Meat Science 99 (2015) 8–17

Contents lists available at ScienceDirect

Meat Science

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

Nitrite spray treatment to promote red color stability of vacuum packaged beef

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ARTICLE INFO

Article history:
Received 31 October 2013
Received in revised form 10 July 2014
Accepted 11 August 2014
Available online 20 August 2014

Keywords:
Beef
Nitrite
Color
Package
Spray
Display

ABSTRACT

Sodium nitrite solutions were sprayed on select grade boneless rib (*M. longissimus thoracis*) and bottom round (mainly *M. biceps femoris*) steaks individually, to form bright red nitric oxide myoglobin (NO-Mb) in vacuum packages. Our objective was to determine the optimum level of nitrite in spray for stable raw steak redness, low or no residual nitrite, and low surface pinking (ham-like cured color) after cooking. Results showed that steaks sprayed with 100–350 ppm nitrite solutions had 3.0–3.6 g weight gain and a calculated level of 1.3–5.3 mg nitrite added/kg steak, but very low (<1 ppm) residual nitrite. Nitrite sprays of 250–350 ppm were optimum for raw steak color during 21 days of storage at 1 °C ($a^* > 10$; chroma $C^* > 16$). Raw steak redness was less stable in round than rib. Visual scores for pinkness after cooking were low, indicating that cooked color at even the highest nitrite treatment (350 ppm) was acceptable.

1. Introduction

Consumers use product appearance to select or reject products. Suppliers of muscle foods must create and maintain desired appearance during retail display (Carpenter, Cornforth, & Whittier, 2001). Two important visual cues that determine perceived beef quality are color and packaging (Issanchou, 1996). Meat packaging plays an important role in red color stability and prevention of discoloration.

Refrigerated shipment of boxed, vacuum-packaged fresh red meat has long been a practical packaging format. Compared to bulky modified-atmosphere packaging (MAP), vacuum packaging is more environmental-friendly and compact, less costly and needs no headspace (Siegel & Nelson, 2011). It provides a refrigerated shelf life of up to 70 days (Meischen, Huffman, & Davis, 1987), which is considerably longer than fresh meat in 80% oxygen MAP (12–16 d), for example (McMillin, 2008). Meat in 80% oxygen MAP also has accelerated fat and protein oxidation, associated with oxidized flavor (Jayasingh, Cornforth, Brennand, Carpenter, & Whittier, 2002) and meat toughening (Lund, Lametsch, Hviid, Jensen, & Skibsted, 2007; Lindahl, Lagerstedt, Ertbjerg, Sampels, & Lundstrom, 2010). And in contrast to meat in MAP or tray-wrapped with PVC film, consumers can freeze vacuum-packaged meat in its original packaging, with no threat of freezer burn (Siegel & Nelson, 2011).

The drawback to vacuum packaging is that it deprives fresh red meat of oxygen, and consequently causes the meat to darken to a purplish color. Consumers in the USA have repeatedly shown that they prefer fresh beef to be red, not purple (Meischen et al., 1987).

Nitrate/nitrite has a long history of use as a precursor in the formation of pink cured meat pigment. Current regulations on nitrite use in the United States vary depending on the product and method of curing. For comminuted products, the maximum ingoing concentration of sodium or potassium nitrite is 156 ppm. For immersion cured, and massaged or pumped products, maximum ingoing sodium or potassium nitrite and nitrate concentrations are 200 ppm, based on the green weight of the meat (Sebranek & Bacus, 2007; USDA, 2005).

The red color is developed via a series of reactions until bright red NO-Mb is formed. The pathway usually proceeds as follows: 1) nitrite oxidizes myoglobin to metmyoglobin with concomitant reduction of nitrite to NO, 2) ferric heme iron binds NO, forming NO-metMb, 3) ferric heme iron is reduced to the ferrous state (Fe^{2+}) by reducing compounds commonly found in meat (Fox, 1966), forming bright red NO-Mb (Shahidi & Samaranayaka, 2004; AMSA, 2011). On heating the NO-Mb, the protein moiety is denatured but the red NO-porphyrin ring system still exists, forming NO-hemochrome, which is ham-like pink. NO-hemochrome is formed at relatively low heat conditions (58 °C in ham), but is stable in meat products heated as high as

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http://dx.doi.org/10.1016/j.meatsci.2014.08.003
0309-1740/

120 °C (Honikel, 2008). Formation of cured meat pigment is sometimes the cause of consumer complains about the doneness of cooked beef. In such cases, the surface pinking is undesirable, since consumers may associate pinking with undercooking (Cornforth et al., 1998).

Recently, Curwood Inc. (Oshkosh, WI) received USDA approval for fresh meat packaging using a novel nitrite-impregnated polyethylene film (FreshCase®), allowing vacuum packaged fresh meat to develop a bright red surface due to formation of NO-Mb (Siegel & Nelson, 2013). Curwood provided data showing that nitrite levels in the meat were undetectable. Thus, nitrite is not required to be included in the ingredient statement (USDA GRAS notice GRN 000228). Claus and Du (2013) also reported that nitrite-embedded film (Curwood) extended beef color display life. We now propose that spraying steaks with a nitrite solution before vacuum packaging may also be a practical and economic alternative method to form bright red NO-Mb in vacuum-packaged beef.

