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ORIGINAL ARTICLE

Effects on colour characteristics of buffalo meat during blooming, retail display and using vitamin C during refrigerated storage

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Abstract Experiments were conducted to determine the effect of blooming, retail display and vitamin C on colour changes/improvement of buffalo meat. To evaluate the effect of blooming, top round cuts of buffalo were allowed to bloom for 60 min. As colour bloomed, a* value increased from 6.47 to 10.01 at 45 min; no further changes occurred. In another study, top round cuts were kept at ambient temperature (36±2 °C) and evaluated for instrumental colour during display. The instrumental redness value (a*) and chroma significantly increased ($P<0.05$) after 12 h of display. During storage at refrigerated temperature, treatments consisted of injecting muscle section with 5 % by weight of 0.5, 1 and 2 % vitamin C solutions and a non-injected control (0 %). Each part was evaluated for instrumental colour changes and sensory traits (colour and discoloration score) at 0, 3, 6 and 9th day of refrigerated storage. The a* value (redness) increased significantly in all vitamin C treated buffalo meat samples as compared to control stored at 4 °C. The chroma was significantly higher ($P<0.05$) in treated meat as compared to control. Buffalo meat containing vitamin C maintained the desired red meat colour throughout the storage period. The buffalo muscle treated with 2 % vitamin C was more effective in preventing discoloration than treated with 0.5 and 1 % vitamin C. In our study it is evident that as colour bloomed, a* value (redness) increased which indicated that buffalo muscles became redder immediately after exposure to air during blooming and retail display. Vitamin C at levels between 0.5 and 2 % will minimize the rapid discoloration that occurs at the muscle surface. However, 2 % concentration of vitamin C was more effective in minimizing the discoloration and improving colour stability.

Keywords Buffalo · Blooming · Display · Colour · Vitamin C

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The immense livestock wealth of India claims a remarkable 57 % of the world buffalo population (107 million) and India produces 1.50 MT buffalo meat which accounts 46.88 % of the world's share and contributes about 30 % of total meat production in India (FAO 2009). The meat is produced mainly from very old unproductive animals, which results in it being dark in colour. The first 30–60 min immediately after muscle tissue is exposed to air are critical to myoglobin oxygenation and "bloom" of muscle colour from that typical of reduced myoglobin (purple) to that typical of oxymyoglobin (true red). Bloom time in beef is the amount of time necessary for oxygenation to occur to the myoglobin molecule on the surface of the steaks after being exposed to the air (Ledward 1992). Bloom time of 20–30 min is recommended before taking the measurements of colour in case of pork (Skrlep and Candek-Potokar 2007). Beef freshly in rigor bloomed slowly and that entered rigor at relatively high temperature bloomed sooner. Lee et al. (2008) reported that as much as 90 % of the total increase in instrumental color and oxymyoglobin percentages was achieved during the first 60 min after cutting of beef. Therefore, it is important to understand how the freshly slaughtered muscle is bloomed with respect to time after which tissue is first exposed.

In India, prevailing situation is that meat immediately after slaughter are displayed at room temperature in the retail outlets and sold throughout the day. The appearance of meat is of primary importance in modern marketing as

most consumers "buy by the eye". Very few reports are available on colour changes of buffalo meat during display at refrigeration and mainly in pork (Zhu and Brewer 1998) and beef muscles (Kerth et al. 1995). The fact that meat colour changes and discoloration occurs during refrigerated storage is well established. Metmyoglobin formation of beef cuts is the most important problem in maintaining a stable display of retail meat. Exogenous addition of ascorbic acid delayed metmyoglobin formation and lipid oxidation in ground beef (Shivas et al. 1984). Vitamin C has been used in various ways to enhance the lean colour stability of meat during display (Sahoo and Anjaneyulu 1997; Naveena et al. 2006; Yin et al. 2006; Friedrich et al. 2008). Recently, Naveena et al. (2011) indicated the potential antioxidant and myoglobin redox stabilizing effect of ammonium hydroxide in ground buffalo meat patties. Little information is available on the blooming and retail display of buffalo muscles and use of vitamin C in buffalo meat. Therefore, the objectives of our work were (1) to evaluate the changes in colour of buffalo meat during blooming, (2) to assess the instrumental colour changes during retail display of buffalo meat at ambient temperature, (3) to determine the optimum level of vitamin C required to enhance the lean colour stability of buffalo meat during refrigerated storage.

