Meat Science 81 (2009) 589–595

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Effect of grape seed extract on descriptive sensory analysis of ground chicken during refrigerated storage

R.G. Brannan *

School of Human and Consumer Sciences, Ohio University, W324 Grover Center, Athens, OH 45701, United States

ARTICLE INFO

Article history:
Received 18 June 2008
Received in revised form 10 October 2008
Accepted 14 October 2008

Keywords:
Grape seed extract
Descriptive sensory analysis
Color
Yield
pH
Binding strength

ABSTRACT

Descriptive sensory analysis, instrumental color, yield, pH, water activity, and binding strength were determined on ground chicken breast and thigh with or without grape seed extract (GSE) during refrigerated storage. In chicken breast, GSE inhibited the intensity of musty and rancid odor, and rancid flavor compared to control patties, but GSE caused significantly darker (L^*), redder (a^*), and less yellow (b^*) patties. No differences were observed for pH, water activity, or yield, though differences were observed for binding strength. In chicken thigh, sensory scores were significantly different for 14 of 15 sensory attributes, although the differences were due to storage time or precooking, not the presence of GSE. GSE caused significantly darker sensory scores and L^* values, and redder (a^*) and less yellow (b^*) patties. Differences in binding strength and yield were attributable to precooking, not the presence of GSE. GSE may be an effective antioxidant in precooked chicken breast systems.

1. Introduction

There is increasing evidence demonstrating the ability of grape seed extract (GSE) to retard lipid oxidation in meat during storage, most likely due to the fact that GSE is a rich source of polyphenolic compounds, especially proanthocyanidins (Weber et al., 2007). In raw meat, GSE has been shown to be effective in reducing the amount of primary lipid oxidation products (e.g. lipid hydroperoxides and hexanal) and secondary lipid oxidation products (e.g. thiobarbituric acid reactive substances, a.k.a. TBARS) in beef (Banon, Diaz, Rodriguez, Garrido, & Price, 2007), chicken (Lau & King, 2003), fish (Pazos, Gallardo, Torres, & Medina, 2005), and pork (Carpenter, O'Grady, O'Callaghan, O'Brien, & Kerry, 2007). In cooked meat, GSE also has been shown to be effective in reducing the amount of primary and secondary lipid oxidation biomarkers in ground beef (Ahn, Grun, & Fernando, 2002; Ahn, Grun, & Mustapha, 2007; Rojas & Brewer, 2007), turkey breast (Mielnik, Olsen, Vogt, Adeline, & Skrede, 2006), chicken breast (Rababah et al., 2006), and pork (Carpenter, O'Grady, O'Callaghan, O'Brien, & Kerry, 2007; Rojas & Brewer, 2007).

However, polyphenolic-rich GSE has a very red color and is known to be astringent (Monteleone, Condelli, Dinnella, & Bertuccioli, 2004) which may affect the sensory characteristics of products to which it is incorporated. GSE reduced the development of rancid meat flavor but did not affect meat color during 6 d of refrigerated storage of raw beef (Banon et al., 2007). GSE also reduced warmed over flavor in cooked beef during 3 d of refrigerated storage (Ahn et al., 2002) and rancid and wet-cardboard off-odor scores without affecting color during 8 d of refrigerated storage (Rojas & Brewer, 2007). In raw and cooked pork that was stored refrigerated, addition of GSE did not affect sensory scores or color (Carpenter, O'Grady, O'Callaghan, O'Brien, & Kerry, 2007; Rojas & Brewer, 2007). Addition of GSE did not cause any initial changes in flavor scores in irradiated and non-irradiated whole chicken breasts (Rababah, Hettiarachchy, Eswaranandam, Meullenet, & Davis, 2005).

The current study was built upon previous work that demonstrated that 0.1% GSE completely inhibited the formation of lipid hydroperoxides and thiobarbituric acid reactive substances (TBARS) in cooked beef, pork, chicken breast, and thigh after 7 d of refrigerated storage (Brannan & Mah, 2007). This work also showed that GSE is an effective antioxidant in cooked chicken breast and thigh during frozen storage. Subsequently, ground chicken thigh meat with and without the addition of GSE and NaCl was held under refrigerated storage at 59%, 76%, 88%, and 99% relative humidity. GSE was shown to be an effective antioxidant in ground chicken thigh meat that did not affect moisture content or pH during storage, inhibited TBARS formation, helped to mitigate the pro-oxidative effects of NaCl, and altered the effect of NaCl on protein solubility in salted chicken patties (Brannan, 2008). What is not known is how these physicochemical interactions of GSE affect raw and cooked meat quality attributes. The objective of the current study was to quantify the sensory odor, taste, flavor,

* Tel.: +1 740 593 2879; fax: +1 740 593 0289.
E-mail address: brannan@ohio.edu.

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doi:10.1016/j.meatsci.2008.10.014

and color changes that occur in raw and precooked ground chicken breast and thigh with and without GSE during 12 d of refrigerated storage. Instrumental color, binding strength, yield, water activity, and pH were also determined.

2. Materials and methods

2.1. Raw materials, sample preparation, and storage conditions

GSE (Gravinol-S®) was obtained from a commercial source (Kikkoman International, San Francisco, CA). Through an arrangement with a local retailer, boneless chicken thighs were obtained on the morning that they arrived at the store. Boneless chicken breasts were obtained from the same retailer. Food used as sensory standards and references were obtained from retail markets. All other chemicals and solvents were obtained from Fisher Scientific (Waltham, MA).

Skinless chicken breast or thigh meat was cut by hand into strips and then ground once through a stand mixer using a food grinder attachment with a coarse grinding plate (model K45SS/250W, KitchenAid®, Whirpool Corporation, MI). An aqueous stock solution of GSE and/or water were incorporated into the ground meat to standardize the systems to final reaction concentrations of 0.1% GSE (w/w) by mixing by hand for 1 min. Control patties contained no GSE. Ground meat (20 g) was formed into disc-shaped patties, placed in FoodSaver® bags with no attempt made to exclude oxygen from the bags, then heat sealed. Some were immediately stored refrigerated (4 °C) while others were cooked before storage. The cooking procedure involved placing a single layer of the square bags in boiling water for 3 min, then turning the bags over and cooking for an additional 3 min to achieve an internal temperature of at least 77 °C. The temperature was monitored using an eight-channel thermocouple (Omega Industries, Grafton, WI). The bags were cooled on ice then stored refrigerated (4 °C). After 0, 4, 8, or 12 days of refrigerated storage, the bags were moved to a freezer (−18 °C) for up to 14 days before sensory analysis was performed.

