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Research Paper

Carcass Yield, Microbiological and Chemical Evaluation of Vacuum Packaged Raw Goat Meat from Two Florida Small Goat Producers

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Twenty Boer-Spanish crossbred goats were purchased from two different farms (10 goats/farm) to determine live and carcass yields; proximate composition, and storage stability (pH, microbiology, and sensory characteristics) for rib roasts produced from the carcasses. Although goats from Farm A had higher ($P < 0.05$) live and carcass weights than Farm B, the hot and chilled carcass and dressing yields, and carcass composition were similar ($P > 0.05$). Rib roasts were treated with water (control, CON), apple cider vinegar (ACV), spice rub (SRB) or ACV + SRB, vacuum packaged, and stored at 4±1°C for 21 days. Except for fat and ash, proximate composition was similar ($P > 0.05$) among all treatments. At 21 days storage, psychrotrophic (except SRB) and anaerobic bacteria were less than the control ($P < 0.05$), aerobic plate counts remained less than 6 log CFU/g among all treatments, and fecal coliforms remained less than 1.80 log CFU/g. pH for SRB and ACV + SRB was less than ($P < 0.05$) the control on days 7-21. Neither *Staphylococcus aureus*, *Salmonella* spp., *Escherichia coli* 0157:H7 nor *Listeria monocytogenes* was isolated. Panelists rated overall texture and goat flavor intensity slightly to moderately tender, and moderately bland to slightly intense, respectively. Estimated cost for vacuum packaged raw rib roasts ranged from $6.40 to $6.64 per 454 g.

Keywords: Carcass yield, Goat rib roast, Microbiology, Shelf life, Vacuum packaged goat meat

INTRODUCTION

Although goat meat inventory has remained essentially constant in the past 9 years, the demand for goat meat in the United States exists and is due mainly to the growth of ethnic populations, and others familiar with goat meat. Goat meat inventory makes up only 2% of the global meat. Approximately 95% of the world's goats are raised in the Middle East, Africa, and South Asia, including Pakistan (Atab *et al*., 2015; Haque *et al*., 2008). For this reason, goat is considered the animal of developing countries (Haque *et al*., 2008). All U.S. goat inventory on January 1, 2018 totaled 2.62 million head, down slightly from 2017 (USDA National Agricultural Statistics Service, 2018a). In comparison, the USDA National Agricultural Statistics Service reported cattle inventory for January 1, 2018 totaled 94.4 million head, which was 1 percent above the 93.7 million head on January 1, 2017 (USDA National Agricultural Statistics Service, 2018b). Goat meat production represents approximately 2.80% of the cattle inventory for January 1, 2018. The disparity between cattle production and goat production suggests that meat goats should be considered as a niche market that produces products for its current audience (ethnic populations, and others familiar with goat meat) with the goal of educating and expanding to a larger audience (Williams *et al*., 2018). Currently, goat meat products include primarily fresh wholesale and retail cuts. The retail cuts are usually marketed in a Styrofoam tray and overwrapped with a plastic/polyvinyl chloride packaging film. These products have a limited 3 to 6-day maximum shelf life (Fresher Pantry, 2017; Atab *et al*., 2015), which reveals the need for production of a refrigerated shelf stable uncooked product using a vacuum packaging

system to increase shelf life of the fresh product. Research has revealed the acceptability of value added goat meat further processed products (Williams *et al*., 2018; Cosenza *et al*., 2003a and 2003b).

In addition to vacuum packaging systems, the use of antimicrobial agents in combination with vacuum packaging systems may provide the beneficial effect of maintaining quality, wholesomeness, and extending the shelf life of the goat meat product. Williams *et al*. (2018) demonstrated that the use of apple cider vinegar resulted in reductions in psychrotrophic bacteria (1.73 and 2.69 log CFU/g on day 42) and lactic acid bacteria (2.00 and 3.00 log CFU/g on day 42) in precooked vacuum packaged goat meat rib roasts stored at 4±1°C for 42 days. Various antimicrobials have been used alone or in combination in the meat and poultry industry to retard and/or prevent the growth and survival of pathogenic bacteria, and the spoilage microflora of poultry, meat and related food products. Some of these have included acidified sodium chlorite, bromine, chlorine dioxide, cetyl pyridium chloride, organic acids, peracetic acid, trisodium phosphate, sodium metasilicate (Sharma *et al*., 2013), monochloramine, electrolyzed water, hypochlorous acid (Bilgili, 2009), and gamma irradiation (Atab *et al*., 2015). The objectives of this study were to monitor goat meat characteristics from live animal (live weight, hot carcass and chilled carcass yields) through finished goat meat product (storage stability), and to ascertain the effects of antimicrobials on the finished vacuum packaged goat meat rib product.

