{a,w,x}$
2	1.00^{b}	0.50^{b}	1.56^{b}	3.28^{b}	2.20^{a}	2.34	1.80^{b}
3	$3.72^{a,w,x}$	$1.38^{b,y,z}$	$5.67^{a,w}$	$5.61^{a,w}$	$0.00^{b,z}$	5.86^{w}	$2.91^{ab,x,y}$
4	$3.07^{a,w,x}$	$4.30^{a,w}$	$5.16^{a,w}$	$0.00^{c,x}$	$0.00^{b,x}$	3.39^{w}	$2.84^{ab,w,x}$

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-c}$ means in same column with different superscripts are significantly different ($P < 0.05$).
$^{w-y}$ means in same row with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-11. Mean total anaerobes counts for refrigerated vacuum-packaged heat and serve goat ribs stored at 4 ± 1°C for 42 days.

	(log CFU/g)						
Treatments*	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
1	0.00^{x}	$1.62^{a,wx}$	$2.96^{a,w}$	$2.61^{bc,w}$	$2.69^{b,w}$	$2.29^{ab,w}$	0.00^{x}
2	0.00^{x}	$0.00^{b,x}$	$0.00^{b,x}$	$0.00^{c,x}$	$2.65^{b,w}$	$0.00^{b,x}$	0.00^{x}
3	0.00^{z}	$1.09^{ab,y,z}$	$3.21^{a,x,y}$	$6.05^{a,w}$	$4.78^{a,w,x}$	$4.61^{a,w,x}$	0.00^{z}
4	0.00^{y}	$1.71^{a,x,y}$	$3.09^{a,w,x}$	$3.23^{ab,w,x}$	$2.81^{b,w,x}$	$4.53^{a,w}$	0.00^{y}

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-c}$ means in same column with different superscripts are significantly different ($P < 0.05$).
$^{w-z}$ means in same row with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-12. Mean total lactic acid bacteria counts for refrigerated vacuum-packaged heat and serve goat ribs stored at 4 ± 1°C for 42 days.

	(log CFU/g)						
Treatments*	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
1	$1.07^{x,y}$	$1.60^{x,y}$	$3.06^{a,x}$	$5.29^{c,w}$	$5.13^{a,w}$	$1.71^{ab,x,y}$	0.00^{y}
2	0.00^{x}	$0.91^{w,x}$	$1.68^{b,w,x}$	$0.00^{d,x}$	$2.75^{b,w}$	$0.00^{b,x}$	0.00^{x}
3	$1.00^{x,y}$	0.00^{y}	$3.26^{a,w,x}$	$5.71^{b,w}$	$2.78^{b,xy}$	$2.90^{a,x}$	0.00^{y}
4	$1.00^{x,y}$	$1.84^{x,y}$	$3.13^{a,x}$	$6.40^{a,w}$	$2.80^{b,x}$	$3.25^{a,x}$	0.00^{y}

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-c}$ means in same column with different superscripts are significantly different ($P < 0.05$).
$^{w-z}$ means in same row with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-13. Mean pH values for refrigerated vacuum-packaged heat and serve goat ribs stored at 4 ± 1°C for 42 days.

Treatments*	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
1	$6.70^{a,w}$	$6.63^{a,w,x}$	$6.63^{a,w,x}$	$6.38^{a,y}$	$6.70^{a,w}$	$6.46^{a,x,y}$	$6.78^{a,w}$
2	$6.17^{b,w,x,,y}$	$6.10^{b,x,y}$	$6.05^{c,y}$	$5.89^{c,z}$	$6.20^{c,w,x}$	$6.24^{b,v,w}$	$6.36^{b,v}$
3	$6.59^{a,w}$	$6.50^{a,w,x}$	$6.42^{b,x,y}$	$6.25^{b,z}$	$6.33^{b,y,z}$	$6.43^{a,x,y}$	$6.44^{b,x,y}$
4	6.20^{b}	6.16^{b}	5.95^{c}	5.95^{c}	6.14^{c}	5.81^{c}	5.99^{c}

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-c}$ means in same column with different superscripts are significantly different ($P < 0.05$).
$^{v-z}$ means in same row with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-14. Mean proximate values for refrigerated vacuum-packaged heat and serve goat ribs stored at 4 ± 1°C for 42 days.