2.2. Descriptive sensory analysis

A descriptive panel with six members underwent more than 20 h of general training of which the final 3–4 h was used to determine the consensus list of odors, basic tastes, and flavors and the references for each descriptor. The list of descriptors, definitions, and references are shown in Table 1. The descriptor for "rancid odor" was added at the suggestion of the panel after analyzing the first replication of the chicken thigh patties. A 15-point line scale anchored only by the references and the warm-up sample was used in assigning values to the various descriptors. During training and sampling, panelists had access to unlimited water and unsalted saltines. Twelve sampling days of 5 or 6 samples per sampling day were required. On each day of sampling, panelists spent a few minutes familiarizing themselves with the anchored references and then were presented a warm-up sample consisting of cooked chicken that was used for calibration. Completely thawed patties for sampling in the bags in which they were stored were coded with random three digit numbers. Patties that were stored raw were cooked and patties that were stored cooked were reheated using a water bath then held under infrared lamps for not more than 15 min before being presented to the panelists. Panelists were instructed to cut open a corner of the bag and immediately sniff the released steaming vapor to rate the odor descriptors. Panelists then tasted the sample and rated the basic tastes and flavors.

2.3. Measurement of water activity, pH, binding strength, color, and yield

Crude water activity (a_w) of the chicken thigh meat (3 g) was measured using a PawKit water activity meter (Decagon Devices Inc., Pullman, WA) with an accuracy of ±0.02a_w units. A pH meter (Accumet AB15 Plus, Fisher Scientific, Waltham, MA) calibrated daily to pH 4 and 7 was used to monitor the pH of a 20 g sample of cooked chicken meat by plunging the pH meter electrode into direct contact with the chicken meat. Binding strength was measured as the grams of force required to dislodge a 1.27 cm cylindrical plug from the patty using a Ta-XT2i Texture Analyzer (Texture Technologies Corp., Scarsdale NY/Stable Micro Systems, Godalming, Surrey, UK). The meat patty rested on a flat platform with a 1.27 cm circular whole through which a 1.27 cm cylindrical probe traveling at a crosshead speed of 1 mm/s would pass. The probe was deployed at a distance sufficient to completely dislodge the plug from the patty. The texture analyzer was controlled via Texture Expert Software and this package was used to record data and generate force-determination curves. CIE L^*, a^*, and b^* values for color were measured using a Konica BC-10 (Konica Minolta Sensing Americas Inc., Ramsey, NJ) colorimeter. The measurements were made on patties after they were heated for sensory analysis and were taken through the clear packaging film with enough pressure applied such that there was no space between the color-

Table 1
Attributes, standard references, and ratings used in descriptive sensory analysis of raw and cooked ground chicken.

	Attribute	Definition	Reference	Rating
Odors	Chicken brothy	Aromatics associated with chicken broth	Swanson® Natural Goodness™ chicken broth	12
	Fishy	Aromatics associated with cooked fish	Freshly cooked talapia	10
	Sulfury	Aromatics associated with boiled egg yolk	Boiled egg yolk	5
	Musty	Aromatics associated with wet cardboard	Wet cardboard	4
	Rancid	Aromatics associated with oxidized oil	Oxidized flax seed oil	None
Tastes	Sweet	Taste associated with sucrose solutions	5% sucrose	5
	Sour	Taste associated with citric acid solutions	0.08% citric acid	5
	Salty	Taste associated with sodium chloride solutions	0.5% sodium chloride	5
	Bitter	Taste associated with caffeine solutions	0.05% caffeine	5
	Umami	Taste associated with monosodium glutamate solutions	0.1% monosodium glutamate	7.5
Flavors	Metallic/serumy	Flavor associated with blood or rare meat	Rare beef (top sirloin)	3
	Cooked chicken	Flavor associated with cooked chicken breast tenderloins	Boiled chicken breast tenderloin	9
	Fatty	Flavor associated with rendered chicken fat	Rendered chicken skin	8
	Fishy	Flavor associated with cooked white fish	Freshly cooked tilapia	11
	Rancid	Flavor associated with rancid/oxidized oil	Oxidized flax seed oil	6
Appearance	Surface color	Color of the outer surface of the sample	Boiled chicken tenderloin	1
			Rare beef (top sirloin)	14

imeter, the film, and the patty. Yield was measured as the percent difference between the cooked weight and the raw weight of each patty.

2.4. Statistical analysis

Two replications of the study were performed. For each replication, measurements of binding strength, a_w, yield, and pH were made in triplicate while non-destructive measurements for instrumental color (L^*, a^*, b^*) were made on each patty that was subsequently used for sensory analysis ($n = 6$). SPSS (Chicago, IL) was used to analyze data using the general linear model procedure. Two separate $2 \times 2 \times 4$ full factorial designs were implemented, one for chicken breast and one for chicken thigh, that included the main effects of treatment (±GSE), storage condition (raw or precooked) or storage time (0 d, 4 d, 8 d, 12 d). Two-way, three-way, and four-way interactions were included in the analysis. The level of significance for all tests was set at $p < 0.05$. Means separations were achieved according to Duncan's multiple-range test.

3. Results and discussion

3.1. Effect of GSE in cooked and raw ground chicken breast during refrigerated storage

3.1.1. Descriptive sensory analysis – odors, tastes, and flavors

Mean sensory scores for odor, taste, and flavor attributes of raw or precooked ground chicken breast with and without GSE during refrigerated storage are shown in Table 2. Of the 15 attributes assessed by the descriptive panel, significant differences were observed for two odor attributes (musty and rancid), two taste attributes (sour and bitter), and two flavor attributes (cooked chicken flavor and rancid flavor). The differences observed for musty and rancid odor largely affected the precooked patties, as no differences were observed over time or between treatments for the raw patties. In the precooked patties, musty odor increased significantly between 0 and 12 d in the control patties but not in the GSE-treated patties. These observations are supported by analysis of the main effects. For musty odor, treatment ($P = 0.001$), storage condition ($P = 0.002$), and storage time ($P = 0.029$) were all significantly different, with higher musty odor scores reported in control patties, precooked patties, and after 12 d of refrigerated storage. For rancid odor, the only main effect that was significant was treatment ($P = 0.014$), with control patties eliciting higher rancid odor scores than GSE-containing patties. These results suggest that GSE was effective in limiting the intensity of two attributes that are commonly associated with warmed over flavor in precooked meat, which agrees with previous research that showed that rancid and wet-cardboard odors were reduced by GSE in cooked beef and pork (Rojas & Brewer, 2007).

The flavor attributes cooked chicken flavor and rancid flavor also were found to be significantly different in the ground chicken breast. The differences observed for cooked chicken flavor are primarily due to the main effect of storage time ($P < 0.001$) because in spite of the cooked chicken flavor decline during storage in the control patties, the scores were not significantly different between the control and the GSE-containing samples at any of the storage days. The difference observed in rancid flavor were affected by the main effects of treatment ($P = 0.002$), storage condition

Table 2
Effect of grape seed extract on mean sensory scores ($n = 12$) ± standard deviation for odor descriptors, tastes, and flavor descriptors of raw and cooked ground chicken breast during refrigerated storage.

