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Functional properties of bicarbonates on physicochemical attributes of ground beef

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ABSTRACT

In this study, we investigated the effects of sodium bicarbonate ($NaHCO_3$), potassium bicarbonate ($KHCO_3$), and NaCl, alone or in combination, on raw ground beef. Raw ground beef was mixed with $NaHCO_3$ (5 g/kg; 10 g/kg), $KHCO_3$ (5 g/kg; 10 g/kg), and/or NaCl (5 g/kg), and the results of the treatment(s) were compared with ground beef treated with modified food starch (20 g/kg) or potato starch (20 g/kg). Adding the bicarbonates significantly increased ($p < 0.05$) pH and water-holding capacity (WHC) of raw ground beef. Bicarbonates with or without salt improved the WHC more than either modified food starch or potato starch. KHCO3 with NaCl provided the best adhesive values in raw ground beef. The bicarbonates and combinations of NaCl maintained the L^*- values of the ground beef during retail display storage. Our findings suggest that using bicarbonates increases the WHC by increasing the pH, resulting in raw ground beef that is more tender and adhesive.

1. Introduction

Emerging trends in food processing and ingredient technology have focused on evaluating alternative ingredients that can optimize the functional properties of processed meats. In the meat industry, including functional ingredients helps modify the overall technological and sensory characteristics of a meat system. Alkaline salts of bicarbonates have been reported to improve palatability attributes (Lee, Sharma, Brown, & Mohan, 2015) and minimize the problem of pale, soft, and exudative meat products (Alvarado & Sams, 2003) in chicken meat.

More recent studies (Petracci, Bianchi, Mudalal, & Cavani, 2013; Sen, Naveena, Muthukumar, Babji, & Murthy, 2005 b) have demonstrated that salts of bicarbonate are able to reduce shear-force and improve cook-yield of marinated chicken meat. The efficacy of bicarbonate salts are attributed to their ability to solubilize myofibrillar proteins and enhance their electrostatic repulsion. Bertram, Meyer, Wu, Zhou, and Anderson (2008) found that sodium bicarbonate was effective in increasing myofibrillar hydration and reduced cook-loss in marinated pork.

Bicarbonates have previously been used as an alternative for phosphate (Detienne, Zheng, Barnes, & Wicker, 2000; Kauffman et al., 1998; Sheard & Tali, 2004; Bertram, Meyer, Wu, Zhou, & Anderson, 2008; Petracci et al., 2013; Lee, Sharma, Brown, & Mohan, 2015). Beef palatability is a function of many attributes: tenderness, texture, juiciness, and flavor profile (Miller, Carr, Ramsey, Crockett, & Hoover, 2001). Bicarbonate salts enhance the textural quality of meat products by improving product juiciness, overall palatability, reduced drip-loss, and shear force (Kauffman et al., 1998; Sheard & Tali, 2004; Wynveen et al., 2001b; Sen et al., 2005a; Lee, Sharma, Brown, & Mohan, 2015). $NaHCO_3$ is a GRAS (generally recognized as safe) food ingredient used as a leavening agent, to control pH, as an antimicrobial, and to improve taste, texture, and tenderness characteristics (Corral, Post, & Montville, 1988; Curran & Montville, 1989; Bechtel, Oreskovich, McKeith, Martin, & Novakofski, 1989; Lee, Sharma, Brown, & Mohan, 2015).

Phosphate, as a nonmeat ingredient, has been used for decades to improve the overall quality and palatability attributes of processed meat product. However, a new consumer trend suggests that phosphate presents a problem for consumers needing to reduce dietary sodium in their food (Detienne et al., 2000;

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Desmond, 2006). Bicarbonate compounds are being investigated for their use as a functional ingredient for phosphate. Some researchers have used bicarbonates to minimize quality defects like pale, soft, exudative (PSE) in pork (Kauffman et al., 1998) and in broiler meat (Woelfel & Sams, 2001; Alvarado & Sams, 2003). However, little research has documented the effects of sodium or potassium bicarbonate on physicochemical properties of processed bulk raw ground beef. Therefore, the objective of this research was to (1) investigate the effects of potassium bicarbonate ($KHCO_3$), sodium bicarbonate ($NaHCO_3$), and modified food starch (alone or in combination with salt) on pH, WHC, textural attributes (adhesiveness and hardness), and instrumental color properties; and (2) evaluate the potential of replacing sodium bicarbonate with potassium as a way to reduce sodium in processed raw bulk ground beef products.

