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Bloom Development from Frozen to Fresh of Vacuum Packaged Steaks

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Abstract

Meat surface color is a key attribute that influences the purchase of meat products in stores because consumers consider color to be an indicator of wholesomeness. Changes in surface color of meat during display can be detrimental to consumer purchase intent in the retail setting. Vacuum packaging is a technology often reserved for extended storage of meat and food products. To extend storage conditions of fresh meats, freezing is commonly used to reduce meat quality deterioration while retail use of vacuum packaging for meat products is increasing. Therefore, the current study evaluated the influence of thermoforming vacuum packaging on bloom development in beef *Longissimus dorsi* (L.D.) steaks undergoing the transition from frozen to fresh storage conditions. Surface color of the steak was measured objectively every 4 hours after removing steaks from frozen storage and placing on display cases to recreate a retail storage exposure that similar to what is common in supermarkets. Steak surface color became lighter, redder, and more yellow ($p < 0.05$) as bloom time increased. Calculated spectral values chroma, red-to-brown, and calculated relative values of deoxymyoglobin increased ($p < 0.05$) with increasing bloom time. Current results suggest that thermoforming vacuum packaging positively influences surface color of beef steaks during the first 8 hours after increasing storage temperatures.

Keywords: Beef; Blooming; Instrumental color; Vacuum packaging

Introduction

Fresh meats are a group of global commodities stored using a variety of packaging systems for retail display in supermarkets [1]. Consumers select meat products based on characteristics such as surface color, price, and consumer convenience. Selection criteria suggests that the color of meat is a primary indicator of quality and freshness. Consumers perceive red meat to be fresher and higher quality in contrast to discolored cuts that are commonly considered to be of poor quality [2].

Blooming in meat surface color is caused by oxygen exposure to the cut surface and can be altered by the diffusion of oxygen into the muscle tissue through factors such as temperature and pressure [3]. Elevated oxygen concentrations can increase the rate of oxygen dispersion into the muscle tissue, leading to greater oxymyoglobin development, and causing a surface color change from purple to bright red [4]. However, this process is also more effective under conditions that increase oxygen solubility and decrease the enzymatic activity of muscle tissue recovers the original bright-red color. Additionally, it has been demonstrated that meat undergoing prolonged aging can experience surface color blooming more quickly and intensely [5].

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Consumers often view meat at its peak surface color bloom, typically after being removed from its packaging or during storage, surface color can alter the consumer perception of quality [3].

Discoloration is one of the major quality changes that should limit the shelf-life on meat products, the selection of suitable packaging system would be retard or prevent this unfavorable quality change during storage and distribution [6]. Recently the meat industry makes use of a wide range of packaging, differing in the properties that constitute each of them.

Vacuum packaging is a technique used throughout the meat and food industry to ex-tend meat storage life and to maintain meat quality during the transition from frozen storage to fresh display at refrigerated temperatures ranging from 4 °C to 6 °C [7,8]. Variability in packaging methods for fresh meat has been well documented to alter the surface blooming process of beef steaks [9]. However, various packaging forms have been adopted by the meat industry, one such method, modified atmosphere packaging (MAP) with a gas mixture (80% O_2 and 20% CO_2) has been shown to be an effective packaging method for beef that supports a stable bright-red color during storage [10]. Vacuum skin packaging (VSP) uses a top cover film shrink wrapped around the meat surface resulting in a pack-aging method that can sustain a longer storge period but limits bloom development [11].

Therefore, the objectives of this study were to evaluate the influence of thermoforming vacuum packaging on blooming time when steaks transition from frozen to fresh storage conditions.

Materials and Methods

Raw materials

Beef ribeye rolls (Institutional Meat Purchasing Specifications No. 112A) were purchased from a commercial meat processor, transported to the Auburn University Lambert-Powell Meat Laboratory, and stored in refrigerated conditions (2°C ± 1.25°C) for 21 days (Model LEH0630, Larkin, Stone Mountain, GA, USA). After aging, ribeye rolls (N = 20) were fabricated into steaks. Steaks were cut 2.54-cm-thick using a BIRO bandsaw (Model 334, Biro Manufacturing Company, Marblehead, Ohio, USA). To mimic industry applications of steak fabrication, the cut surface of each steak was allowed to bloom for 30 min in atmospheric conditions at 2°C ± 1.25°C before packaging.

Packaging treatments and simulated display conditions

Steaks (n = 4/ribeye roll) were assigned randomly to a packaging treatment. Each steak was packaged individually using a Variovac Optimus (OL0924, Variovac, Zarrentin am Schaalsee, Germany). Steaks were placed into one of three different thermoformaing packaging films (TA, TB and TC) and sealed with a non-forming layer (NF) using commercial packaging guidelines (WINPAK, Winnipeg, MB, Canada). Packaging film com-ponents, oxygen transmission rate (OTR) and vapor transmission rates (VPR) are presented in table 1.