	% content			
Treatments*	Moisture	Protein	Fat	Ash
1	57.83^{a}	22.08	16.25	3.65
2	55.82^{ab}	26.66	14.60	3.38
3	52.79^{b}	23.50	17.74	3.52
4	56.60^{ab}	21.32	16.75	3.28

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub
$^{a-b}$ means in same column with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-15. Comparative cost analysis for 100 kg batches of vacuum packaged heat and serve goat ribs

Ingredients	Heat and Serve Goat Ribs
Meat	1007.60
Water	0.03
Salt	0.72
Apple Cider Vinegar	13.00
Sodium Tripolyphosphate	2.48
Black pepper	5.60
Cayenne pepper	2.12
Dried Thyme	4.56
Garlic powder	2.30
Onion powder	1.20
Paprika	5.70
Vacuum pouches	173.00
Total cost/ 100 kg batch	1218.31
Total cost/ 1 kg	12.18
Mark up (30%)	
Total cost/ 100 kg batch	1583.80
Total cost/ 1 kg	15.84
Total cost/ 454g	7.19

Table 4-16. Mean TBARS for refrigerated vacuum-packaged heat and serve goat ribs stored at 4 ± 1°C for 42 days.

	mg of malonaldehyde// kg sample						
Treatments*	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
1	0.68^{x}	$0.82^{ab,x}$	0.84^{x}	$2.00^{w,x}$	4.10^{w}	$1.74^{w,x}$	$2.19^{w,x}$
2	4.29	1.81^{a}	0.70	1.46	4.79	3.73	1.25
3	0.34	1.25^{ab}	0.66	0.90	4.58	0.42	2.30
4	0.78^{x}	$0.49^{b,w}$	$1.41^{w,x}$	$0.81^{w,x}$	2.52^{w}	$1.70^{w,x}$	$0.86^{w,x}$

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub

$^{a-b}$ means in same column with different superscripts are significantly different ($P < 0.05$).

$^{w-x}$ means in same row with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

Table 4-17. Mean trained sensory panel scores for goat flavor intensity and overall tenderness for heat and serve goat ribs stored at 4 ± 1°C for 42 days

		Storage time						
Parameter	Treatment*	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
Goat flavor intensity[1]	1	$4.5^{w,x}$	$4.6^{w,x}$	5.7^{w}	4.0^{x}	$5.3^{a,wx}$	DP	DP
	2	4.6	4.8	5.2	4.7	5.2	5.3	5.5
	3	4.5	5.2	4.9	4.7	4.7	5.2	4.0
	4	4.0	4.8	4.9	4.7	5.2	4.9	4.6
Overall tenderness[2]	1	5.3	6.5	6.5^{a}	5.8	6.0	DP	DP
	2	4.9	5.9	5.9^{ab}	5.7	5.2	5.5	5.0
	3	5.5	5.6	6.1^{a}	6.0	6.2	5.6	6.0
	4	5.3	5.6	4.9^{b}	5.5	6.0	6.0	6.0

*1: Control, 2: Goat + marinade, 3: Goat + spice rub, 4: Goat + marinade + spice rub

$^{a-b}$ means in same column with different superscripts are significantly different ($P < 0.05$).

$^{w-x}$ means in same row with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

DP: Discontinued Panel

[1]Score Scale. 8 = extremely intense, 7 = very intense, 6 = moderately intense, 5 = slightly intense, 4 = slightly bland, 3 = moderately bland, 2 = very bland, 1 = extremely bland

[2]Score Scale. 8 = extremely tender, 7 = very tender, 6 = moderately tender, 5 = slightly tender, 4 = slightly tough, 3 = moderately tough, 2 = very tough, 1 = extremely tough.

