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A review on some factors affecting colour of fresh beef cuts

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Abstract
This research paper aims to cover the latest information about the colour of fresh beef cuts which is one of the quality attributes, and the factors significantly affecting it. The effects of some treatment techniques used to maintain it, such as dietary antioxidants and packaging under high oxygen concentration as well as modified atmosphere packaging (MAP), also reported. The outcome of this review paper revealed that colour of beef cuts is a critical and important visual quality attribute, highly affecting consumer decisions to purchase the cuts. Selection of correct animal diets and presences of some enzymes in the muscles may positively affect the colour. Increasing both lipid and protein oxidation negatively influence the storage life of the colour. To maintain good beef colour, techniques of using natural antioxidants such as dietary vitamin E, ascorbic acid, carnosine and tea catechins (TC) as well as MAP with different methods were found significantly keeping this quality attribute.

Key words: Beef, colour, oxidation, antioxidants, vacuum.

Introduction

The colour of beef is a critical quality attribute of muscle foods, since together with price it represents the principal factor influencing consumer decisions to purchase meat cuts at the point of sale [1, 2]. Consumers demand high quality appreciated fresh appearance of beef [3]. The color of muscle depends on the amount and oxidation/reduction state of myoglobin and beef surface characteristics related to its final pH [4]. Colour stability varies according to the muscle type which can be associated with the different balance of antioxidative and pro-oxidative compounds that control the oxidation rate of myoglobin [5].

Colour is influenced by some factors such as the animal species, breeding, genotype, gender, age, variation in muscle reducing systems and metabolic type, nutrition, pre-slaughter and handling procedures (relating specifically to dark cutting) [6]. In addition to that, the *postmortem* technological factors, such as electrical stimulation, muscle temperature, cooling rate, duration of ageing, freezing rate, packaging and lighting conditions are also found affecting to the colour [7-11]. According to literature [12], the factors that affect beef quality have been broadly categorized into either intrinsic factors, such as breed, gender, age, muscle, carcass weight and fatness, or extrinsic factors. However, extrinsic factors that may affect meat quality relate both to: (i) environmental (including 'on-farm') conditions under which animals are produced, e.g., climate, nutrition, accommodation, stocking densities/space allowance, floor type/underfoot conditions, social behaviours and interactions, habituation to handling, acute ante-mortem stress; (ii) *postmortem* technological factors that affect muscle tissue properties and thus meat quality, e.g., electrical stimulation, carcass suspension techniques, chilling rate, ageing, packaging, freezing and further processing. In *postmortem*, addition of vitamin C to ground beef was found to be effective in retarding red colour deterioration in grain or grass produced meat [13]. Several researches have been recently justified to investigate colour of beef as main quality attribute [14-24]. As the colour is an important parameter that consumers use to judge the freshness and wholesomeness of beef and it has substantial influence on acceptability and purchasing decision at retail points [25], this review paper was done to cover the scattered published recent investigated research works in this regard to trace the intellectual progress in this field.

Effect of Animal Feeding on Colour of the Meat

Animal diet plays a critical role that affecting the colour of the produced meat. The effect of grass and concentrate feeding of cattle on beef redness ('*a*' values) was reported [26]. Higher '*a*' values were found with grass feeding than with concentrate feeding. This finding was in a good agreement with the studies reported earlier [27], but other researchers [28] found no significant effect of the grass feeding and concentrate feeding on the colour of beef cuts. Dietary vitamin E supplementation of 1204 I.U./head/day for 122 days delayed metmyoglobin formation in muscle and resulted in higher '*a*' values than in non-supplemented animals[29]. In another study [30], surface redness (Hunter '*a*' value) after 8 days of refrigerated storage was significantly lower in meat samples with an α-tocopherol concentration of <2.5 µg/g meat compared to samples with >3.3 µg/g. The effect of different finishing strategies (beef was grown on pasture from 157 kg live weight until finished at 380–400 kg (all pasture) or grown on pasture until reaching 320 kg and then finished on a high grain diet in feedlot for 40, 60 or 80 days) on physical attributes of beef quality of Hereford steers was investigated [31]. Regarding the beef colour, only minor differences were found among treatments. Only the b^* parameter differed, but within a small range (4.8–5.9).