MATERIALS AND METHODS

Sample preparation

Twenty Boer-Spanish crossbred meat goats, approximately 6 to 8 months old, were purchased from two local Florida producers and utilized in this study. Ten goats were used in Trial 1 (Farm A) and 10 goats were used in Trial 2 (Farm B). In general, the diets for the goats consisted of a combination of pasture and browse, with supplementations of pelletized concentrate. The concentrate was formulated to achieve average feed intake per day of 1.32 to 1.36 kg, 9.00 to10.5% crude protein, and 57 to 60% total dietary nitrogen. The actual feeding regimen was proprietary, and therefore, not available to the researchers.

Carcass yields and composition

The animals were weighed, and harvested in the University of Florida Animal Sciences USDA inspected processing facility. The resulting carcasses were weighed in order to determine hot carcass yields. All carcasses were treated with a 2% lactic acid antimicrobial intervention solution prior to chilling. The lactic acid treatment is a routine antimicrobial intervention treatment utilized in the University of Florida Meat processing facility. The carcasses were chilled at 0°C immediately after lactic acid treatment for 24 h prior to fabrication. Each chilled carcass was weighed prior to fabrication to obtain chilled percentage. For each farm, five carcasses were completely deboned, and five carcasses were deboned except for the rib racks. The rib racks were used for production and evaluation of the vacuum packaged rib roast product. Yields were recorded for skeletal meat, rib racks, fat, and bones (excluding rib racks). The deboned skeletal meat was vacuum packaged and stored for later use in other processed goat meat products. The bones, fat, viscera and hide were placed into offal rendering barrels. The whole rib racks with *longissimus dorsi* intact, were prepared for treatment as described by Williams *et al*. (2018). Visible fat covering on the racks was trimmed during fabrication. The meat color was cherry red (oxymyoglobin pigment), and the meat contained little or no visible marbling. The whole racks (44.02 kg per 10 racks in Trial 1, and 27.99 kg per ten racks in Trial 2) were split and cut according to the USDA Agricultural Marketing Service Institutional Meat Purchase Specifications (USDA Agriculture Marketing Service, 2006) for fresh goat, barbeque style. Each half rib rack was cut into approximately three longitudinally 12 cm by 10 cm pieces beginning at loin area, with a Biro 44 Band Saw (The Biro Manufacturing Company) as described by Williams *et al*. (2018). No distinctions were made between left and right sides of the racks. A cross sectional cut was made to remove the riblets, which were packaged and frozen. The remaining rib roasts (bone-in) were each cut longitudinal into approximately three 12 cm by 10 cm rib roast bone-in samples and divided into four groups.

Sample treatment

The rib roasts were treated with (1) water only (Con), (2) apple cider vinegar (ACV, White House, Las Vegas, NV), (3) water plus Spice rub (SRO, Williams *et al*., 2018) and (4) water plus apple cider vinegar plus spice rub (ACV-SRO). The meat was placed into a vacuum tumbler (approximately 50 kPa, Lyco vacuum tumbler, model 40, Columbus, WI) along with water and the ingredients specific for each treatment, and tumbled for 25 min in processing room (10°C). Ingredients included water (10%), salt (1.0%), ACV (2.0%), and sodium tripolyphosphate (0.4% - dissolved first in the formula water, followed by formula salt). After vacuum tumbling, the meat in treatments SRO and ACV-SRO were coated with spice rub. Approximately 300 g units of meat were vacuum packaged in Cryovac B4770 vacuum barrier bags (0.5- 0.6 g/100 in^2/24 h at 37.8°C, 100% relative humidity, water vapor transmission rate; and 1cm^3/m^2/24 h

atm at 4.4°C, 0% relative humidity, oxygen transmission rate) and stored at 4 ± 1°C for 21 days. The samples were analyzed at 0, 7, 14, and 21 day intervals for proximate composition, pH, microbiology (fecal coliforms, aerobic plate counts, psychrotroph counts, and anaerobic plate counts), and sensory characteristics. Cost analysis for the vacuum packaged uncooked goat meat roasts was also conducted. The spice rub was analyzed on day 0 only for total plate count to determine if it contributed to microbial growth in the finished product.