2. Materials and methods

2.1. Raw materials and chemicals

Fresh raw ground beef (lean/fat blend: 80/20; experimental unit) was obtained from a local beef purveyor (FPL Foods, Augusta, GA) along with a certificate of analysis certifying the composition of the purchased ground beef blend (lean/fat ratio). Food grade sodium chloride (NaCl), $NaHCO_3$, and $KHCO_3$ were purchased from Fisher Scientific (Fisher Scientific, Fairlawn, NJ). Potato starch was obtained from National Starch (Novation® 6600, National Starch, Bridgewater, NJ), and modified food starch was obtained from Grain Processing Corporation (PURE-GEL® B990, Grain Processing, Muscatine, IA). Table 1 provides the complete formulation for each treatment and treatment formulation combination.

2.2. Ground beef processing, packaging, and retail display

The ground beef was mixed with the treatment ingredients in a cold room at 4 ± 1 °C. All treatment samples were mixed according to the formulation presented in Table 1. Ingredients were mixed with ground beef in a Hobart mixer (Model C-100 T, The Hobart Mfg. Co., Troy, OH). All preparation, including ingredient mixing, patty making, and packaging, and further storage was performed at 4 ± 1 °C. The ground beef samples were aerobically packaged with polyvinyl chloride overwrap film (PVC; MAPAC L, 21,700 cc O^2/m^2/24 h, Borden Packaging and Industrial Products, North Andover, MA) on foam trays (17S; McCune Paper Company, Salina, KS) with a Dri-Loc soaker pad (AC-50; Sealed Air Corp, Duncan, SC). The packaged trays were stored and displayed at 2–4 °C for 8 d under 2150 ± 50 lux continuous fluorescent lighting (bulb F32T8/ADV830, 3000 K, CRI = 86; Phillips, Bloomfield, NJ) in an open-front refrigerated display case (Hussmann M3X, Self-contained, Multi-deck, Supermarket Equipment Sales, Inc., Rutledge, GA). Packages were rotated daily to minimize case location effects.

2.3. pH

The pH of the raw ground beef patties was measured using a pierce probe pH meter (Model H260G, IQ Scientific, HACH, Loveland, CO); measurements were taken before and after treatment. The pH was measured three times on each treatment sample, and measurements were averaged for statistical analysis.

2.4. Scanning electron microscopy

A Zeiss 1450 EP scanning electron microscope (Carl Zeiss MicroImaging, Inc., Thornwood, NY) with an acceleration potential of 20 kV was used to show surface morphological properties of the ground beef after samples were sputter-coated with gold using Loksuwan's (2007) method.

2.5. Water holding capacity

The WHC of the processed ground beef was determined using the methods outlined in the American Meat Science Association guidelines for sensory, physical, and chemical measurements in ground beef (1983) and Dagbjartsson's (1972) methods with slight modifications. Briefly, 1.0 g of molecular sieve (2–4 mm; Applied Science Labs., Inc., PA, USA) was weighed and placed into a 50 mL polycarbonate centrifuge tube. Two discs of filter paper (Whatman No. 42) were cut to fit the centrifuge tube's inner diameter and carefully inserted to fit to the top surface of the molecular sieve. The weight of the polycarbonate tube with molecular sieve and filter paper was recorded. Approximately 1.0 g of the pulverized ground beef sample was placed on the top of the filter paper, and the weight of the tube with sample was recorded. The tube was then centrifuged for 10 min at 12,000 × *g* (Sorval RC6 Plus centrifuge, Thermo Fischer Scientific Inc., Waltham, MA) at 2 °C temperature. The meat cakes thus formed by centrifugation were gently removed with forceps from the surface of the filter paper, ensuring that no residual meat remained on the filter paper. The tube was reweighed and the WHC was expressed as the amount of water lost per gram of meat. WHC was calculated using the following equation:

Table 1
Mixture formulations for ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Treatment	Composition of the ingredients formulation in the finished product, g/Kg				
	NaCl	$NaHCO_3$	$KHCO_3$	Modified food starch	Potato starch
None (Control)	–	–	–	–	–
NaCl	5	–	–	–	–
$NaHCO_3$	–	5	–	–	–
$NaHCO_3$	–	10	–	–	–
$KHCO_3$	–	–	5	–	–
$KHCO_3$	–	–	10	–	–
$NaHCO_3$ + NaCl	5	5	–	–	–
$NaHCO_3$ + NaCl	5	10	–	–	–
$KHCO_3$ + NaCl	5	–	5	–	–
$KHCO_3$ + NaCl	5	–	10	–	–
Modified Food Starch + NaCl	5	–	–	20	–
Potato Starch + NaCl	5	–	–	–	20

[a] NaCl, $NaHCO_3$, $KHCO_3$, modified food starch, and potato starch were all diluted in distilled water for better homogeneity and dispersability.
[b] No ingredient (NaCl, $NaHCO_3$, $KHCO_3$, modified food starch, or potato starch) was added except distilled water.