Attribute	Treatment	Storage condition							
		Stored raw, then cooked				Stored cooked, then reheated			
		0 d	4 d	8 d	12 d	0 d	4 d	8 d	12 d
Chicken brothy odor	Control	5.3 ± 0.4	5.6 ± 0.9	5.0 ± 0.5	4.5 ± 0.7	5.1 ± 0.9	4.9 ± 0.8	5.1 ± 0.8	4.7 ± 1.2
	GSE	5.1 ± 1.0	5.4 ± 0.7	5.2 ± 0.7	4.7 ± 0.7	5.2 ± 0.5	5.1 ± 0.8	5.2 ± 0.7	5.3 ± 0.6
Fishy odor	Control	5.1 ± 0.5	5.1 ± 0.3	5.0 ± 0.5	5.2 ± 0.4	5.0 ± 0.2	5.2 ± 0.3	5.0 ± 0.5	5.0 ± 1.0
	GSE	4.9 ± 0.3	4.9 ± 0.4	5.0 ± 0.6	5.4 ± 0.6	5.0 ± 0.6	5.0 ± 0.4	5.1 ± 0.3	5.0 ± 0.3
Sulfury odor	Control	4.1 ± 0.4	3.9 ± 0.3	3.8 ± 0.9	4.0 ± 0.2	4.2 ± 0.4	4.2 ± 0.4	4.0 ± 0.3	3.9 ± 0.4
	GSE	3.7 ± 0.3	3.9 ± 0.3	4.0 ± 0.4	4.1 ± 0.4	4.0 ± 0.4	4.0 ± 0.4	4.0 ± 0.2	4.1 ± 0.2
Musty odor	Control	1.1 ± 0.4 ^{c}	1.0 ± 0.3 ^{c}	1.0 ± 0.2 ^{c}	1.3 ± 0.5 ^{bc}	1.2 ± 0.5 ^{bc}	1.6 ± 0.6 ^{ab}	1.6 ± 0.8 ^{ab}	1.8 ± 0.7 ^{a}
	GSE	1.0 ± 0.3 ^{c}	1.1 ± 0.4 ^{c}	1.1 ± 0.3 ^{c}	1.5 ± 0.5 ^{abc}	1.3 ± 0.4 ^{bc}	1.1 ± 0.2 ^{c}	1.1 ± 0.2 ^{c}	1.0 ± 0.2 ^{c}
Rancid odor	Control	0.5 ± 0.6 ^{bc}	0.4 ± 0.4 ^{c}	0.5 ± 0.4 ^{bc}	0.8 ± 0.7 ^{bc}	0.5 ± 0.7 ^{bc}	1.1 ± 1.2 ^{abc}	1.2 ± 1.4 ^{ab}	1.6 ± 1.4 ^{a}
	GSE	0.3 ± 0.3 ^{c}	0.6 ± 0.7 ^{bc}	0.5 ± 0.6 ^{bc}	0.9 ± 0.5 ^{bc}	0.8 ± 0.8 ^{bc}	0.5 ± 0.6 ^{bc}	0.4 ± 0.6 ^{bc}	0.4 ± 0.4 ^{c}
Sweet	Control	1.1 ± 0.3	1.1 ± 0.4	1.2 ± 0.6	1.1 ± 0.3	1.1 ± 0.3	1.1 ± 0.2	0.9 ± 0.3	0.9 ± 0.3
	GSE	1.1 ± 0.4	0.9 ± 0.3	0.8 ± 0.4	0.9 ± 0.4	1.0 ± 0.3	1.0 ± 0.2	1.0 ± 0.3	1.0 ± 0.2
Sour	Control	1.0 ± 0.5 ^{b}	1.0 ± 0.4 ^{b}	1.3 ± 0.4 ^{ab}	1.4 ± 0.5 ^{a}	1.0 ± 0.1 ^{b}	1.1 ± 0.2 ^{ab}	1.1 ± 0.2 ^{ab}	1.3 ± 0.3 ^{ab}
	GSE	1.2 ± 0.5 ^{ab}	1.0 ± 0.3 ^{b}	1.4 ± 0.6 ^{a}	1.5 ± 0.4 ^{a}	1.3 ± 0.4 ^{ab}	1.2 ± 0.3 ^{ab}	1.1 ± 0.3 ^{ab}	1.0 ± 0.1 ^{b}
Salty	Control	1.2 ± 0.2	1.0 ± 0.3	1.2 ± 0.3	1.3 ± 0.6	1.2 ± 0.3	1.2 ± 0.3	1.1 ± 0.3	1.2 ± 0.6
	GSE	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.3	1.1 ± 0.3	1.1 ± 0.2
Bitter	Control	1.1 ± 0.3 ^{cd}	0.9 ± 0.3 ^{d}	1.4 ± 0.4 ^{abc}	1.4 ± 0.6 ^{ab}	1.1 ± 0.1 ^{cd}	1.0 ± 0.1 ^{cd}	1.3 ± 0.3 ^{abc}	1.4 ± 0.4 ^{abc}
	GSE	1.1 ± 0.5 ^{bcd}	1.0 ± 0.3 ^{cd}	1.2 ± 0.4 ^{abcd}	1.5 ± 0.8 ^{a}	1.1 ± 0.3 ^{bcd}	1.2 ± 0.3 ^{abcd}	1.1 ± 0.4 ^{bcd}	1.0 ± 0.1 ^{cd}
Umami	Control	1.0 ± 0.1	0.9 ± 0.4	1.2 ± 0.3	1.1 ± 0.2	1.1 ± 0.2	1.2 ± 0.3	1.1 ± 0.2	1.2 ± 0.3
	GSE	1.2 ± 0.3	1.1 ± 0.3	1.0 ± 0.4	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.3	1.1 ± 0.2	1.1 ± 0.3
Metallic/serumy	Control	1.2 ± 0.2	1.1 ± 0.4	1.4 ± 0.5	1.6 ± 0.5	1.2 ± 0.2	1.2 ± 0.3	1.3 ± 0.3	1.1 ± 0.4
	GSE	1.3 ± 0.5	1.1 ± 0.2	1.3 ± 0.4	1.4 ± 0.5	1.3 ± 0.3	1.2 ± 0.3	1.1 ± 0.4	1.0 ± 0.2
Cooked chicken	Control	5.1 ± 0.4 ^{ab}	5.3 ± 0.6 ^{a}	4.7 ± 0.7 ^{bc}	4.6 ± 0.6 ^{bc}	5.1 ± 0.3 ^{ab}	5.0 ± 0.6 ^{ab}	4.7 ± 1.1 ^{bc}	4.3 ± 0.9 ^{c}
	GSE	5.0 ± 0.7 ^{ab}	5.0 ± 0.5 ^{ab}	5.0 ± 0.5 ^{ab}	4.6 ± 0.5 ^{bc}	4.9 ± 0.4 ^{ab}	4.9 ± 0.4 ^{ab}	4.8 ± 0.5 ^{abc}	4.8 ± 0.4 ^{abc}
Fatty flavor	Control	4.1 ± 0.1	3.9 ± 0.3	4.1 ± 0.5	4.2 ± 0.4	4.1 ± 0.4	4.0 ± 0.3	3.7 ± 0.4	3.5 ± 1.1
	GSE	4.1 ± 0.3	3.9 ± 0.2	4.1 ± 0.6	4.1 ± 0.5	4.1 ± 0.5	4.0 ± 0.3	3.8 ± 0.4	4.0 ± 0.4
Fishy flavor	Control	1.0 ± 0.3	1.1 ± 0.8	1.4 ± 0.8	1.4 ± 0.6	1.2 ± 0.3	1.1 ± 0.2	1.3 ± 0.4	1.3 ± 0.6
	GSE	1.0 ± 1.4	0.9 ± 0.3	1.4 ± 1.1	1.3 ± 0.7	1.2 ± 0.5	1.1 ± 0.2	0.9 ± 0.3	1.1 ± 0.3
Rancid flavor	Control	0.9 ± 0.4 ^{e}	0.9 ± 0.4 ^{e}	1.4 ± 1.0 ^{bcde}	1.6 ± 0.6 ^{abcd}	1.4 ± 0.9 ^{bcde}	1.6 ± 1.2 ^{abcd}	2.1 ± 1.5 ^{a}	2.0 ± 0.9 ^{ab}
	GSE	0.8 ± 0.3 ^{e}	0.9 ± 0.4 ^{e}	1.2 ± 0.6 ^{cde}	1.8 ± 0.8 ^{abc}	1.3 ± 0.5 ^{cde}	1.1 ± 0.4 ^{cde}	1.0 ± 0.2 ^{de}	1.0 ± 0.3 ^{de}