Packaged steaks were placed into cardboard boxes and stored in a blast freezer (Model LHE6950, Larkin, Stone Mountain, GA, USA) for seven days at -20°C ± 1.50°C to simulate frozen distribution from manufacturer to retailer at the Auburn University Lambert-Powell Meat Laboratory. Frozen steaks were placed into a three-tiered, multi-deck, lighted display case Avantco (Model 178GDC49HCB, Turbo Air Inc., Long Beach, CA, USA) operating at 3.0 °C ± 1.5 °C. Lighting within the retail case consisted of cool LED strips (TOM-600-12-v4-3, Philips Xitanium 40W-75W, Korea) with a lighting intensity of 2297 lux (ILT10C, International Light Technologies, Peabody, MA, USA).

Instrumental color

Instrumental surface color was measured every 4 hours with a HunterLab MiniScan EZ colorimeter, Model 45/0 LAV (Hunter Associates Laboratory Inc., Reston, WV, USA) through the packaging film. Prior to surface color readings, the colorimeter was standardized using a black and white tile covered with the packaging films to confirm instrument accuracy.

Instrumental color values were determined from the average of three readings using illuminant A, a 10° observer, and a 31.8mm aperture to measure the lightness (L*), redness (a*), and yellowness (b*) of each steak. In addition, the

Table 1: Thermoforming vacuum packaging specifications.

Trt.[3]	Components	OTR[1]	VPR[2]
TA	250µ nylon/EVOH/enhanced polyethylene coextrusion	0.1 cc/sq. m/24 h	2.5 g/sq. m/24 h
TB	250µ nylon/EVOH/enhanced polyethylene coextrusion	0.1 cc/sq. m/24 h	2.0 g/sq. m/24 h
TC	125µ nylon/EVOH/enhanced/polyethylene coextrusion	0.6 cc/sq. m/24 h	4.9 g/sq. m/24 h
NF [4]	110µ nylon/EVOH/enhanced/polyethylene coextrusion	0.7 cc/sq. m/24 h	6.0 g/sq. m/24 h

[1]OTR: Oxygen transmission rates. [2]VPR: Vapor transmission rates. [3]Packaging treatments defined as (TA, TB, TC). [4]NFL (Non-forming film).

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hue angle was calculated as fol-lows: tan−1 (b*/a*), with a greater value indicative of the surface color shifting from red to yellow. Chroma (C*) was calculated as √ a*2 + b*2 where a larger value indicates a more vivid color. Lastly, reflectance values within the spectral range 400 to 700 nm were used to capture the surface color changes from red to brown by calculating the reflectance ratio of 630 nm:580 nm and the relative calculated percentages of deoxymyoglobin (%DMb = {2.375 × [1 − ({A473 − A700}/{A525 − A700})]} × 100), metmyoglobin (%MMb = {[1.395 − ({A572 − A700}/{A525 − A700})]} × 100) and oxymyoglobin (%OMb = 100 – (%MMb + %DMb). Surface color measurement was conducted according to American Meat Science Association (AMSA) Meat Color Measurement Guidelines [12].

Statistical analysis

Data was analyzed as a completely randomized design using the GLIMMIX model procedures of SAS (version 9.2; SAS Inst., Cary, NC, USA). Least square means were generated and significant (α = 0.05) F-values were separated using a pair-wise t-test (PDIFF option).

Results and Discussion

Instrumental color

Subprimals were aged for 21 days, cut into steaks, and subsequently stored frozen for 7 days before collecting objective color measurements. Surface color measured over the period of 32 hours indicated there was no interaction ($p > 0.05$) for packaging treatment × bloom time on beef steaks. Nonetheless, steak surface color became lighter ($p < 0.05$) with-in 4 hours of removing steaks from frozen storage temperatures (Table 2). Additionally, steak redness was darker initially (0 hour) but with increasing time surface redness in-creased ($p < 0.05$). Similar results were reported in a previous study evaluating blooming using longissimus lumborum indicating lightness (L*) values increase after 5 hours in retail display exposure [13]. Current results agree with previous studies noting similar objective color development observations on fresh beef semimembranosus displaying surface color changes occurring within increasing time [3]. Furthermore, additional results agree with the current results noting increases in lightness, redness, and yellowness of aged beef steaks, suggesting the blooming ability of vacuum-aged beef steaks can occur [14,15]. Surface color changes in red meat such as beef have been well documented to influence consumer purchase decisions. Such decisions based on surface color are often related to retail cuts frequently packaged in oxygen permeable films. It is plausible that the changes in partial pressure within a vacuum package after freezing and thawing can alter the surface color of the steaks whereby causing color values to increase.

