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Efficacy of lactic acid salts and sodium acetate on ground beef colour stability and metmyoglobin-reducing activity ☆

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Abstract

This study examined two concentrations (0.6 and 1.0 mol) of three lactic acid salts (calcium lactate, CaL; potassium lactate, KL; and sodium lactate, NaL), with and without 0.01 mol sodium acetate ($n = 3$ replications), for effects on ground beef colour stability and metmyoglobin-reducing activity (MRA). Ground beef with CaL was least colour stable ($P < 0.05$). Increasing CaL and NaL concentration decreased ($P < 0.05$) colour stability. Ground beef with acetate only was most colour stable ($P < 0.05$), but it did not result in more MRA ($P > 0.05$) than control ground beef. Including both lactate and acetate was not as effective ($P > 0.05$) in increasing colour stability as acetate alone. In general, both KL levels were equal ($P > 0.05$) to the lower NaL concentration, and all three were superior in colour stability ($P < 0.05$) to CaL and the higher NaL concentration. More MRA was generated by including lactates ($P < 0.05$); KL and NaL had more MRA than CaL ($P < 0.05$). However, these increases in MRA did not result in improved colour stability. Overall, adding KL to ground beef would not increase ground beef colour stability over adding nothing, but CaL and high levels of NaL would decrease colour stability. Using 0.01 mol sodium acetate maximized ground beef colour stability.

Keywords: Colour stability; Ground beef; Lactate; Metmyoglobin-reducing activity; Sodium acetate

1. Introduction

Lactate products with three different cations (calcium, potassium, and sodium) are commercially available. Which of these products ultimately is used in meat applications is a balance between cost and functionality. Lactates exhibit antimicrobial properties against nonpathogenic (Chen & Shelef, 1992) and pathogenic (Miller & Acuff, 1994) microflora. In addition, the lactate anion seems to promote colour stability, so lactate is a single ingredient that may address both safety and quality issues. Enhancing beef steaks with a solution containing calcium lactate (CaL) increased colour stability and decreased metmyoglobin formation (Lawrence, Dikeman, Hunt, Kastner, & Johnson, 2004) as did potassium lactate (KL; Mancini et al., 2005). But, using KL darkens meat's appearance and decreases L^* value (Kim, Hunt, Mancini, Kropf, & Smith, 2005; Mancini et al., 2005; Wagner et al., 2006).

Mancini, Kim, Hunt, and Lawrence (2004) measured the effects of injection-enhancement solutions that contain KL on meat colour chemistry. Inclusion of KL resulted in increased lactate dehydrogenase (LDH) activity, metmyoglobin-reducing activity (MRA), and colour stability during a 7-d display. The authors proposed a mechanism in which lactate addition results in the conversion of lactate to pyruvate by LDH and the generation of NADH. The NADH subsequently increases the amount of reducing equivalents available within meat, thus increasing MRA and resulting in a more stable colour display. Kim et al. (2005) further investigated the proposed mechanism *in situ* and *in vivo* by using differing levels of KL. Increasing

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KL further enhanced LDH activity and MRA, indicating that the proposed mechanism may indeed account for the augmented colour stability afforded by lactate usage. Although a comparison of the antimicrobial effects of the three commercially available lactic acid salts has been undertaken (Weaver & Shelef, 1993), no comparison of the three with regard to colour stability is available.

Sodium acetate improved colour stability in injection-enhanced pork (Jensen et al., 2003b; Livingston, Brewer, Killifer, Bidner, & McKeith, 2004). Sodium acetate and KL exhibited a synergistic effect on improving enhanced pork colour stability (Jensen et al., 2003a), but did not improve stability versus KL alone in enhanced beef (Wagner et al., 2006). Despite this evidence for improved colour stability in enhanced pork, no available literature has examined the effects of sodium acetate alone in beef.

Although it seems that the hypothesized mechanism of Mancini et al. (2004) has merit, it is unclear whether sodium, potassium, and calcium lactate have similar impacts on beef colour stability and MRA. The objectives of this research were to determine the effects of two concentrations of three lactic acid salts and sodium acetate on colour stability and MRA in ground beef.