$^{a-e}$Different letters within an attribute indicate significant differences ($P < 0.05$).

($P = 0.014$), and storage time ($P = 0.002$), with higher rancid flavor scores for control patties, precooked patties, and after 12 d of refrigerated storage. As seen in Table 2, significant increases in rancid flavor during storage were observed in both raw and precooked control and raw GSE-containing patties, but not precooked GSE-containing patties. Earlier research has suggested that in cooked chicken breast during refrigerated storage, GSE is not acting as a metal chelator since the formation of oxidation biomarkers (lipid hydroperoxides, TBARS) were inhibited by GSE but not by a known metal chelator (Brannan & Mah, 2007). Taken together, these results suggest that GSE is an effective radical scavenger that can reduce attributes associated with warmed over flavor in precooked chicken breast.

3.1.2. Objective and sensory color

Previous results have shown that the effect of GSE on the control of oxidation in meat is concentration dependent (Ahn et al., 2002) and others speculate that higher GSE concentrations adversely affect the color of meat (Rojas & Brewer, 2007). As shown in Table 3, the concentration of GSE used in ground chicken breast (0.1%) caused significantly darker (L^*), redder (a^*), and less yellow (b^*) patties as measured by instrumental means. However, the descriptive sensory panel scores were not significantly different, but when pooled across storage condition and storage days, GSE-containing patties exhibited darker sensory color scores than control patties. These results suggest that GSE altered the color of the chicken breast patties but that consumer sensory analysis is probably required to determine if the color change is unacceptable.

3.1.3. Yield, pH, binding strength, and water activity

As shown in Table 4, neither yield nor pH was affected by GSE in the ground chicken breast samples. A significant difference was observed for binding strength, but no differences were observed for the main effects of treatment, storage condition, or storage temperature. The only difference of note in binding strength is the fact that GSE-containing precooked chicken breast patties exhibited less binding strength after 12 d of refrigerated storage than the control patties. The water activity for all ground chicken breast patties, either raw or precooked, with or without GSE, at each storage day was between 0.97 and 0.99 and no significant differences were observed.

3.2. Effect of GSE in cooked and raw ground chicken thigh during refrigerated storage

3.2.1. Descriptive sensory analysis – odors, tastes, and flavors

Mean sensory scores for odor, taste, and flavor attributes of raw or precooked ground chicken thigh with and without GSE during refrigerated storage are shown in Table 5. Significant differences were observed for 14 of the 15 attributes assessed by the descriptive panel and in most cases the differences are difficult to interpret since no clear patterns emerge. However, careful examination of the main effects reveals that these differences are driven by storage condition and storage day, for which 13 and 12 attributes are significantly different, respectively. In precooked chicken thigh patties, no difference between treatments was observed for any of the attributes that characterize warmed over flavor, suggesting that GSE is not an effective antioxidant against warmed over flavor in chicken thigh meat. This is in spite of the research that has shown that 0.1% GSE reduces the formation of lipid oxidation biomarkers in raw and precooked chicken thigh during refrigerated storage (Brannan, 2008; Brannan & Mah, 2007).

3.2.2. Objective and sensory color

As mentioned earlier, speculation exists that higher GSE concentrations may adversely affect the color of meat to which it is added (Rojas & Brewer, 2007). Results of the instrumental color analysis in ground chicken thigh, shown in Table 6, mirrors that observed for ground chicken breast as GSE caused significantly darker (L^*), redder (a^*), and less yellow (b^*) patties. Unlike the re-

Table 3
Effect of grape seed extract on sensory and instrumental color ($n = 12$) ± standard deviation of raw and cooked ground chicken breast during refrigerated storage.

	Day	Sensory color		L^*		a^*		b^*	
		Control	GSE	Control	GSE	Control	GSE	Control	GSE
Stored raw, then cooked	0	3.5 ± 1.2	4.7 ± 1.0	81.9 ± 1.0 ^{ab}	79.0 ± 1.6 ^{de}	2.0 ± 0.3 ^{fg}	3.1 ± 0.8 ^{abc}	11.3 ± 1.4 ^{bc}	8.5 ± 1.0 ^{ef}
	4	3.7 ± 1.3	4.1 ± 0.7	80.1 ± 2.4 ^{cd}	78.5 ± 1.8 ^{ef}	2.4 ± 0.5 ^{def}	2.9 ± 0.8 ^{cd}	11.6 ± 0.9 ^{bc}	8.1 ± 1.2 ^{f}
	8	4.0 ± 0.5	4.5 ± 1.3	80.9 ± 2.1 ^{bc}	77.4 ± 1.9 ^{fg}	3.1 ± 0.9 ^{cd}	4.1 ± 0.8 ^{ab}	11.3 ± 1.6 ^{bc}	8.5 ± 1.2 ^{ef}
	12	3.5 ± 0.9	4.5 ± 1.4	81.0 ± 1.3 ^{bc}	78.8 ± 1.7 ^{def}	3.0 ± 0.5 ^{cd}	4.2 ± 0.7 ^{a}	11.2 ± 1.5 ^{c}	9.8 ± 0.8 ^{d}
Stored cooked, then reheated	0	3.8 ± 0.4	4.4 ± 0.7	81.6 ± 1.2 ^{abc}	77.7 ± 2.4 ^{g}	1.5 ± 0.4 ^{g}	3.3 ± 1.4 ^{c}	12.8 ± 1.1 ^{a}	10.0 ± 0.9 ^{d}
	4	4.0 ± 0.1	4.1 ± 0.5	82.3 ± 1.0 ^{ab}	77.6 ± 1.7 ^{efg}	1.9 ± 0.4 ^{fg}	2.8 ± 0.7 ^{cde}	12.5 ± 1.5 ^{ab}	9.4 ± 0.8 ^{de}
	8	4.1 ± 0.4	4.1 ± 0.5	82.7 ± 1.3 ^{a}	76.5 ± 2.3 ^{g}	1.8 ± 0.4 ^{fg}	3.2 ± 1.5 ^{c}	12.3 ± 1.0 ^{abc}	9.6 ± 1.1 ^{de}
	12	3.4 ± 0.9	4.5 ± 0.5	81.7 ± 1.6 ^{ab}	76.5 ± 1.5 ^{g}	2.2 ± 0.8 ^{ef}	3.5 ± 1.0 ^{bc}	12.2 ± 2.9 ^{abc}	9.4 ± 0.8 ^{de}

$^{a–g}$Different letters within sensory color, L^*, a^*, or b^* indicate significant differences ($P < 0.05$).