Proximate analysis

Analysis was performed on each of the goat rib formulations for the two trials. All analyses were conducted in duplicate 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), 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).

Microbiological analysis

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 × 30 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. One-ml of the sample rinse was transferred to a test tube containing 9 mL of sterile 0.1% peptone water to prepare the appropriate serial dilutions. One hundred µl from the dilutions was pipetted and spread (using a glass hockey stick which was flame sterilized before spreading) onto the surface of duplicate 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, Remel Mannitol Salt Agar (Cat. No. 453902) for Staphylococcus aureus, and MacConkey Sorbitol Agar (Cat. No. DF0075-17-1) for Escherichia coli 0157:H7. AnaeroGen™ 3.5L packets (Remel, Cat. No. 6535) were used in plastic anaerobic jars for the generation of anaerobic conditions. The m-FC plates were incubated for 18-24 h at 44 ± 1°C, PCA plates 25 ± 1°C for 5 days, and TSA, Mannitol Salt Agar, Modified Oxford Agar, and MacConkey Sorbitol Agar plates were incubated for 48 h at 35 ± 1°C. The XLD, and Anaerobic Agar plates were stored for 24 ± 2 h at 37 ± 1°C. After incubation, typical colonies from all plates were counted, averaged and reported as colony forming units (CFU) per gram of sample.

pH measurements

Immediately after the microbiological analyses were completed, pH values were measured using the Accumet pH meter (Model AB15, Vernonhills, IL), and recorded for all treatments. The probe was submerged into the sample homogenate and allowed to equilibrate for 1 min before the reading was taken. All pH readings were performed in duplicate, and averaged.

Trained sensory panel evaluation

The University of Florida Institutional Review Board preapproved all sensory evaluations. Training and sensory evaluations were conducted following the procedure outlined by Williams *et al*. (2018) for goat meat. Most panelists were already familiar with goat meat and had previously participated in trained panels involving goat meat. Goat meat acquired in this study was utilized in the training session. Panelists were trained to identify goat meat flavor and overall tenderness. The panelists were presented with roasted goat meat 1) without additives, 2) treated with apple cider vinegar, and 3) without additives, reheated, held at refrigeration temperature and reheated again to create a rancid oxidized flavor. The panelists were trained to detect the characteristic goat flavor in goat meat with and without apple cider vinegar added. Prior to the training session, researchers and assistants conducted a preliminary evaluation of the treated goat meat samples to verify that rancid flavor, and differences between all treatments could be detected. During training and the actual sensory panels, 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 bland, 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. The

panelists were asked to describe any off-flavor detected. Panelist were given a list of descriptions (sour, bitter, sweet, grassy, musty, metallic, stale, cardboard-like, and painty) to assist in their identification of the off-flavor detected. They were also requested to describe the flavor using other terms, if the listed descriptors were not adequate. The descriptors bitter, metallic, stale, cardboard-like and painty were emphasized as descriptions that were associated with rancidity.

Sensory panels were conducted in a taste panel facility equipped with 11 private booths. Each booth was equipped with seating and the appropriate lighting for the specific food being evaluated. In this study, the booths were illuminated with red filtered lights to enhance objectivity. In preparation for taste panels, four 300 g packages of goat meat were placed in a 1.5-L stainless steel kettle filled to approximately ¾ of its capacity with cold tap water and heated to boiling on a conventional Magic Chef® electric range. The packaged meat remained in the boiling water for 20 min and reached internal temperature of 71°C. The meat was allowed to cool at room temperature. After cooling, the meat was removed from the package, and separated from the bones and connective tissue as suggested by American Meat Science Association (1995). Four Separate cutting boards and knives were used to prepare each treatment for sensory evaluation in an effort to avoid any crossover in flavor. The boneless meat was cut into 1cm x 1cm pieces and served in a five-jar capacity thermal controlled yogurt warmer (Salton Inc., Bronx, NY). Each jar was labeled with a code that corresponded to the codes on the sensory scoring sheet. Prior to placing the samples into the jars, the jars were pre-heated at 135°C for 1 h in a conventional electric oven. The samples were served at ambient temperature with tap water and crackers. Panelists were instructed to drink water and eat crackers to cleanse their palates, and pause for 20 sec between samples.