2. Materials and methods

2.1. Ground beef preparation and formulation

Ground beef was used as a meat-model system that afforded improved ingredient distribution within meat and mimicked the usage of lactic acid salts and sodium acetate in injection-enhanced, whole-muscle beef. Paired USDA Select beef strip loins ($n = 3$ pairs) were obtained 2 d postmortem and held at 1 °C. On d 11 postmortem, strip loins had the dorsal subcutaneous fat and *longissimus lumborum* (LL) muscle separated from accessory muscles. Only the subcutaneous fat and LL muscle from paired loins were ground through a 12.5-mm-diameter plate by using a Hobart Grinder (Model 4732; Hobart Manufacturing Co., Troy, OH). This process was repeated twice, for a total of 3 replications.

From each of the 3 loin pairs, one of 15 treatments was assigned randomly to a 500-g batch of coarse-ground beef (Table 1). The ingredient levels incorporated into ground beef in this experiment closely approximate those used by the meat industry in enhanced beef and in previous research (Kim et al., 2005). Due to differing water contents of the three lactate products, care was taken to equalize added water for each lactate-containing treatment by using deionized water to minimize dilution effects. Lactate products used in this study were potassium lactate (KL, PURASAL HiPure P, 60% KL), sodium lactate (NaL, PURASAL S, 60% NaL), and calcium lactate (CaL, PURACAL PP/USP, dry powder; PURAC America, Lincolnshire, IL) in addition to sodium acetate (Verdugt, Tiel, The Netherlands). Treatments were incorporated by hand, and then ground through a 3.2-mm plate. Between each treatment, the grinder was disassembled, thoroughly cleaned, and rinsed prior to grinding the subsequent treatment.

2.2. Patty preparation and packaging

From each of the 15 batches, two 113.5-g patties were formed by hand with a 9.1-cm-diameter patty mold, resulting in patties approximately 1.5-cm thick. One patty was placed on a foam tray (17S; McCune Paper Company, Salina, KS) with a Dri-Loc pad (AC-50; Cryovac, Duncan, SC) and overwrapped with polyvinyl chloride film (MAPAC L, O_2 transmission rate of 21,700 cc/m^2/24 h; Borden Packaging and Industrial Products, North Andover, MA) for simulated retail display. The other patty was used for initial chemical and compositional assays.

2.3. Retail-display conditions

Packaged ground beef patties were placed into display for 3 d with continuous fluorescent lighting (Bulb F32T8/ADV830, 3000 K, CRI = 86; Phillips, Bloomfield, NJ) of 2150 ± 50 lux intensity in open-top display cases (Model DMF8; Tyler Refrigeration Corp., Niles, MI). Cases defrosted every 12 h. Case temperatures, 2.6 ± 3.1 °C, were monitored at the meat level by using temperature loggers (RD-TEMP-XT; Omega® Engineering, Inc., Stamford, CT).

2.4. Instrumental and visual colour

All samples were analyzed on d 0, 1, 2, and 3 for instrumental colour by using a HunterLab MiniScan™ XE Plus Spectrophotometer (Model 45/0 LAV, 2.54-cm-diameter aperture, 10° standard observer; Hunter Associates Laboratory, Inc., Reston, VA). The MiniScan was calibrated using reference white and black tiles provided by the manufacturer. Values of CIE L^*, a^*, and b^* (Illuminant A) were used to calculate chroma $(a^{*2} + b^{*2})^{1/2}$. Three scans from each patty were obtained and averaged for statistical analysis.

A trained panel ($n = 6$) conducted daily visual colour evaluations. All panelists passed the Farnsworth Munsell 100-hue test (Macbeth, Newsburgh, NY) and attended orientation sessions to evaluate and discuss the colour of ground beef used in the study. Initial beef colour was evaluated to characterize the colour at the beginning of display on d 0 following patty formation to the nearest 0.5 on an 8-point scale: 1 = bleached red, 2 = slight cherry red, 3 = moderately light cherry red, 4 = cherry red, 5 = slightly dark red, 6 = moderately dark red, 7 = dark red, and 8 = very dark red. Visual colour stability was assessed each day of display by using a 7-point scale to the nearest 0.5: 1 = very bright cherry red, 2 = bright cherry red, 3 = dull red, 4 = slightly dark red, 5 = moderately dark red to tan, 5.5 = borderline panelist acceptable, 6 = dark red to brown, and 7 = very dark red to brown. Panelists