Table 4
Effect of grape seed extract on yield, pH, and binding strength ± standard deviation of raw and cooked ground chicken breast during refrigerated storage.

		Yield (%)		pH		Binding strength (g)	
		Control	GSE	Control	GSE	Control	GSE
Stored raw, then cooked	0	70.5 ± 2.2	70.8 ± 1.0	6.21 ± 0.05	6.21 ± 0.02	2801 ± 229 ^{cd}	3053 ± 428 ^{bcd}
	4	68.8 ± 1.0	75.0 ± 4.9	6.23 ± 0.05	6.22 ± 0.03	3032 ± 427 ^{bcd}	4144 ± 423 ^{a}
	8	72.0 ± 3.5	73.2 ± 3.2	6.23 ± 0.04	6.22 ± 0.04	3138 ± 331 ^{bcd}	2937 ± 562 ^{cd}
	12	78.3 ± 0.4	71.8 ± 3.2	6.23 ± 0.11	6.22 ± 0.10	2711 ± 641 ^{d}	3172 ± 521 ^{bcd}
Stored cooked, then reheated	0	69.0 ± 1.4	69.0 ± 8.9	6.23 ± 0.13	6.23 ± 0.13	3016 ± 925 ^{bcd}	3500 ± 632 ^{bc}
	4	65.5 ± 1.4	63.5 ± 4.2	6.20 ± 0.12	6.37 ± 0.11	2869 ± 464 ^{cd}	3127 ± 286 ^{bcd}
	8	68.5 ± 3.5	69.0 ± 1.4	6.23 ± 0.12	6.32 ± 0.12	3396 ± 474 ^{bcd}	2829 ± 494 ^{cd}
	12	64.0 ± 5.7	65.8 ± 3.9	6.23 ± 0.11	6.20 ± 0.10	3674 ± 303 ^{ab}	2785 ± 640 ^{d}

$^{a–d}$Different letters within yield, pH, or binding strength indicate significant differences ($P < 0.05$).

Table 5
Effect of grape seed extract on mean sensory scores ($n = 12$) ± standard deviations for odor descriptors, tastes, and flavor descriptors of raw and cooked ground chicken thigh during refrigerated storage.