Materials and methods

Source of meat samples The spent, adult buffaloes were slaughtered according to traditional halal method at the buffalo slaughter house, Municipal corporation of Hyderabad, A.P. India. Top round cuts (*semimembranosus and adductor*) from buffalo carcass were collected within five min of slaughter, packed in Low density polyethylene (LDPE) bags and brought to the laboratory within 15 min. We took the Hunter Lab equipment in slaughter house and blooming in fresh muscle was conducted in the slaughter house laboratory.

Colour evaluation during blooming and retail display To evaluate the effect of bloom time, instrumental colour was recorded at 0, 10, 20, 30, 45 and 60 min of blooming. All colour measures at 0 min bloom time are referred to as unbloomed colour. Further, top round cuts were immediately brought to fresh meat technology laboratory of the Institute and kept at ambient temperature for display. The average ambient temperature through out this experiment (blooming and retail display) was noted to be 36±2 °C. Buffalo muscle was evaluated for Hunter L*, a*, b*, hue and chroma values.

Colour evaluation with vitamin C during refrigerated storage Buffalo muscles (*semimembranosus and adductor*) were brought to the laboratory and kept at 4 °C for 24 h chilling and divided into four equal parts. Treatments consisted of injecting muscle section with 5 % by weight of 0.5, 1 and 2 % Vitamin C solutions and a non injected control (0 %). The solutions were made in pre chilled distilled water. Each part was assigned randomly to one of the four treatments and was allowed to equilibrate for 5 min and packed separately. Four parts were then kept at 4 °C in the refrigerator and was evaluated for instrumental colour changes and sensory traits (colour and discoloration score) at 0, 3, 6 and 9th day of refrigerated storage.

Experimental analyses

Colour appraisal Colour measurements were conducted on the surface of samples with a Miniscan XE plus (Hunter Associated Labs, Inc, Reston, VA., USA) that had been calibrated against black and white reference tiles (X=78.6, Y=83.4, Z=89.0). CIE L* (lightness), a* (redness) and b* (yellowness) values were obtained using a setting of D65 (daylight, 65-degree light angle). The hue angle (arc b*/a*) and chroma $(a^{*2} + b^{*2})^{1/2}$ were calculated based on illuminant D65 and 10° standard observer (CIE 1978). An average value from 4 random locations in each sample surface was used for statistical analysis.

Sensory evaluation Buffalo muscle was evaluated for colour score (1=extremely bright red, 2=bright red, 3=slightly dark red or brown, 4=moderately dark red or brown, 5=dark red or brown) and percentage surface discoloration (1=0 %, 2=1 to 19 %, 3=20 to 39 %, 4=40 to 59 %, 5=60 to 79 %, 6=80 to 99 %, 7=100 %) according to AMSA (1991) by a five member trained panel. Discoloration was defined as a predominantly brown colour.

Statistical analysis Three trials were conducted and the statistical analysis was done using SPSS 12.0 statistical programe (SPSS 2003). A three-way analysis of variance was used to study the main effects and their interaction. All significant tests were conducted at the 5 % level for comparing the means.