Cost analysis

A cost analysis of the four goat rib treatments was performed in order to determine the production cost and the approximate end price. The information was used to determine the economic feasibility of production of the different formulations of goat ribs. Cost analysis consisted of expenses for goat meat, nonmeat ingredients, packaging, processing of the goat carcasses, and labor. The cost of three commercially available retail raw vacuum packaged products were compared to the goat meat products.

Statistical analysis

A complete randomized block design, with four formulations, four sampling intervals over 21 storage days, duplicate sample replications and two trials, was used in this study. A total of 64 samples were analyzed. The analysis of variance of General Linear Model (PROC GLM) and LSMEANS procedures for generating standard errors of the mean (SEM) were used to analyze trial, day, treatment, and treatment by day interaction (SAS Institute, 2002). Significant differences among means were determined using the multiple comparison procedure of Duncan's Multiple range test, at a level of alpha = 0.05 significance. Statistical analyses revealed no significant differences ($P > 0.05$) between trials (Farms A and B). Therefore, trials were combined into a single statistical analysis.

RESULTS AND DISCUSSION

Carcass yield

Although goats from Farm A had higher ($P < 0.05$) live, hot, and chilled carcass weights (28.84, 13.64, and 13.28 kg, respectively) than goats from Farm B (20.68, 10.00, and 9.72 kg, respectively), the hot and chilled carcass and dressing yields, and carcass composition were similar ($P > 0.05$) (Table 1). Yields for skeletal meat, rib racks, fat trimmings, and bones (excluding bones in rib racks) were similar for Farms A and B. Pophiwa *et al*. (2017) reported similar data for South African Boer goats and indigenous goats (dressing percentage, 46.04 to 47.00%; hot carcass yield, 47.30 to 48.42%). Ngwa *et al*. (2014) determined that the Carcass yield for Boer-Spanish crossbred goats (3/4 Boer × 1/4 Spanish wethers) and pure Spanish breeds had similar hot carcass yields of 41.53% and 39.47%, respectively. The researchers (Ngwa *et al*., 2014) concluded that the body composition of growing Boer and Spanish goats was similar regardless of nutritional plane and growth rate.

Proximate analysis

Except for fat and ash, proximate composition was similar ($P > 0.05$) among all treatments. Fat was higher for ACV treatment ($P < 0.05$), when compared to all other treatments (Table 2). Ash was lowest for Con and ACV when compared to SRB, and similar ($P > 0.05$) to ACV+SRB, which suggested that SRB contributed a higher concentration of ash to the product. The moisture and protein values of 65.37 to 67.64, and 11.22 to 17.22, respectively, in this study were similar to the 69.4% moisture and 15.36% protein reported by Ngwa *et al*. (2014) for Boer-Spanish crossbred goats, but lower than the 75.84% moisture, and 20.60% protein, reported by USDA Agricultural Research Service (2018) for 'raw goat meat'. The 14.50 to 15.60% fat reported in this study for raw goat meat exceeded the 2.31% fat reported by USDA

Table 1. Means and standard deviations for carcass yields and carcass composition for ten Spanish, Boer Crossbred Meat Goats purchased from two local Florida goat producers.

Attributes[1,2]	Farm	
	A	B
Live Weight (kg)	28.84[a] (8.95)	20.68[b] (5.74)
Hot carcass weight (kg)	13.64[a] (4.05)	10.00[b] (3.77)
Chilled carcass weight (kg)	13.28[a] (3.85)	9.72[b] (3.99)
Hot carcass yield (%)	47.30[a] (3.24)	48.42[a] (6.47)
Chilled carcass loss (%)	2.66[a] (1.02)	2.80[a] (2.27)
Dressing (%)	46.04[a] (2.05)	47.00 [a](2.12)
Chilled carcass Composition[3]		
Skeletal lean meat	45.33	46.10
Rib racks (%)	30.15	28.40
Fat trimmings (%)	4.48	5.00
Bones (excluding portion of ribs) (%)	20.12	20.50

[1]Data for each farm represents a composite sample of 10 goats per farm.
[2]Hot carcass yield (%) = (weight of the carcass/ weight of live animal) x 100.
Chilled carcass yield (%) = (Chilled carcass weight/ Hot carcass weight) x 100.
Dressing percentage = (Chilled weight/Live weight) x 100.
[3]Carcass composition represents composite sample for 5 goat carcasses per farm.
[a-b]Means in same row within each attribute bearing different superscripts differ significantly ($P < 0.05$).
Values in parentheses represent standard deviation.