		Stored raw, then cooked				Stored cooked, then reheated			
		0 d	4 d	8 d	12 d	0 d	4 d	8 d	12 d
Chicken brothy odor	Control	7.3 ± 0.8 ^{a}	6.3 ± 2.2 ^{ab}	5.5 ± 2.1 ^{bcd}	6.1 ± 1.0 ^{abc}	6.0 ± 0.8 ^{bcd}	5.9 ± 0.8 ^{bcd}	5.7 ± 0.5 ^{bcd}	4.8 ± 1.3 ^{cd}
	GSE	6.3 ± 1.2 ^{ab}	5.9 ± 1.7 ^{bcd}	4.8 ± 2.3 ^{d}	4.8 ± 1.8 ^{cd}	5.5 ± 0.3 ^{bcd}	5.5 ± 0.6 ^{bcd}	6.0 ± 0.7 ^{bcd}	5.8 ± 1.4 ^{bcd}
Fishy odor	Control	0.2 ± 0.5 ^{e}	0.4 ± 0.6 ^{d}	1.3 ± 1.7 ^{bc}	1.2 ± 1.4 ^{cd}	2.0 ± 0.4 ^{abc}	2.1 ± 0.3 ^{abc}	2.3 ± 0.3 ^{ab}	2.6 ± 1.4 ^{a}
	GSE	0.1 ± 0.1 ^{e}	0.2 ± 0.3 ^{e}	1.4 ± 1.6 ^{bc}	1.8 ± 2.8 ^{abc}	2.2 ± 0.5 ^{abc}	2.1 ± 0.5 ^{abc}	2.2 ± 0.4 ^{abc}	2.2 ± 0.5 ^{abc}
Sulfury odor	Control	4.3 ± 1.4 ^{abcd}	4.7 ± 0.8 ^{abc}	5.2 ± 1.4 ^{a}	5.1 ± 1.0 ^{a}	3.7 ± 0.8 ^{d}	3.9 ± 0.4 ^{bcd}	3.9 ± 0.4 ^{bcd}	3.9 ± 0.5 ^{bcd}
	GSE	3.9 ± 1.3 ^{bcd}	3.7 ± 2.0 ^{cd}	4.8 ± 1.7 ^{ab}	5.3 ± 1.0 ^{a}	3.8 ± 0.8 ^{bcd}	3.8 ± 0.5 ^{bcd}	4.1 ± 0.3 ^{bcd}	4.0 ± 0.3 ^{bcd}
Musty odor	Control	0.1 ± 0.2 ^{e}	0.5 ± 1.1 ^{de}	0.4 ± 0.3 ^{de}	0.1 ± 0.2 ^{e}	0.8 ± 0.4 ^{bcd}	1.3 ± 1.0 ^{abc}	1.4 ± 0.6 ^{ab}	1.8 ± 1.2 ^{a}
	GSE	0.1 ± 0.2 ^{e}	0.4 ± 1.2 ^{de}	0.3 ± 0.4 ^{de}	0.7 ± 0.2 ^{cde}	0.9 ± 0.5 ^{bcd}	0.9 ± 0.4 ^{bcd}	1.2 ± 0.9 ^{abc}	1.2 ± 0.7 ^{abc}
Rancid odor	Control	ND	ND	ND	ND	1.0 ± 1.0 ^{b}	1.0 ± 0.8 ^{b}	1.7 ± 1.5 ^{ab}	2.0 ± 1.6 ^{a}
	GSE	ND	ND	ND	ND	1.0 ± 0.8 ^{b}	0.7 ± 0.4 ^{b}	0.9 ± 0.7 ^{b}	2.5 ± 3.3 ^{a}
Sweet	Control	0.2 ± 0.3 ^{e}	0.2 ± 0.4 ^{de}	0.0 ± 0.1 ^{e}	0.0 ± 0.1 ^{e}	0.8 ± 0.3 ^{ab}	0.9 ± 0.4 ^{ab}	0.7 ± 0.4 ^{bc}	0.7 ± 0.3 ^{ab}
	GSE	0.3 ± 0.5 ^{cde}	0.6 ± 1.4 ^{bcd}	0.0 ± 0.0 ^{e}	0.0 ± 0.1 ^{e}	0.9 ± 0.4 ^{ab}	0.9 ± 0.4 ^{ab}	1.0 ± 0.2 ^{ab}	1.2 ± 0.6 ^{ab}
Sour	Control	0.1 ± 0.2 ^{ef}	0.1 ± 0.3 ^{ef}	1.2 ± 0.9 ^{abc}	1.6 ± 1.4 ^{a}	0.5 ± 0.1 ^{bcdef}	0.8 ± 0.4 ^{bcde}	0.7 ± 0.3 ^{bcdef}	0.9 ± 0.6 ^{bc}
	GSE	0.0 ± 0.1 ^{f}	0.2 ± 0.3 ^{def}	0.9 ± 1.4 ^{bc}	1.3 ± 1.4 ^{ab}	0.6 ± 0.3 ^{bcdef}	0.5 ± 0.2 ^{cdef}	0.7 ± 0.3 ^{bcdef}	0.8 ± 0.5 ^{bcd}
Salty	Control	1.5 ± 0.6 ^{b}	1.2 ± 0.7 ^{b}	1.7 ± 0.7 ^{b}	2.3 ± 0.7 ^{a}	1.4 ± 0.4 ^{b}	1.4 ± 0.5 ^{b}	1.4 ± 0.4 ^{b}	1.5 ± 0.5 ^{b}
	GSE	1.6 ± 0.6 ^{b}	1.6 ± 0.8 ^{b}	1.6 ± 0.8 ^{b}	2.2 ± 0.9 ^{a}	1.4 ± 0.4 ^{b}	1.4 ± 0.3 ^{b}	1.6 ± 0.3 ^{b}	1.5 ± 0.4 ^{b}
Bitter	Control	0.0 ± 0.0 ^{d}	0.0 ± 0.0 ^{d}	0.7 ± 1.1 ^{ab}	0.5 ± 1.0 ^{abcd}	0.6 ± 0.3 ^{abcd}	0.8 ± 0.5 ^{ab}	0.8 ± 0.4 ^{ab}	1.1 ± 0.8 ^{a}
	GSE	0.0 ± 0.1 ^{cd}	0.2 ± 0.6 ^{bcd}	1.0 ± 1.5 ^{a}	0.6 ± 1.0 ^{abcd}	0.7 ± 0.5 ^{ab}	0.7 ± 0.4 ^{ab}	0.6 ± 0.2 ^{abc}	0.7 ± 0.3 ^{ab}
Umami	Control	0.3 ± 0.6	0.3 ± 0.4	0.3 ± 0.5	0.2 ± 0.6	0.5 ± 0.1	0.6 ± 0.2	0.6 ± 0.2	0.7 ± 0.4
	GSE	0.3 ± 0.8	0.4 ± 0.9	1.1 ± 2.1	0.4 ± 0.4	0.6 ± 0.2	0.6 ± 0.2	0.6 ± 0.3	0.6 ± 0.3
Metallic/serumy	Control	3.2 ± 1.1 ^{bc}	3.2 ± 1.0 ^{bc}	3.5 ± 0.6 ^{abc}	4.0 ± 0.8 ^{a}	2.0 ± 0.6 ^{e}	2.1 ± 0.4 ^{e}	1.9 ± 0.4 ^{e}	2.4 ± 0.9 ^{de}
	GSE	3.9 ± 1.2 ^{ab}	2.9 ± 1.0 ^{cd}	3.5 ± 1.6 ^{abc}	3.8 ± 0.9 ^{ab}	2.1 ± 0.4 ^{e}	2.0 ± 0.4 ^{e}	2.2 ± 0.3 ^{de}	2.1 ± 0.3 ^{e}
Cooked chicken	Control	6.9 ± 0.6 ^{abcd}	7.0 ± 0.6 ^{abcd}	5.5 ± 1.1 ^{fg}	5.7 ± 1.9 ^{efg}	7.6 ± 2.4 ^{abc}	7.8 ± 1.4 ^{ab}	7.4 ± 1.5 ^{abc}	7.0 ± 1.6 ^{abcd}
	GSE	6.3 ± 1.1 ^{cdef}	6.7 ± 0.7 ^{bcde}	4.9 ± 1.8 ^{g}	5.8 ± 0.9 ^{defg}	8.2 ± 0.6 ^{a}	7.4 ± 1.4 ^{abc}	7.6 ± 1.2 ^{abc}	7.4 ± 1.3 ^{abc}
Fatty flavor	Control	2.1 ± 0.6 ^{cd}	2.3 ± 0.9 ^{bcd}	2.8 ± 0.9 ^{bc}	3.0 ± 1.0 ^{b}	5.5 ± 1.2 ^{a}	5.9 ± 0.4 ^{a}	5.7 ± 0.5 ^{a}	5.5 ± 0.7 ^{a}
	GSE	2.0 ± 1.0 ^{d}	2.5 ± 1.1 ^{bcd}	3.0 ± 1.0 ^{b}	2.7 ± 1.0 ^{bcd}	5.9 ± 0.5 ^{a}	5.4 ± 1.0 ^{a}	6.0 ± 0.4 ^{a}	6.1 ± 0.3 ^{a}
Fishy flavor	Control	0.0 ± 0.0 ^{d}	0.1 ± 0.2 ^{d}	0.7 ± 1.4 ^{abc}	0.5 ± 0.9 ^{bcd}	0.9 ± 0.1 ^{ab}	1.0 ± 0.4 ^{ab}	1.3 ± 0.4 ^{ab}	1.4 ± 0.8 ^{a}
	GSE	0.0 ± 0.0 ^{d}	0.1 ± 0.3 ^{cd}	1.0 ± 1.3 ^{ab}	1.0 ± 1.6 ^{ab}	1.1 ± 0.6 ^{ab}	0.9 ± 0.4 ^{ab}	1.1 ± 0.3 ^{ab}	1.1 ± 0.3 ^{ab}
Rancid flavor	Control	0.1 ± 0.3 ^{fg}	0.0 ± 0.1 ^{g}	1.3 ± 1.1 ^{cde}	1.0 ± 1.4 ^{defg}	1.1 ± 0.8 ^{cdef}	1.7 ± 1.0 ^{abc}	2.2 ± 1.5 ^{abc}	2.7 ± 1.4 ^{a}
	GSE	0.0 ± 0.1 ^{g}	0.2 ± 0.4 ^{efg}	1.0 ± 1.0 ^{defg}	1.1 ± 1.1 ^{defg}	1.4 ± 0.9 ^{cd}	1.0 ± 0.4 ^{defg}	1.5 ± 1.2 ^{bcd}	2.6 ± 2.9 ^{ab}

$^{a–g}$Different letters within an attribute indicate significant differences ($P < 0.05$).
ND, not determined.

Table 6
Effect of grape seed extract on sensory and instrumental color ($n = 12$) ± standard deviation of raw and cooked ground chicken thigh during refrigerated storage.