Subcutaneous fat colour showed a higher ($P < 0.05$) b^* value in the pasture-finished animals compared to the feedlot-finished ones (16.06 vs. 11.7, respectively).

Effect of Enzymes Activity on Beef Cuts Colour

Catalase (CAT), superoxide dismutase (SOD) and glutathione peroxidase (GPX) are the common enzymes normally present in muscle food and may involve in the meat oxidation and work as antioxidants. CAT remained active in samples of beef, pork and chicken after 60 days of freezing storage [32]. The same observation was recorded by others[33] who found that CAT remained active for at least 8 days in *Diaphragm* muscle of bulls when exposed to air. When CAT was inhibited using sodium azide, lipid oxidation in ground beef increased significantly, and it was concluded that it has an important role in modulating lipid oxidation in uncooked beef [32]. Gatellier *et al.* [34] found that feeding beef with different diets changed the activity of SOD and GPX. They described higher SOD activity in pasture-fed Charolais cattle as compared with mixed-diet produced beef. Larraín *et al.*[16] found that feeding beef with high-tannin sorghum (HTS) may possible cause modulation of oxidative stability of beef by changing the activity of these enzymes. Larraín *et al.* [16] evaluated the activities of CAT, SOD and GPX enzymes on *Longissimus lumborum* (LL) and the *Gluteus medius* (GM) beef muscles and observed no differences in the activity of any of the evaluated enzymes when comparing between beef fed with HTS and beef fed any other diet. Researchers [35] found that SOD activity was higher in the muscles of pasture-fed crossbreed steers.

Effect of Lipid Oxidation on Colour of Beef Cuts

The oxidative processes in meat and its products not only cause the rapid development of meat rancidity but also affect colour, nutritional quality and texture of beef [36]. Lipid oxidation can have negative effects on the quality of meat and meat products causing changes in sensory attributes including colour, texture, odor and flavor and nutritional quality [37]. Some researchers studied the technique of animal diets modification to increase the content of beneficial polyunsaturated fatty acids (PUFA) (C18:3-n-3, linolenic acid; C20:5n-3, eicosapentaenoic acid (EPA); C22:6n-3 docosahexaenoic acid (DHA); conjugated linoleic acid (CLA)) in meat products [38-41]. Mercier *et al.* [42] reported that oxidation of lipid and protein, which are closely associated with deteriorative processes occurring in meat, might play a serious role resulting in the loss of enzyme activity, solubility and formation of protein complexes and non-enzymatic browning products and could be linked to meat colour and tenderness. On the other hand, increment in oxidation of muscle proteins early post-mortem could have negative effects on meat colour and tenderness [43]. O'Grady *et al.*,[44] reported higher TBA numbers for ground beef stored in 40, 60 or 80% oxygen modified atmosphere packs after 10 days of storage. Another published work [45] agreed with this finding. They found that after 6 days of storage, ground beef samples packaged in modified atmosphere packs (80% O_2, 20% CO_2) had higher mean TBA numbers than controls. This is supported by a study by others [15] who found that the oxidative stability of beef steaks decreased depending on the level of O_2 used in the package. They reported that TBARS was in the order: $O_2 80 < O_2 50 < O_2 20 < O_2 10 < O_2 0$. By Day 9, lipid oxidation increased with increasing oxygen level in MAP, but only differences between samples packed in $O_2$50 or $O_2$80 treatments on Day 15 were significant. However, off-flavour in modified atmosphere may develop due to oxidative rancidity under high oxygen conditions, as indicated by the high TBA numbers of these samples [15]. Jayasingh *et al.* [45] reported that a TBA number less than 1.0 is usually associated with rancid flavour/odour by sensory panelists. The same finding was reported earlier [46]. The lipid oxidation causes deterioration of beef flavour in atmospheres enriched in O_2, and this deterioration can be closely related to TBARS [47]. Greene and Cumuze [48] reported that the general population of meat consumers would not detect oxidation flavours until oxidation products reached levels of at least 2.0 mg/kg. Recently researchers [15] proposed that because the TBARS levels were below 2 mg MDA/kg, the panellists found higher O_2 samples more acceptable. The $O_2$50 samples produced mean levels of 1.1 mg MDA/kg whereas the $O_2$80 samples produced mean levels of 1.3 mg MDA/kg.

