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Functional properties of carrageenan on color stability and sensory characteristics of beef steaks

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ABSTRACT

This study was designed to evaluate the effects of ingredients and USDA beef quality grade response on meat quality attributes and sensory characteristics. Beef strip loins representing two quality grades (USDA Choice and Select) were enhanced with either 0.25 CG [0.25% kappa-carrageenan + 1% sea salt + 0.3% sodium tripolyphosphate]; 0.50 CG [0.50% kappa-carrageenan + 1% sea salt + 0.3% sodium tripolyphosphate]; or 2.5 KL [2.5% potassium lactate + 1% sea salt + 0.3% sodium tripolyphosphate]; or NEC = non-enhanced control. Changes in surface color, visual appearance, discoloration, and metmyoglobin formation during a 7 d retail display at 2 °C were evaluated. Enhancement with 0.50 CG and 2.5 KL affected ($P < 0.05$) tenderness, moisture content, shear force, and retail display color properties and metmyoglobin reduction. Enhanced Choice steaks with 2.5 KL outperformed ($P < 0.05$) Select steaks in color stability and palatability characteristics and induced red color darkening. This study shows that kappa-carrageenan can effectively enhance color stability, improve expected eating quality, and minimize discoloration during retail display and storage.

1. Introduction

Increasing consumer demands and global food competition are influencing the meat industry to embrace new ingredient systems for product and process development. Bio-based ingredients are naturally occurring and add value in the food systems. In recent years, consumer perception about processed meats have challenged the meat industries to produce minimally meat products with maximum palatability benefits at the lowest costs (Morgan et al., 1991). Meat quality attributes that consumers associate with freshness at retail determine their purchasing decisions. Inconsistencies in quality attributes cause billions of retail sales dollars lost each year. Discoloration of meat surface alone leads to price discounts for about 15% of retail beef, for annual revenue losses of $1 billion (Mohan et al., 2010). Meeting consumer expectations for a consistent, high-quality meat product has been a challenge for the US beef industry. Consumers consider color and tenderness the most important purchasing criteria, so maintaining meat color during retail cold chain management requires a delicate balance of biochemical factors affecting meat color during retail sales (Mancini and Hunt, 2005).

Quality grade determination for beef are a subjective assessment criteria used in the beef industry to describe the expected eating quality of beef. Changes in the skeletal characteristics with animal age is critical for growth. However, differences in distribution of the amount of intramuscular fat (marbling) with animal's physiological maturity do not follow a definitive pattern causing differences in end meat product quality variations. Differences in quality grades of beef with inherent differences in intrinsic quality traits are known to influence expected eating quality, meat quality, and other sensory characteristics (Beriain et al., 2009).

Carrageenans are naturally-occurring hydrocolloids used primarily to enhance functional properties of meat. As a non-meat ingredient, application of carrageenan in roasted turkey increased processing yield and improved product functional properties (Bater et al., 1992); improved water holding capacity in breakfast sausages (Barbut & Mittal, 1992); and increased cook-yield and bind strength of low-fat sausages (Xiong et al., 1999). Hsu and Chung (2001) reported that *kappa*-carrageenan (κ-Carr) improved the textural profile of low fat meat balls. In a similar study, κ-Carr improved water retention in sausage (Lin & Ketton, 1998), enhanced sensory properties of ham (Huang et al. 1997), and textural properties of beef patties (Pietrasik & Jarmoluk, 2003; Prabhu & Sebranek, 1997; Shand et al., 1994).

Non-meat ingredients such as phosphate is a multifunctional ingredient in that several forms of phosphates are used for improving flavor, texture, and juiciness in processed meat products (Honikel, 2010). Inclusion of sea salt, potassium lactate, and

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phosphate as a multifunctional ingredients provide unique product specific effects and contribute to improve expected properties of processed meat products. The objective of this study was to evaluate the effects of injection-enhancement with κ-Carr, sodium tripolyphosphate, potassium lactate, and sea salt on beef strip loin muscle (USDA Choice and Select grades) color stability during retail display and storage.

2. Materials and methods

2.1. Raw materials

Forty-eight boneless, beef strip loins (Institutional Meat Purchase Specification # 180) representing two quality grades (n=24 USDA Select, and n=24 USDA Choice) from A-maturity (9–30 months old cattle) carcasses were obtained from a local commercial abattoir at 10-d postmortem.

2.2. Proximate analyses

Ten grams of sample, visually devoid of intermuscular fat and connective tissue, was frozen in liquid nitrogen and pulverized for proximate analysis. Samples were analyzed (n=5) for protein [LECO Combustion Analysis (AOAC Official Method 990.03) (Thiex, 2009)] and moisture and fat [CEM SMART and SMART Trac systems (AOAC PVM 1:2003; Keeton and Morris (1996))].

2.3. Chemicals

Sodium tripolyphosphate (STPP) was obtained from Sigma Chemical Co. (St. Louis, MO, USA). κ-Carrarrageenan (κ-Carr) was obtained from S-100Fi, Ingredient Solutions Inc., Waldo, ME. Potassium lactate (KL) was obtained from PURAC America, Inc. (PURASAL HiPure P, 60% potassium lactate/40% water; Lincolnshire, IL, USA). Low sodium sea-salt (SS) was obtained from ICL Performance Products (Salona™, ICL Performance Products LP, St. Louis, MO). Distilled water was used throughout the preparation of all treatment solutions.