Table 2. Proximate analysis for vacuum packaged raw goat ribs stored at 4 ± 1°C for 21 days.

Formulations[1]	Moisture (%)	Fat (%)	Protein (%)	Ash (%)
CON	67.20	13.48[b]	14.50	1.98[b]
ACV	65.37	17.22[a]	14.70	1.87[b]
SRB	67.64	11.22[b]	14.82	2.98[a]
ACV+SRB	67.41	13.34[b]	15.60	2.51[ab]

[1]CON = Control, ACV = Apple cider vinegar, SRB = Spice rub only, ACV+SRB = Apple cider vinegar plus spice rub.
[2] Each mean value represents four measurements.
[a-b] Means in same column with different superscript are significantly different ($P < 0.05$).

Agriculture Research Service (2018), but was similar to values 10.30% to 10.50% fat reported by Tshabalala *et al*. (2003), Webb *et al*. (2005) and Ngwa *et al*. (2014).

Microbiological analyses

Aerobic plate count (APC) was less than 5.80 log CFU/g for all treatments through 21 days storage (Table 3). Except for ACV+SRB, APC increased ($P < 0.05$) for all treatments among storage days, when day 0 was compared to day 21. ACV remained lower ($P < 0.05$) than the control on days 14 through 21. The growth of aerobic microorganisms in the vacuum packaged system on days 7, 14 and 21 suggested the existence of facultative anaerobes. It is also possible that if the product contains dissolved oxygen, aerobic and microaerophilic micro-organisms will continue to grow until the oxygen is depleted. Thus, low concentrations of residual oxygen, especially in packages containing meat with a high pH, will contribute to rapid deterioration (Hernández-Macedo, 2011).

In general, psychrotrophic counts increased ($P < 0.05$) as storage time increased (Table 3) for all treatments. Psychrotrophs for ACV+SRB were lower ($P < 0.05$) than CON on all storage days. Except for day 21, psychrotrophs for SRB and ACV+SRB treatments were lower ($P < 0.05$) than the control among all storage days. It has been well documented that psychrotrophic organisms are the primary spoilage bacteria for fresh meat, poultry and seafood (Jackson *et al*., 1997). In general, spoilage defects in meat become evident when the number of bacteria at the surface reaches 7 log CFU/g. Decomposition of the muscle tissue is evident

Table 3. Mean aerobic plate count, total psychrotrophs, total anaerobic bacteria, fecal coliform counts, and pH for vacuum packaged raw goat rib roasts stored at 4 ± 1°C for 21 days.

Treatments[1]	Days of Storage (log CFU/g)			
	0	7	14	21
Aerobic plate count				
CON	2.07^{c,y}	3.35^{a,x}	5.70^{a,w}	5.77^{aw}
ACV	3.07^{b,x}	3.42^{a,x}	2.45^{b,x}	4.75^{b,w}
SRB	3.60^{b,x}	3.95^{a,x}	5.35^{a,w}	4.90^{ab,w}
ACV+SRB	4.62^{a,w}	2.32^{b,x}	5.45^{a,w}	5.35$^{ab.w}$
Total psychrotrophic counts				
CON	3.65^{a,x}	7.25^{a,w}	6.98^{a,w}	7.40^{a,w}
ACV	3.80^{a,x}	5.95^{b,w}	6.51^{a,w}	6.85^{b,w}
SRB	2.60^{b,y}	6.25^{b,x}	5.81^{b,x}	7.75^{a,w}
ACV+SRB	2.00^{b,y}	6.10^{b,w}	3.42^{c,x}	6.65^{b,w}
Total anaerobic counts				
CON	1.00^{b,y}	5.52^{a,x}	7.53^{aw}	7.57^{aw}
ACV	1.00^{b,y}	4.01^{b,x}	5.20^{bw}	6.15^{bw}
SRB	2.55^{a,x}	5.82^{a,w}	5.85^{b,w}	6.37^{b,w}
ACV+SRB	1.00^{b,y}	4.27^{bx}	5.57^{bw}	5.24^{c,w}
Fecal coliform				
CON	1.30^{a,w}	1.00^{a,w}	1.00^{ab,w}	1.50^{a,w}
ACV	0.70^{b,w}	1.00^{a,w}	1.00^{ab,w}	1.00^{a,xw}
SRB	1.20^{abw}	1.25^{a,w}	1.32^{aw}	1.77^{aw}
ACV+SRB	0.77^{abw}	0.37^{b,w}	0.65^{bw}	1.15^{aw}
pH				
CON	6.22^{abw}	6.20^{aw}	6.20^{aw}	6.10^{aw}
ACV	5.99^{b,x}	6.26^{a,w}	6.23^{a,w}	6.03^{ab,x}
SRB	6.40^{a,w}	5.99^{c,x}	5.98^{b,x}	5.95^{b,x}
ACV+SRB	6.05^{b,w}	6.14^{b,w}	6.02^{b,wx}	5.79^{c,x}