Thus, the objective of this study was to develop a new treatment (nitrite spray) to obtain red color of vacuum-packaged beef. The optimum level range of sodium nitrite ($NaNO_2$) in spray solution (to be determined in this study) should be sufficient to give a bright red color to vacuum packaged beef steaks, and also be low enough to have low or no residual nitrite on steak surfaces. Color of cooked steaks will also be measured to make sure that there is no objectionable pink, ham-like color in the cooked product.

2. Materials and methods

2.1. Experimental design

The experiment process flow chart is shown in Fig. 1.

Experiment 1 was a preliminary test to determine the approximate range of $NaNO_2$ concentration that was sufficient for red color development of vacuum-packaged bottom round steaks, but with minimum cured pink color development after cooking. Hunter color measurements were conducted on three round steaks (raw) for each treatment level at storage 0 d, 1 d, 2 d, 3 d and 7 d. At 7 d, steaks were cooked and visual colors were evaluated.

After evaluation of the Hunter color and visual color results of Experiment 1, a range of nitrite levels was selected for further study in Experiment 2.

Experiment 2 was a factorial design, with two types of Select grade muscles (rib and bottom round), 6 levels of $NaNO_2$ spray treatments (0, 100, 200, 250, 300, 350 ppm), 8 storage times (before spraying, 0 d (3 h after spraying), 1 d, 2 d, 3 d, 7 d, 14 d, 21 d), and 3 complete replications for each muscle type (separate 21-day periods). For each replication, residual nitrite of raw steaks was measured on 0 d and 7 d, using 2 rib and 2 round steaks/treatment × storage time combination. Another 6 rib and 6 round steaks/treatment were used for color (raw and cooked, 0–21 d) and residual nitrite measurements (cooked, on 7 d). On storage days 0–3, Hunter and visual colors were repeatedly measured on the same 2 rib and 2 round steaks/treatment. On 7 d, 14 d and 21 d, after raw color measurements, 2 rib and 2 round steaks/treatment × storage time combination were cooked, then used for measurements of residual nitrite (7 d), cooked steak color, NO-hemochrome content, and total pigment content (7 d, 14 d and 21 d). On 21 d of replications 1 and 2, all remaining steaks (2/treatment for each muscle type per replication) were frozen (−20 °C), and thawed on 21 d of replication 3. Sensory and microbial tests were conducted on 21 d and 28 d of replication 3, respectively, including samples from all 3 replications.

2.2. Steak sample preparation

Select grade boneless ribs (*M. longissimus thoracis*; n = 3) and bottom rounds (mainly *M. biceps femoris*; n = 4) were purchased as vacuum-packaged wholesale cuts from a commercial plant.

One wholesale bottom round was used for screening in Experiment 1. Three wholesale ribs and three wholesale bottom rounds from separate animals (purchased at 3 separate times) were used for 3 replications in Experiment 2. For each replication, one wholesale rib and one wholesale bottom round were selected from a box of 5 wholesale ribs or bottom rounds, respectively. The remaining wholesale cuts were processed for other research projects or for retail sale in the USU meat lab.

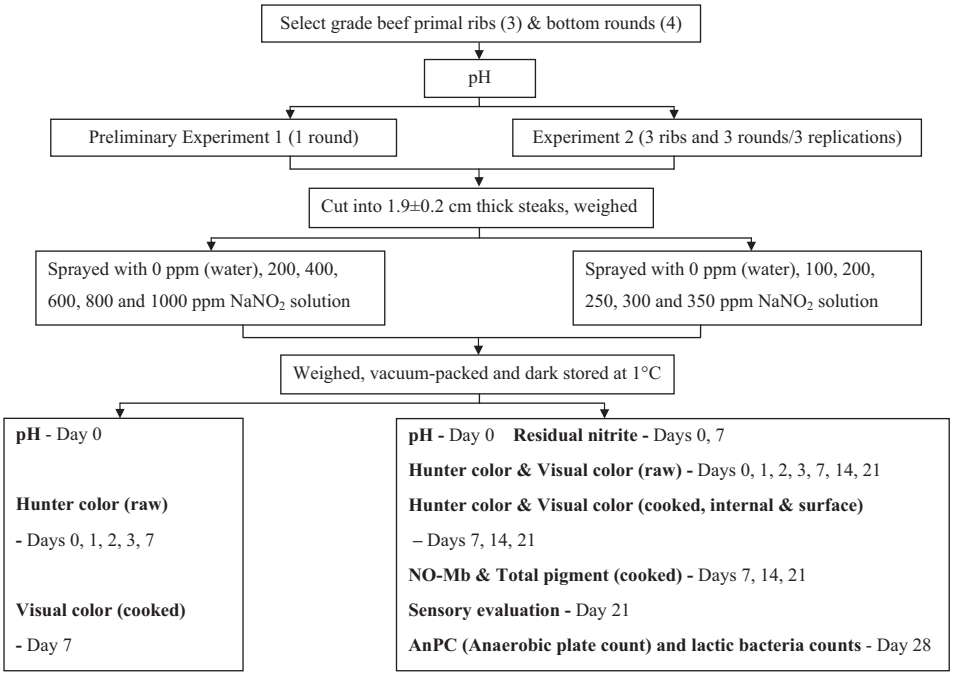

Fig. 1. Process flow chart.