2.4. Sampling and injection enhancement

Six loins of each quality grade were cut into halves and randomly assigned to four injection enhancement treatments. The anterior cut portion served as non-enhanced (untreated) control (NEC), and the posterior half portion was weighed (raw product weight) and injection enhanced (Schroder Injector/marinator, model N50, Wolf-Tec Inc., Kingston, NY) with either 0.25 CG; 0.50 CG; or 2.5 KL. Injected cuts were allowed to drain and were re-injected to targeted percentages (110 ± 2% of the green weight). Following a 2 min rest period, injected loins were reweighed to ensure brine was assimilated to achieve minimum 110% of the original weight. All κ-Carr, phosphate, sea-salt, and/or lactate injection solutions were formulated to yield enhanced final product with 0.25% κ-Carr, 0.3% STPP, 1.0% SS, and 2.5% KL.

2.5. Packaging and display

Two hours after enhancement, loins were cut into six 2.54 cm thick steaks. Three steaks were used for metmyoglobin reducing activity (MRA) measurements: one for visual color, one for instrumental color measurement, and one for pH and proximate analysis. Steaks for the color measurements were overwrapped with polyvinyl chloride film (PVC; MAPACL, 21,700 cc $O_2/m^2/24$ h at standard temperature (23 °C) and pressure (760 mm Hg), Borden Packaging and Industrial Products, North Andover, MA, USA) on foam trays (polystyrene foam; 17S; McCune Paper Company, Salina, KS, USA) with a Dri-Loc soaker pad (AC-50; Sealed Air Corp, Duncan, SC, USA). Steaks were displayed at 2 °C ± 1 for 7-d under 2150 ± 50 lx of continuous fluorescent lighting (bulb F32T8/ADV830, 3000 K, CRI=86; Phillips, Bloomfield, NJ, USA) in an open-front refrigerated display case (Model: Hussmann M3X, self-contained, multi-deck, Supermarket Equipment Sales, Inc., Rutledge, GA, USA). Packages were rotated twice daily to obtain a random sample placement and to minimize display case location effects.

Table 1.
LS means for the muscle pH × quality grade × treatment interaction and SE[£] for the beef strip loin steaks.

Quality grade	Treatments[£]	pH	
		Non-enhanced	Enhanced
Choice	NEC	5.6^{a}	–
	0.25 CG	5.7^{abm}	6.1^{an}
	0.50 CG	5.8^{bm}	6.1^{an}
	2.5 KL	5.9^{bm}	6.2^{an}
Select	NEC	5.7^{b}	–
	0.25 CG	5.6^{abm}	6.1^{an}
	0.50 CG	5.5^{am}	6.2^{an}
	2.5 KL	5.7^{bm}	6.4^{bn}

[a,b] Means within a row with different superscript letters differ ($P<0.05$).
[m,n] Means within a row with different superscript letters differ ($P<0.05$). ± SE=0.1
[£] ± SE=0.1.
[£] NEC=Non-enhanced Control; 0.25 CG=0.25% κ-Carrageenan+1% Sea salt+0.3% Sodium tripolyphosphate; 0.50 CG=0.50% κ-Carrageenan+1% Sea salt+0.3% Sodium tripolyphosphate; 2.5 KL=2.5% Potassium lactate+1% Sea salt+0.3% Sodium tripolyphosphate.

2.6. pH measurement

The pH measurements were recorded for all meat portions before and after injection using a pierce-probe pH meter (Model pH 77-SS, metal probe, IQ Scientific, HACH, Loveland, CO, USA). The pH was measured in triplicate at three different locations on the same loin and averaged for statistical analysis (Table 1).

2.7. Instrumental color measurement

Instrumental color measurements were recorded on each steak through the packaging film at three different locations (randomly selected) and averaged for statistical analysis. Color measurements were recorded using HunterLab MiniScan™ EZ Plus Spectrophotometer 45/0 LAV, 2.54 cm-diameter aperture, 10° standard observer (Hunter Associates Laboratory, Inc., Reston, VA, USA). Values for CIE L^*, a^*, and b^* (Illuminant A) were collected, and Hue Angle (HA) ($\tan^{-1}$ b^*/a^*) and Saturation Index (SI) or chroma $[(a^{*2}+b^{*2})^{1/2}]$ were calculated from instrumental measurements according to American Meat Science Association, *Meat Color Guidelines* (AMSA, 2012). The spectrophotometer was standardized against a black and white glass tile at least once every day before taking the color measurements.

2.8. Metmyoglobin reducing activity

Metmyoglobin reducing activity (MRA) was measured on the top half portion of the steak that had been exposed to light as described by Sammel et al. (2002). A 3 cm × 3 cm × 2 cm portion was removed from the displayed surface of the steak with no visible fat or connective tissue. The portion was submerged in 0.3% sodium nitrite solution for 30 min at 20 °C ± 2. The oxidized tissue