	Day	Sensory color		L^*		a^*		b^*	
		Control	GSE	Control	GSE	Control	GSE	Control	GSE
Stored raw, then cooked	0	4.4 ± 1.2 ^{gh}	5.8 ± 2.2 ^{defg}	70.7 ± 1.9 ^{a}	65.3 ± 2.4 ^{cd}	3.3 ± 1.0 ^{hi}	4.7 ± 0.9 ^{efg}	13.2 ± 0.5 ^{c}	8.7 ± 0.9 ^{h}
	4	4.0 ± 1.7 ^{h}	6.6 ± 2.7 ^{def}	68.9 ± 2.7 ^{ab}	59.3 ± 2.3 ^{g}	4.1 ± 0.5 ^{fgh}	5.6 ± 0.3 ^{cd}	12.3 ± 1.2 ^{d}	9.6 ± 0.6 ^{fg}
	8	4.9 ± 0.8 ^{gh}	5.6 ± 2.9 ^{efg}	65.4 ± 0.7 ^{cd}	61.4 ± 1.4 ^{f}	7.0 ± 0.3 ^{ab}	7.9 ± 0.8 ^{a}	15.0 ± 1.2 ^{a}	11.0 ± 0.9 ^{e}
	12	5.3 ± 0.9 ^{fgh}	6.4 ± 2.8 ^{def}	67.1 ± 1.7 ^{bc}	62.7 ± 2.1 ^{ef}	5.7 ± 0.7 ^{cd}	6.5 ± 0.9 ^{bc}	13.8 ± 0.7 ^{bc}	10.4 ± 1.1 ^{ef}
Stored cooked, then reheated	0	6.9 ± 0.4 ^{cde}	8.6 ± 1.0 ^{a}	68.9 ± 1.8 ^{ab}	62.6 ± 1.2 ^{ef}	2.9 ± 0.4 ^{i}	5.1 ± 1.3 ^{de}	13.0 ± 0.6 ^{cd}	9.7 ± 0.9 ^{fg}
	4	6.9 ± 0.6 ^{cde}	8.5 ± 0.7 ^{a}	66.9 ± 2.0 ^{bc}	61.7 ± 1.9 ^{f}	4.0 ± 0.5 ^{fgh}	4.6 ± 1.3 ^{efg}	13.3 ± 0.8 ^{c}	9.7 ± 0.5 ^{efg}
	8	7.1 ± 0.5 ^{bcd}	8.5 ± 1.0 ^{ab}	67.2 ± 1.4 ^{bc}	63.0 ± 1.3 ^{ef}	4.5 ± 0.9 ^{efg}	3.7 ± 0.9 ^{ghi}	14.1 ± 0.5 ^{b}	9.2 ± 0.6 ^{gh}
	12	6.7 ± 0.9 ^{def}	8.2 ± 0.9 ^{abc}	67.2 ± 1.5 ^{bc}	64.0 ± 2.0 ^{de}	5.0 ± 0.6 ^{def}	4.2 ± 1.1 ^{efgh}	13.9 ± 1.0 ^{bc}	9.4 ± 0.8 ^{gh}

$^{a–i}$Different letters within sensory color, L^*, a^*, or b^* indicate significant differences ($P < 0.05$).

sults obtained from ground chicken breast, however, sensory color scores for ground chicken thigh showed that GSE caused darker color in both raw and precooked patties. As with the ground chicken breast, these results suggest that GSE altered the color of the chicken thigh patties. Consumer sensory analysis can determine if the color change is unacceptable.

3.2.3. Yield, pH, binding strength, and water activity

As shown in Table 7, significant differences were revealed for yield and binding strength of chicken thigh patties during refrigerated storage. Yield was largely affected by storage condition, as the only significant main effect was observed for this variable ($P < 0.001$). Across both treatments and across each storage day, raw patties exhibited a yield of 80.6% compared to 63.4% for cooked patties. This trend was also observed for binding strength, as the only main effect that was significant was storage condition, with raw patties exhibiting a 26% higher binding strength (2000 g) compared to cooked patties (1583 g) across both treatments and each day of storage. These results suggest that precooking, rather than the presence of GSE, affects yield and binding strength of chicken thigh patties.

The pH significantly declined in the raw control patties, but this decline was not observed in the raw GSE-containing patties or the precooked patties. The pH drop, from 6.85 to 6.72 after 12 d of storage, was the opposite of that previously observed in chicken thigh patties with and without GSE during storage, where an increase from about 6.4 to about 7.0 was observed (Brannan, 2008). However, the patties for which a pH increase was observed were held in open trays rather than in sealed bags. The water activity for all ground chicken thigh patties, either raw or precooked, with or

Table 7
Effect of grape seed extract on yield, pH, and binding ± standard deviation strength of raw and cooked ground chicken thigh during refrigerated storage.

		Yield (%)		pH		Binding strength (g)	
		Control	GSE	Control	GSE	Control	GSE
Stored raw, then cooked	0	78.5 ± 12.0 ^{abc}	79.5 ± 2.8 ^{abc}	6.85 ± 0.14 ^{a}	6.68 ± 0.02 ^{bc}	2.166 ± 45 ^{abc}	2.241 ± 136 ^{ab}
	4	74.0 ± 3.5 ^{abcd}	79.3 ± 13.1 ^{abc}	6.56 ± 0.04 ^{de}	6.62 ± 0.12 ^{cd}	1.879 ± 421 ^{abcde}	2.474 ± 262 ^{a}
	8	90.5 ± 21.9 ^{a}	76.0 ± 1.4 ^{abcd}	6.72 ± 0.00 ^{b}	6.73 ± 0.02 ^{b}	1.961 ± 418 ^{abcd}	1.715 ± 344 ^{bcde}
	12	85.0 ± 16.3 ^{ab}	82.5 ± 7.1 ^{abc}	6.72 ± 0.00 ^{b}	6.78 ± 0.09 ^{ab}	1.628 ± 284 ^{bcde}	1.937 ± 47 ^{abcde}
Stored cooked, then reheated	0	55.8 ± 8.8 ^{d}	61.0 ± 2.1 ^{cd}	6.49 ± 0.07 ^{e}	6.53 ± 0.03 ^{de}	1.319 ± 157 ^{e}	1.495 ± 432 ^{de}
	4	70.3 ± 3.9 ^{abcd}	63.0 ± 6.4 ^{bcd}	6.49 ± 0.05 ^{e}	6.53 ± 0.03 ^{de}	1.779 ± 295 ^{bcde}	1.660 ± 311 ^{bcde}
	8	66.3 ± 3.9 ^{bcd}	63.0 ± 0.7 ^{bcd}	6.52 ± 0.02 ^{de}	6.54 ± 0.03 ^{de}	1.717 ± 442 ^{bcde}	1.721 ± 146 ^{bcde}
	12	64.3 ± 3.9 ^{bcd}	64.3 ± 6.7 ^{bcd}	6.50 ± 0.05 ^{e}	6.48 ± 0.11 ^{e}	1.404 ± 370 ^{de}	1.577 ± 378 ^{cde}

$^{a–d}$Different letters within yield, pH, or binding strength indicate significant differences ($P < 0.05$).

without GSE, at each storage day was between 0.97 and 0.99 and no significant differences were observed.