Effect of Some Antioxidants on Protection of Fresh Beef Colour

The use of antioxidants is one of the effective control methods against oxidation of meat lipids as well as colour [49,50]. However, use of natural antioxidants has been recently given special attention due to the worldwide trend to avoid or minimize the use of synthetic food additives [49,51]. It was [52] reported that dietary vitamin E supplementation plays an important role in improving the antioxidant to pro-oxidant balance in muscle. Previous studies have shown that accumulation of α-tocopherol in muscle tissue delays pigment oxidation [53-56]. Kerry *et al.* [55] described the use of vitamin E supplementation to preserve meat colour (compiled by addition of antioxidants to the meat surface) and found that it has been successfully used to preserve buffalo meat colour. Naveena *et al.* [57] found that treatments of buffalo meat with a combination of clove oil antioxidant extracts, lactic acid and vitamin C successfully protected buffalo meat from oxidation and, thus, preserved red pigments during shelf-life storage. Two groups of researchers[58, 59] found that dietary supplementation with vitamin E reduced myoglobin and lipid oxidation and extended beef shelf life. Dunne *et al.* [60] found that there was a linear decrease of '*a*' value during retail display of beef that had been previously aged for 21 days. They found that *Longissimus dorsi* colour shelf-life of steers fed supplemental vitamin E was extended by 0.75 days, from 2.5 to 3.25 days.

Researchers [18] studied the effects of pasture and grain diets on oxidative/antioxidative status and colour stability of beef during retail display times of 1, 3, 5, 7 and 9 days and found that after 7 days of display "*a*" value was higher for *Psoas major* steaks from pasture diet ($P < 0.05$). Besides, "*L*" parameter showed higher values for samples from grain diets but it was not affected by display time. No differences were observed between both treatments for "*b*" value, but a significant decrease ($P < 0.05$) was observed along storage. α-Tocopherol was found to be the most abundant lipid-soluble antioxidant vitamin incorporated into LD buffalo muscles [19]. The concentration of this antioxidant in buffalo LD was 4.22±0.93 µg/g. Literature data indicate different concentrations of antioxidant vitamins in bovine LD muscle compared to 2.33±0.09 µg/g for non-supplemented beef [61]. In addition, Walshe *et al.*[62] found values of 4.051±1.303 and 0.152±0.100 µg/g of α-tocopherol and β-carotene, respectively, for steers reared under organic systems. At present there appears to be no information available on the α-tocopherol content of buffalo beef to compare against the results from the present study.

Protein oxidation in meat may decrease the eating quality by reducing tenderness and juiciness and enhancing flavour deterioration and discoloration [63]. Protein oxidation products in meat are formed depending on the nature of the proteins present, and different oxidation initiators may result in different oxidation products. Among the changes in proteins caused by oxidation is formation of hydroperoxides and carbonyls, inter- and intramolecular cross-linking through the formation of disulfide bonds and dityrosine, fragmentation of the peptide backbone, and decreased protein solubility [63].

Ascorbic acid is known to preserve red meat colour and possess antioxidative properties against lipid oxidation. Numerous researches have been carried to investigate the antioxidant activity of ascorbic acid in meat and meat products on colour and lipid oxidation and have been found to depend on concentration, the presence of transition metal ions and the presence of other antioxidants [64-69, 59].