Results and discussion

Bloom time had a significant (P<0.01) effect on all colour characteristics measured (Table 1). In the present study, instrumental colour measures continued to change during the entire 60 min. As colour bloomed, a* value increased from 6.47 to 10.01 at 45 min; no further changes occurred. This indicated that buffalo muscles became redder immediately after exposure to air. Almost 40 % of the increase in a* value occurred within 30 min and approximately 55 % of

Table 1 Effects of bloom and display time on colour characteristics (Mean ± SD) of buffalo meat

Bloom time(min)	Colour characteristics[x]				
	L*	a*	b*	Hue[y]	Chroma[z]
0	34.8±2.10^{d}	6.4±1.05^{a}	6.7±1.22^{a}	46.0±2.22^{b}	9.3±1.57^{a}
10	32.6±1.38^{c}	7.1±1.01^{a}	8.0±0.56^{b}	48.5±2.28^{c}	10.7±1.07^{b}
20	34.6±1.61^{d}	6.9±1.04^{a}	7.5±0.51^{b}	47.6±2.47^{bc}	10.2±1.07^{ab}
30	30.9±1.79^{bc}	8.9±0.60^{b}	9.1±0.65^{c}	45.8±0.61^{b}	12.8±0.87^{c}
45	28.1±1.99^{a}	10.0±1.42^{c}	8.5±0.64^{c}	40.5±2.25^{a}	13.1±1.48^{c}
60	29.4±1.80^{ab}	9.8±1.00^{bc}	7.9±0.37^{bc}	39.2±1.82^{a}	12.6±1.00^{c}
SEM	0.82	0.43	0.29	0.83	0.49
Display time (Hr)					
0	34.8±2.10^{e}	6.4±1.05^{a}	6.7±1.22^{a}	46.0±2.22^{e}	9.3±1.57^{a}
2	27.8±1.94^{bcd}	9.4±1.07^{b}	10.3±0.72^{d}	47.6±1.36^{e}	14.0±1.25^{b}
4	28.8±1.29^{d}	11.7±0.69^{c}	9.4±0.47^{c}	38.8±1.58^{c}	16.7±1.33^{d}
6	28.2±1.06^{cd}	11.6±0.85^{c}	9.1±0.78^{c}	38.0±1.99^{c}	14.8±0.62^{bc}
8	27.1±0.37^{bc}	12.6±0.65^{d}	12.0±0.54^{e}	43.4±1.08^{d}	17.4±0.79^{d}
10	26.8±0.17^{b}	13.2±0.41^{d}	9.5±0.88^{c}	35.7±2.40^{b}	16.3±0.41^{cd}
12	24.4±0.24^{a}	16.0±0.14^{e}	8.1±0.10^{b}	26.9±0.37^{a}	18.0±0.14^{d}
SEM	0.62	0.31	0.31	0.90	0.80

[x]Hunter Lab Spectrocolorimeter, illuminant D_{65}, 10 ^{0} observer, 2.5 cm port

[y]Hue angle = $\tan^{-1}(b^*/a^*)$

[z]Chroma = $(a^{*2} + b^{*2})^{1/2}$

SEM standard error of means

SD standard deviation

n=12

Means with same letters in a column are not different (P>0.05)

the change in a* value was completed by 45 min (Based on calculated data not shown here). This may be due to more myoglobin oxygenation immediately after exposure to air. Brewer et al. (2001) also reported that individual colour measures changed at different rates during blooming in pork muscle and that each required a different period of time to stabilize. The b* value also increased significantly (P<0.05) after 10 min up to 60 min of blooming. Hue angle decreased from 46.00 to 39.25 at 60 min. and chroma increased from 9.34 to 12.82 at 30 min; no further changes occurred. Over a 30 % increase in chroma of buffalo muscle occurred within the first 30 min. Zhu et al. (2001) reported that over half the change in instrumental colour of pork *longissimus thoracis* occurred within the first 10 min, but all instrumental colour values continued to change 90 min or greater after exposure to air. The retail display time had significant (P<0.01) effect on instrumental colour characteristics of buffalo meat. The a* value significantly (P<0.05) increased from 6.47 to 16.06 after 12 h of display of buffalo meat (Table 1). The chroma also showed the similar trend. However, the hue value decreased from 46.00 to 26.90 at the end of display. The high display temperature will move the brown metmoyglobin intermediate layer between oxymyoglobin and myoglobin closer to the surface and subsequently metmyoglobin becomes more visible with increasing display time (Renerre 1990).