[1]CON = Control, ACV = Apple cider vinegar, SRB = Spice rub only, ACV+SRB = Apple cider vinegar plus spice rub
[2] Each mean value represents four measurements.
[a-c] Means in the same column with different superscript are significantly different ($P < 0.05$).
[w-x] Means in the same row with different superscript are significantly different ($P < 0.05$).

by surface slime formation at 8 log CFU/g (Jackson *et al*., 1997). Psychrotrophic counts in this study remained less than 7 log CFU/g through 21 days for ACV and ACV+SRB, and increased to 7.40 and 7.75 log CFU/g for CON and SRB, respectively. Anaerobic counts increased ($P < 0.05$) as storage time increased (Table 3). Anaerobic counts remained less than 6.5 log CFU/g for all ACV and SRB treatments through 21 days. All meat treated with ACV alone or in combination with SRB had lower ($P < 0.05$) anaerobic counts than the control on days 7, 14, and 21. The SRB only treatment had lower anaerobic count than CON on days 14 and 21. Fecal coliforms remained less than 2 log CFU/g through 21 days storage (Table 3). The spice rub alone resulted in higher fecal coliform counts ($P > 0.05$) than ACV+SRB on days 7 and 14. Data revealed that fecal coliforms survived, but did not proliferate during storage.

pH

The pH values varied between 5.79 and 6.40 (Table 3). On Day 0, initial pH values for ACV, and ACV+SRB were lower ($P < 0.05$) than SRB and similar ($P > 0.05$) to CON. Meat treated with SRB and ACV+SRB resulted in lower ($P < 0.05$) pH than CON and ACV on days 7 through 21. This observation suggested that the SRB contributed to the lower pH values when used alone and in combination with ACV. ACV only and CON treatments resulted in similar (($P > 0.05$) pH on all storage days. Normal pH of goat meat has been reported in the range of 5.76

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

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

*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 ($P < 0.05$). [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.

(Pophiwa *et al*., 2017) to pH 5.88 (Shija *et al*., 2013). Except for the pH of meat treated with ACV+SRB on day 21, all pH values exceeded this range.

Sensory evaluation

Except for day 7, panelists rated all treatments similar ($P > 0.05$) for overall tenderness (Table 4). On day 7 ACV+SRB higher ($P < 0.05$) in tenderness when compared to CON. Regardless of treatment, all meat was scored slightly tender (score of 5 to 5.9) to moderately tender (score of 6.0 to 6.9). These results may be due to the use of young goats (6 months of age).