Steaks packaged in treatment films TA and TB were lighter ($p < 0.05$), less red and appeared less yellow after removal from frozen storage temperatures (Table 3). However, steaks packaged in TC appeared darker, redder ($p < 0.05$) more yellow than steaks pack-aged in TA or TB packaging films. Previous objective color results agree with the current results, where surface color differences did not occur across time of exposure in these parameters [16]. Additionally, previous studies have reported that vacuum packaging film thickness

Table 2: Influence of bloom time on instrumental surface color blooming of beef steaks.

	Time (Hour)									
Objective Color [1]	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**SEM**
Lightness (L*)	37.08^{b}	37.20^{b}	41.62^{a}	42.18^{a}	42.64^{a}	42.46^{a}	42.46^{a}	42.07^{a}	41.80^{a}	0.472
Redness (a*)	12.34^{e}	14.58^{d}	14.96^{d}	15.97^{c}	16.75^{b}	18.17^{a}	18.17^{a}	18.48^{a}	18.73^{a}	0.281
Yellowness (b*)	9.32^{c}	11.47^{ab}	11.28^{b}	12.00^{a}	11.94^{a}	11.41^{ab}	11.41^{ab}	11.41^{ab}	11.51^{ab}	0.224

[1]Objective Color: L* values are a measure of darkness to lightness (larger value indicates a lighter color); a* values are a measure of redness (larger value indicates a redder color); and b* values are a measure of yellowness (larger value indicates a more yellow color). $^{a-e}$ Means within a row lacking a common letter differ ($p < 0.05$). SEM: Standard error of the mean.

Table 3: Influence of packaging film treatments on instrumental surface color blooming of beef steaks.

	Packaging Treatments[1]			
Objective Color[2]	**TA**	**TB**	**TC**	**SEM***
Lightness (L*)	41.45^{a}	41.28^{a}	40.44^{b}	0.385
Redness (a*)	16.12^{b}	16.20^{b}	17.06^{a}	0.23
Yellowness (b*)	10.99^{b}	11.10^{b}	11.83^{a}	0.183

[1]Packaging treatments: TA (250µ nylon/EVOH/enhanced polyethylene coextrusion), TB (250 µ nylon/EVOH/enhanced polyethylene coextrusion), and TC (125µ nylon/EVOH/enhanced/polyethylene coextrusion). [2]Objective Color: L* values are a measure of darkness to lightness (larger value indicates a lighter color); a* values are a measure of redness (larger value indicates a redder color); and b* values are a measure of yellowness (larger value indicates a more yellow color). $^{a–b}$ Mean values within a row lacking common superscripts differ ($p < 0.05$). * SEM, Standard error of the mean.

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did not alter fresh meat surface color during the first 24 hours [17]. Nevertheless, limited documentation throughout the literature on blooming duration from frozen to re-frigerated temperatures exist. Current results suggest that barrier properties within pack-aging films are instrumental in the changes of surface color that occur in vacuum packaged beef steaks.

There was no interactive impact ($p > 0.05$) of time and packaging film on the calculated relative spectral values for hue angle, red-to-brown (RTB), and chroma (C*). Mean values of calculated spectral values are presented in table 4. Steak surface color became more ($p < 0.05$) vivid (C*) with increase bloom time during refrigerated storage. Chroma variations observed are consistent with results reported in previous studies where filets presented the same trend for more vivid surface color was observed at the beginning of the evaluation [17]. However, in another study that evaluated the influence of vacuum pack-aging on blooming in Longissimus thoracis steaks hue angle values differed throughout the display, whereas red-to-brown color values did not differ [18]. Increases in spectral values of surface color suggest that steak surface color was dark during frozen storage, but surface color bloomed and became redder when storage temperature increased. Interestingly, thermoforming packaging can influence in surface color on steaks from frozen to fresh temperatures [19], surfaces redness can be maintained in the thicker packaging during retail period.

Furthermore, calculated relative spectral values of myoglobin forms differed ($p < 0.05$) as bloom time increased (Table 4). Declining metmyoglobin (MMb) and oxymyoglobin (OMb) values with increasing time is similar to previous studies that evaluated longissimus muscle of lamb where the transition between frozen to thawed (i.e. fresh) resulted in diminished MMb and OMb values [20]. However, as expected, deoxymyoglobin values (DMb) increased with storage time, and this is consistent with previous studies reporting an increase in DMb for lamb steaks stored in vacuum [21]. Furthermore, another study using longissimus thoracis steaks from Nellore and Aberdeen Angus reported similar changes in myoglobin redox forms that are consistent with our current results [22]. Information regarding the bloom of steaks moving from frozen temperatures to refrigerated temperatures is limited throughout the literature. However, the limited previous literature that does exist supports the current findings of bloom development in vacuum packaged beef. Unlike alternative retail packaging methods such as modified atmosphere or breathable poly-vinyl chloride overwrap, vacuum packaging in combination with colder storage temperatures can create a redder surface color with less surface discoloration than red meats stored in warmer temperatures [18].