3.3. Implications

As noted in the Introduction, many studies have associated GSE with a reduction of biochemical markers of oxidation in raw and precooked meats from a variety of substrates. In some of these studies, sensory analysis was performed by trained or semi-trained panelists and the results were generally species specific. In beef, GSE seems to be an effective antioxidant for both raw and cooked systems from both a sensory and biochemical perspective that does not adversely affect meat color (Ahn et al., 2002, 2007; Banon et al., 2007; Rojas & Brewer, 2007, 2008). In raw and cooked pork, GSE was effective at reducing biochemical markers of oxidation but had no effect on sensory scores or color (Carpenter, O'Grady, O'Callaghan, O'Brien, & Kerry, 2007; Rojas & Brewer, 2007). In chicken, the focus of this study, reduction in lipid oxidation biomarkers due to the addition of GSE has been previously observed (Beltran, Pla, Yuste, & Mor-Mur, 2004; Brannan, 2008; Brannan & Mah, 2007; Rababah et al., 2006). Results of this study, however, call into question the use of GSE as an across-the-board solution. The results presented here suggest that GSE is an effective antioxidant in precooked chicken breast systems because the presence of GSE caused reduced levels of lipid oxidation biomarkers, reduced sensory scores for key attributes usually identified with warmed over flavor, and may not affect the color of the product as much as one might predict. This is not to say that GSE addition may not be appropriate for applications using chicken thigh because GSE does reduce the biochemical markers of lipid oxidation. However, caution must be urged as this study suggests that GSE has little effect on ground chicken thigh sensory odor and flavor scores and causes noticeable darkening, more red, and less yellow color.

It is worth noting that preliminary work in lamb has shown that supplementation of GSE in the diet did cause changes to the lamb meat sensory quality, reducing the scores of negative attributes such as "sheepy" and "barnyard flavor" among others. This suggests that supplementation of the diet may be a means of incorporating the beneficial effects of GSE into whole tissues to improve meat quality, although much more research is needed.

4. Conclusions

This study shows that 0.1% GSE may be an effective radical scavenger that in precooked chicken breast can reduce attributes associated with warmed over flavor such as musty and rancid flavors and odors. However, GSE did alter the color of both raw and precooked chicken breast patties, but did not alter the pH, a_w, binding strength or yield. In raw and precooked chicken thigh meat, it appears that GSE may not be an effective antioxidant because GSE did not reduce any of the negative sensory attribute scores during refrigerated storage. GSE did cause an alteration in color of the chicken thigh patties. Although significant differences were observed for yield and binding strength in the chicken thigh patties, it is likely that precooking, rather than the presence of GSE, is the driving force behind these differences. In conclusion, this study shows that GSE may be an effective antioxidant in precooked chicken breast systems. Future work should focus on strategies to maximize the antioxidative effect of GSE in chicken thigh systems, ways to mitigate its effect on meat color, and explorations of the efficacy of GSE on or in whole muscle products.

Acknowledgments

The author acknowledges Gary Saum for technical support and Bobbi Conliffe, Lisa Dael, Jody Grenert, Doug Grammar, Chris Sandford, and Keely Trisel for descriptive sensory analysis.

References

Ahn, J., Grun, I. U., & Fernando, L. N. (2002). Antioxidant properties of natural plant extracts containing polyphenolic compounds in cooked ground beef. *Journal of Food Science, 67*, 1364–1369.

Ahn, J., Grun, I. U., & Mustapha, A. (2007). Effects of plant extracts on microbial growth, color change, and lipid oxidation in cooked beef. *Food Microbiology, 24*, 7–14.

Banon, S., Diaz, P., Rodriguez, M., Garrido, M. D., & Price, A. (2007). Ascorbate, green tea and grape seed extracts increase the shelf life of low sulphite beef patties. *Meat Science, 77*, 626–633.

Beltran, E., Pla, R., Yuste, J., & Mor-Mur, M. (2004). Use of antioxidants to minimize rancidity in pressurized and cooked chicken slurries. *Meat Science, 66*, 719–725.

Brannan, R. G. (2008). Effect of grape seed extract on physicochemical properties of ground, salted, chicken thigh meat during refrigerated storage at different relative humidity levels. *Journal of Food Science, 73*, C36–C40.

Brannan, R. G., & Mah, E. (2007). Grape seed extract inhibits lipid oxidation in muscle from different species during refrigerated and frozen storage and oxidation catalyzed by peroxynitrite and iron/ascorbate in a pyrogallol red model system. *Meat Science, 77*, 540–546.

Carpenter, R., O'Grady, M. N., O'Callaghan, Y. C., O'Brien, N. M., & Kerry, J. P. (2007). Evaluation of the antioxidant potential of grape seed and bearberry extracts in raw and cooked pork. *Meat Science, 76*, 604–610.

Lau, D. W., & King, A. J. (2003). Pre- and post-mortem use of grape seed extract in dark poultry meat to inhibit development of thiobarbituric acid reactive substances. *Journal of Agricultural and Food Chemistry, 51*, 1602–1607.

Mielnik, M. B., Olsen, E., Vogt, G., Adeline, D., & Skrede, G. (2006). Grape seed extract as antioxidant in cooked, cold stored turkey meat. *LWT – Food Science and Technology, 39*, 191–198.

Monteleone, E., Condelli, N., Dinnella, C., & Bertuccioli, M. (2004). Prediction of perceived astringency induced by phenolic compounds. *Food Quality and Preference, 15*, 761–769.

Pazos, M., Gallardo, J. M., Torres, J. L., & Medina, I. (2005). Activity of grape polyphenols as inhibitors of the oxidation of fish lipids and frozen fish muscle. *Food Chemistry, 92*, 547–557.

Rababah, T., Hettiarachchy, N. S., Eswaranandam, S., Meullenet, J. F., & Davis, B. (2005). Sensory evaluation of irradiated and nonirradiated poultry breast meat infused with plant extracts. *Journal of Food Science, 70*, S228–S235.

Rababah, T., Hettiarachchy, N. S., Horax, R., Cho, M. J., Davis, B., & Dickson, J. (2006). Thiobarbituric acid reactive substances and volatile compounds in chicken breast meat infused with plant extracts and subjected to electron beam irradiation. *Poultry Science, 85*, 1107–1113.

Rojas, M. C., & Brewer, M. S. (2007). Effect of natural antioxidants on oxidative stability of cooked, refrigerated beef and pork. *Journal of Food Science, 72*, S282–S288.

Rojas, M. C., & Brewer, M. S. (2008). Effect of natural antioxidants on oxidative stability of frozen, vacuum-packaged beef and pork. *Journal of Food Quality, 31*, 173–188.

Weber, H. A., Hodges, A. E., Guthrie, J. R., O'Brien, B. M., Robaugh, D., Clark, A. P., et al. (2007). Comparison of proanthocyanidins in commercial antioxidants: Grape seed and pine bark extracts. *Journal of Agricultural and Food Chemistry, 55*, 148–156.