Probably the most important colour parameter for fresh meat is the redness value (a*). As meat losses its ability to reduce metmyoglobin to oxymyoglobin, the brownish colour of metmyoglobin begins to appear on the surface of steaks and a* value will decrease. Changes of this value during the storage are shown in Table 2. The main effects of vitamin C concentration and storage days and their interaction were significant (P<0.01) for all the traits studied. The L* value varied a little in control and vitamin C treated buffalo meat during refrigerated storage at 4 °C. The a* value was significantly higher (P<0.05) in all treated meat samples as compared to control. This was also observed by Friedrich et al. (2008). The buffalo meat treated with 2 % vitamin C had the highest redness values, 0.5/1 % treated had the intermediate values and the untreated control had the lowest red lean colour. The hue angle decreased significantly (P<0.05) in treated meat as compared to untreated control during refrigerated storage at 4 °C (Table 2). No significant difference was observed either in 0.5 or 1 % vitamin C treated meat sample. However, storage time had no significant effect on hue angle. The chroma was significantly higher (P<0.05) in treated meat as compared to control (Table 2). Chroma which indicates the intensity of colour was observed to be lowest in control sample and was also reported by Sahoo and Anjaneyulu (1997) in ground buffalo meat.

All the treated buffalo meat had significantly (P<0.05) better colour score than the control (Table 2). Untreated buffalo muscle had an average colour score of 4.0 (moderately dark red or brown) and maintained a brown appearance up to 9th day of storage. In contrast, buffalo meat containing vitamin C maintained the desired red meat colour throughout the storage period. Similarly Shivas et al. (1984) reported that the visual colour for .05 and .1 % ascorbic acid treated ground beef was brighter than the control upto 10th day of display. Realini et al. (2004) also reported that vitamin C improved colour stability by prolonging more red colour. In sensory evaluation, the panelists mostly

Table 2 Effect of Vitamin C concentration on instrumental and sensory colour characteristics (Mean ± SD) of buffalo meat during refrigerated storage at 4 °C