Relative spectral values for packaging treatments did not differ ($p > 0.05$) apart from vividness (C*) and OMb presented in table 5. Current results agree with earlier studies that evaluated veal cuts using film-wrapped and vacuum packages which demonstrated that the thinner the packaging films, the better the chance of presenting a more striking color in a shorter time compared to thicker packaging [23]. However, additional findings indicate that using oxygen-impermeable films for storing frozen beef might offer benefits to instead meat quality [24].

Interestingly, it should be noted that throughout the 32 hours of bloom from frozen to fresh display, packaging treatments did not affect hue angle, red-to-brown, MMb, or DMb values ($p > 0.05$). These results differ from previous literature evaluating vacuum packaging films that can cause meat color parameters to change over time [25]. Mitochondrial oxygen consumption has previously been linked to redox change leading to the conversion of MMb and OMb to DMb [26]. However, current results agree with previous research utilizing different cuts of fresh chevon, suggesting that the calculated spectral values do not tend to undergo major changes in the first hours of exposure to atmospheric gases such as oxygen though they are inconsistent with, another

Table 4: Influence of bloom time for calculated relative spectral values on beef steaks.

	Time (Hours)									
Spectral Values[1]	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**SEM**
C*	15.54^{d}	18.66^{c}	18.86^{c}	20.14^{b}	20.72^{b}	21.55^{a}	21.55^{a}	21.85^{a}	22.11^{a}	0.218
Hue Angle (°)	37.0^{ab}	38.37^{a}	37.17^{ab}	37.25^{ab}	35.6^{b}	32.30^{c}	32.30^{c}	31.87^{c}	31.68^{c}	0.813
RTB	1.71^{e}	2.01^{d}	2.01^{d}	2.12^{d}	2.73^{ab}	2.84^{a}	2.48^{c}	2.70^{abc}	2.57^{bc}	0.083
MMb (%)	42.25^{a}	40.75^{a}	37.11^{b}	34.35^{b}	30.42^{c}	28.07^{cd}	24.59^{de}	24.00^{e}	22.91^{e}	1.259
DMb (%)	26.90^{f}	36.08^{e}	46.68^{d}	48.81^{d}	54.25^{c}	57.34^{bc}	61.30^{ab}	63.96^{a}	66.04^{a}	1.839
OMb (%)	30.85^{a}	23.18^{b}	16.21^{dc}	16.84^{c}	15.34^{cde}	14.59^{de}	14.11^{e}	12.04^{f}	11.05^{f}	0.684

[1]Spectral Values: Chroma (C*), is a measure of total color where a larger number indicates a more vivid color; Hue angle (°), represents the change from the true red axis where a larger number indicated a greater shift from red to yellow; Red-to-brown (RTB), calculated as 630 nm reflectance / 580 nm reflectance which represents a change in the color of red to brown (larger value indicates a redder color); Calculated percentages of metmyoglobin (MMb), deoxymyoglobin (DMb), oxymyoglobin (OMb) using relative spectral values. $^{a–f}$ Mean values within a row lacking common superscripts differ ($p < 0.05$). * SEM, Standard error of the mean.

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study which reported myoglobin redox forms did not differ throughout the first 48 hours of display [27,28]. Such reported differences highlight the need for continued research focusing upon the impact of vacuum packaging on blooming during the transition of frozen to fresh storage of meat and points to the likelihood that differences exist in the utility of vacuum packaging related to species and breed from which the meat product is derived.

Conclusions

Vacuum packaging and storage temperatures can influence the blooming process of beef steaks regardless of aging (>22 days). Surface color, specifically redness increased as storage temperature and duration increased. Herein, instrumental color measurements were monitored for a retail display period of 32 hours to evaluate blooming evolution over a typical commercial setting. However, no decline in bloom on the surface color of the steaks was observed during this period. Therefore, additional studies should be directed at extending the duration of surface color bloom time measurements that may alter red meat color using thermoforming vacuum packaging for retail cuts.

Author contributions

Conceptualization, G.M.B.-M. and J.T.S.; methodology, G.M.B.-M.; validation, B.W.N. and S.L.D.; formal analysis, J.T.S.; investigation, G.M.B.-M., B.W.N. and S.L.D.; resources, J.T.S.; data curation, G.M.B.-M. and J.T.S.; writing-original draft preparation, G.M.B.-M.; writing-review and editing, G.M.B.-M., B.W.N., S.L.D., A.D.B., T.D.B., T.M.R., and J.T.S.; supervision, A.D.B., and J.T.S., project administration, J.T.S.; funding acquisition, J.T.S. All authors have read and agreed to the published version of the manuscript.

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Data availability statement

Data presented in the study are available upon request to the corresponding author.

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Conflicts of interest

The authors declare no conflict of interest.

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