Table 4-18. Age data for consumer sensory panelists evaluating goat ribs containing topical spice rub only and a combination of marinade and spice rub and stored at 4 ± 1°C for 42 days

Age group (years)					
<18	18-29	30-39	40-49	>50	Overall
4.9%	78.1%	6.1%	6.1%	4.8%	100%

Table 4-19. Consumer sensory panel scores for evaluating goat ribs containing topical spice rub only, and a combination of marinade and spice rub and stored at 4 ± 1°C for 42 days

Parameter	Treatment	Sample
Goat Flavor Intensity[1]	Goat meat + Spice rub	5.9[b]
	Goat meat + Spice rub + Marinade	6.8[a]
Overall Flavor[2]	Goat meat + Spice rub	5.8[b]
	Goat meat + Spice rub + Marinade	6.8[a]
Texture[3]	Goat meat + Spice rub	5.7[a]
	Goat meat + Spice rub + Marinade	6.2[a]
Overall Acceptance[4]	Goat meat + Spice rub	5.8[b]
	Goat meat + Spice rub + Marinade	6.6[a]
Purchase Intent[5]	Goat meat + Spice rub	3.4[a]
	Goat meat + Spice rub + Marinade	2.9[b]

[a-b] means in same row with different superscripts are significantly different ($P < 0.05$). Each mean value represents four measurements.

[1]Score Scale: 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Neither like or dislike, 6= Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely

[2]Score Scale. 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Neither like or dislike, 6= Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely

[3]Score Scale. 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Neither like or dislike, 6= Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely

[4]Score Scale. 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Neither like or dislike, 6= Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely

[5]Score Scale. 1 =Definitely Would, 2 = Probably Would, 3 = Might or Might Not, 4 = Probably Would Not, 5 = Definitely Would Not.

CHAPTER 5
SUMMARY AND CONCLUSIONS

Objectives of this study were to develop refrigerated value-added vacuum packaged raw goat ribs, evaluate proximate composition, pH, sensory and microbiological characteristics of four formulations on the raw goat rib formulations, develop a convenient and marketable refrigerated vacuum packaged heat and serve goat meat rib product, and evaluate proximate composition, pH, Thiobarbituric Acid Reactive Substances (TBARS), cost sensory and microbiological characteristics of four heat and serve goat rib formulations. Four different formulations were designed as treatments for the goat ribs. They were as following: the control (plain goat ribs), treatment two (goat ribs marinated in apple cider vinegar), treatment three (goat ribs with spice rub applied), and treatment four (marinated goat ribs with spice rub applied). Typical formulations, processing and cooking steps for the development of the goat products were followed.

Results from this study suggested that marinating and applying a spice rub to goat ribs could produce an acceptable value added product. Except for *Bacillus cereus* being isolated primarily from the spice rub blend, and sporadically on the goat meat, no organisms of public health safety (*Staphylcoccus aureus*, Salmonella, Escherichia coli 0157:H7, and *Listeria monocytogenes*) were found. The trained and consumer panelists found the products acceptable, regarding goat flavor intensity, overall tenderness, texture (consumer panel only). Manufacturing a heat and serve marinated vacuum packaged goat rib product could be a successful venture. Consumers have a desire in the United States for convenience (cut up meats, marinated, ready to eat meals) products. There is a high marketability potential for the raw marinated vacuum packaged goat ribs and the heat and serve marinated vacuum packaged goat ribs. Consumers should not be deterred because of the price. Shelf-life recommendation would be 21 days for the

marinated vacuum packaged raw goat ribs, and 42 days for the heat and serve vacuum packaged goat ribs.

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BIOGRAPHICAL SKETCH

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