Colour characteristics	Treatment	Storage period (days)				Overall means ± SD
		0	3	6	9	
L*	Control	31.3±0.63	37.3±2.22	36.7±1.07	35.5±0.76	35.2±2.69^{a}
	0.5 %Vit C	35.3±1.52	38.3±0.72	37.2±0.97	34.1±0.50	36.2±1.89^{b}
	1 %Vit C	35.7±0.78	36.6±0.58	36.3±0.57	34.3±1.61	35.7±1.27^{ab}
	2 %Vit C	34.9±1.35	35.9±1.78	36.8±1.06	33.3±1.52	35.2±1.89^{a}
	Overall means ± SD	34.3±2.09^{p}	37.0±1.65^{q}	36.7±0.94^{q}	34.3±1.39^{p}	
a*	Control	12.2±0.45	11.6±0.92	12.8±1.92	10.9±0.60	11.9±1.28^{a}
	0.5 %Vit C	13.1±0.80	14.7±0.85	15.5±0.75	17.3±1.12	15.2±1.77^{c}
	1 %Vit C	12.1±0.28	16.0±0.29	15.2±0.51	14.2±0.45	14.4±1.53^{b}
	2 %Vit C	14.1±0.48	16.8±1.69	15.7±0.86	17.3±1.74	16.0±1.74^{d}
	Overall means ± SD	12.9±0.96^{p}	14.8±2.26^{q}	14.8±1.59^{q}	14.9±2.88^{q}	
b*	Control	12.6±0.17	16.2±1.47	16.1±1.36	16.8±0.29	15.4±1.92^{a}
	0.5 %Vit C	16.7±0.79	17.9±0.98	18.4±0.75	20.6±0.64	18.4±1.62^{c}
	1 %Vit C	15.7±0.25	19.4±0.37	18.1±0.54	16.5±1.78	17.4±1.69^{b}
	2 %Vit C	16.8±0.52	17.4±1.57	18.8±0.69	20.7±1.08	18.4±1.82^{c}
	Overall means ± SD	15.4±1.76^{p}	17.7±1.61^{q}	17.8±1.35^{q}	18.6±2.28^{r}	
Hue	Control	45.8±2.06	54.3±2.07	51.5±1.74	56.9±2.01	52.1±3.03^{c}
	0.5 %Vit C	51.8±2.18	50.4±0.58	49.7±0.17	49.9±2.26	50.5±1.85^{b}
	1 %Vit C	52.3±0.67	50.4±0.82	49.9±0.62	49.1±6.55	50.4±3.33^{b}
	2 %Vit C	49.9±0.95	46.0±4.55	50.3±2.90	50.2±4.39	49.1±6.08^{a}
	Overall	50.0±7.88	50.3±2.89	50.3±3.61	51.5±3.50	
Chroma	Control	17.6±0.04	20.0±1.57	20.6±4.22	20.1±0.21	19.6±2.72^{a}
	0.5 %Vit C	21.2±0.98	23.2±1.60	24.1±1.11	26.9±1.19	23.8±5.49^{b}
	1 %Vit C	19.9±0.06	25.1±0.06	23.7±0.44	21.8±2.39	22.6±4.75^{b}
	2 %Vit C	21.9±0.36	24.3±4.51	24.6±0.82	27.0±3.28	24.5±5.29^{c}
	Overall	20.2±3.14^{p}	23.2±5.69^{q}	23.3±3.88^{q}	23.9±1.40^{q}	
Colour	Control	2.5±1.66	3.0±2.00	3.7±0.25	4.1±0.39	3.3±1.29^{b}
	0.5 %Vit C	2.5±1.66	2.7±0.91	2.1±0.65	2.0±0.66	2.3±0.76^{a}
	1 %Vit C	2.5±1.66	2.7±0.91	1.7±0.25	1.7±0.25	2.1±0.83^{a}
	2 %Vit C	2.5±1.66	2.1±0.39	2.2±0.25	1.7±0.25	2.1±0.59^{a}
	Overall	2.5±1.33	2.6±0.95	2.4±0.78	2.4±1.37	
Discolouration	Control	1.0±0.00	2.0±0.66	3.0±0.66	4.5±0.33	2.6±2.11^{b}
	0.5 %Vit C	1.2±0.25	2.0±0.00	1.7±0.25	2.0±0.66	1.7±0.33^{a}
	1 %Vit C	1.2±0.25	1.7±0.25	1.2±0.25	1.7±0.25	1.5±0.27^{a}
	2 %Vit C	1.2±0.25	1.5±0.33	1.5±0.33	1.2±0.25	1.3±0.25^{a}
	Overall	1.2±0.16^{p}	1. 8±0.29^{q}	1.8±0.78^{q}	2.3±1.98^{r}	

Hunter Lab Spectrocolorimeter, illuminant $D_{65,}$ 10^{0} observer, 2.5 cm port

L* lightness

a* redness

b* yellowness

Hue angle = $\tan^{-1}(b^*/a^*)$

Chroma = $(a^{*2} + b^{*2})^{1/2}$

SD standard deviation

n=12

Overall means with same letters in a column (a,b,c) and row (p,q,r) are not different (P>0.05)

preferred the 2 % vitamin C treated meat even after 9th day of storage period. Almost above 60 % visual surface discolouration was noticed in control buffalo meat after 9 days of refrigerated storage while treated buffalo meat showed slight discolouration throughout the storage period (Table 2). The buffalo muscle treated with 2 % vitamin C was more effective in preventing discoloration than treated with 0.5 and 1 % vitamin C. As the natural vitamin C content of fresh meat is negligible (0 ppm in meat) reported by Anderson et al. (1985), vitamin C penetrated into the meat and acted as an antioxidant and prevented oxidation of meat pigments and thereby discoloration.

Conclusions

In our study it is evident that as colour bloomed, a* value (redness) increased which indicated that buffalo muscles became redder immediately after exposure to air during blooming and retail display. Vitamin C at levels between 0.5 and 2 % will minimize the rapid discoloration that occurs at the muscle surface. However, 2 % concentration of vitamin C was more effective in minimizing the discoloration and improving colour stability.

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