Panelists determined that goat flavor intensity was greater ($P < 0.05$) in CON and ACV, when compared to SRB and ACV+SRB on day 21. Goat favor intensity increased ($P < 0.05$) in CON as storage time increased when day 0 was compared to day 21. Goat flavor intensity was similar ($P > 0.05$) among all treatments on days 0 through 14. On days 0 through 14 goat flavor intensity was rated slightly bland (score of 4.0 to 4.9) to moderately bland (score of 3.0 to 3.9). This study revealed that intensity in goat meat flavor remained similar among all storage days, for all treatments except the control. 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). The data suggested that the spice rub functioned to minimize goat flavor intensity with SRB and ACV + SRB treatments. The undesirable flavor in goat meat was described as woody, urine, and medicinal. In comparison to beef and other red meat, goat meat has a characteristically different flavor and aroma. This difference in flavor and aroma in goat meat has been attributed to branched chain fatty acids (Webb *et al*., 2005; Ha and Lindsay, 1990; Johnson *et al*., 1977). Panelists detected a sour and sulfur-like odor in the control samples after 21 days, which was attributed primarily to microbial degradation. The strong goat odor also has been associated with 4-ethyloctanoic acid in goat meat, lamb, and mutton (Brennand, 1989 as cited by Webb, 2014; Ha and Lindsay, 1990). Madruga *et al*. (2000) determined that organoleptic properties of tenderness, appearance, aroma, flavor, juiciness and overall palatability decreased with goat age from 175 to 310 days. The researchers reported that meat from goats slaughtered at 175 days of age had a lower number of volatile compounds and intensity, as measured by total relative abundance, and was preferred by semi-trained sensory panelists over meat from older animals.

Cost analysis

A comparative cost analysis was performed to determine the production costs and retail values for the four formulated rib roast products (Table 5). The price of the raw goat meat rib roasts, ($8.13) was calculated based on purchasing price of $2.76/ kg ($1.25/454g) live weight basis, processing fees $1.10/ kg, and boning fee of $0.44/kg. The non-meat ingredient 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 which included processing fees $1.10/kg live weight, boning fee of $0.44/kg, and estimated labeling, packaging, transportation and advertising expenses.

Table 5. Comparative cost analysis for 100 kg batches of vacuum packaged precooked goat ribs.

	Ingredient, Packaging and Mark-up Expenses ($)			
Ingredients	**Control**	**Marinade Only**	**Spice rub Only**	**Marinade and spice rub**
Meat	813	813	813	813
Water	0.03	0.03	0.03	0.03
Salt	-	0.72	-	0.72
Apple Cider Vinegar	-	13	-	13
Sodium tripolyphosphate	-	2.48	-	2.48
Spice Rub	-	-	21.48	21.48
Packaging Material				
Vacuum pouches	173	173	173	173
Total cost/ 100 kg batch	986.03	1002.23	1007.51	1023.71
Mark up (30%)	422.58	429.53	431.79	438.73
Total adjusted cost/100 kg	1408.61	1431.76	1439.30	1462.44
Total cost/ kg	14.09	14.32	14.39	14.62
Total cost/ 454g	6.40	6.50	6.53	6.64

* A mark up of 30% was used which included processing fees $1.10/ kg live weight, boning fee of $0.44/ kg, and estimated labeling, packaging, transportation and advertising expenses.

The estimated retail costs per 454 g for goat ribs manufactured in this study containing water, apple cider vinegar, spice rub only, and apple cider vinegar plus spice rub were $6.40, $6.50, $6.53, and $6.64, respectively (Table 5). Commercially available vacuum packaged raw ribs included Publix baby back ribs ($1.99 per 454 g), and Smithfield premium baby back raw ribs ($2.94 per 454 g), which represented an average of $2.47 per 454g. All commercial products were vacuum packaged with no sauce, and no indication of being minimally processed. The data revealed that the cost of fresh vacuum packaged goat meat ribs would exceed those of comparable pork products. The cost of the control ribs (CON) in this study exceeded the cost of the commercially available raw ribs by at least 200%. The major reason for the higher cost is the cost of the raw goat meat, which was $8.13 per kg of raw goat meat.

Conclusion

The hot carcass, chilled carcass, and skeletal meat yields of goats utilized in this study were similar to data recorded in other studies for similar crossbred goats. The higher fat composition of the goat meat was attributed primarily to the actual diets of the goats. The data suggested a synergistic effect between ACV and SRB on days 7-21 for reduction in psychrotrophic and anaerobic counts. In addition, it was revealed that the lower pH values (when compared to the control) coincided with the lower ($P < 0.05$) psychrotrophic and anaerobic counts on days 7-21. Overall tenderness and goat flavor intensity were in the range of slightly tender to moderately tender, and moderately bland to slightly intense, respectively, which indicated the lack of toughness, and undesirable off-flavor in the goat meat evaluated.

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