There has been some recent interest in the antioxidant potential of carnosine in processed meat products. It is a naturally occurring skeletal muscle dipeptide composed of β-alanine and histidine and exerts its antioxidant effect on beef by a number of mechanisms [70-72]. Carnosine has been shown to be an effective antioxidant in model systems and meats [67, 73] Tea catechins (TC), the predominant group of polyphenols present in green tea leaves (*Camellia sinensis* L.), have been reported to be effective natural antioxidants in fish muscle model systems [74], chicken meat [75] and red meat systems [76, 77].

Tang *et al.* [78] studied the stability and antioxidant effects of added tea catechins (TC) at levels of 0 (T0), 200 (T200), 400 (T400), 600 (T600), 800 (T800) and 1000 (T1000) mg/kg minced muscle, on susceptibility of the colour of fresh minced beef patties during refrigerated (4°C) display under aerobic and modified atmosphere packaging (MAP, 80:20, O_2:CO_2) conditions and found that the treatment of the meat with TC at a level of 200 mg/kg delayed the formation of metmyoglobin (MetMb) and reduced oxymyoglobin (MbO_2) and redness in minced beef patties held under aerobic and MAP conditions. However, addition of TC at a level of over 200 mg/kg did not give rise to such effects. The higher the concentration of TC in meat, the darker the colour. This probably explains why the meat red colour stabilizing effects of added TC are only observed under the level of 200 mg/kg. Therefore, TC addition at a level of no more than 200 mg/kg meat should be recommended for fresh minced beef red colour stability.

Recently Badr [79] treated ground beef in the absence and presence of 0.5 or 1.0% carnosine, as well as raw and cooked beef patties prepared with 1.5% salt (NaCl), in the absence and presence of 0.5 or 1.0% carnosine which was gamma irradiated at doses of 0, 2 and 4 kGy. The authors found that the presence of carnosine had a significant ($P < 0.05$) effect in maintaining an acceptable red colour of irradiated and non-irradiated ground beef and raw patties during refrigeration and frozen storage. Visual colour scores showed that irradiated samples without added carnosine were less red/more brown than those irradiated in the presence of carnosine. The efficacy of carnosine in maintaining meat colour during storage was also reported [72, 80]. Those authors illustrated that the colour stabilizing effects of carnosine may be due to its ability to chelate transition metals involved in free radical generation and/or free radical scavenging, thereby delaying the oxidation of oxymyoglobin to metmyoglobin.

Effect of Packaging under High Oxygen Concentration on Fresh Beef Colour

The colour of meat is influenced by the chemistry of the heme pigment myoglobin [81]. While reduced myoglobin (Mb) is the predominant muscle pigment in fresh cut and in vacuum packaged meat, the binding of molecular oxygen yields oxymyoglobin (MbO_2), and the colour of meat changes to the customary bright-red. With time, the loss of oxygen and the oxidation of hemic iron from Fe^{2+} (ferrous ion) to Fe^{3+} (ferric ion) lead to the undesirable brown metmyoglobin (MMb) [81]. Saturation levels of oxygen in the packaging environment of meat are useful, favouring myoglobin oxygenation and delaying the formation of MMb [81]. Oxidation of deoxymyoglobin or oxymyoglobin to metmyoglobin is responsible for discoloration of beef under retail display conditions [58] and the products of the oxidative meat negatively affect meat flavor, texture and nutritional value [36, 82].

Zakrys *et al.* [15] investigated the effects of oxygen concentration of 0, 10, 20, 50 and 80% on the quality of MAP beef steaks (*M. longissimus dorsi*) stored at 4°C for 15 days and observed a negative correlation between oxymyoglobin (OxyMb) concentration and O_2 ($O_2$50%, $O_2$80%). Samples packed in $O_2$50 and $O_2$80 treatments had the greatest effect on decreases in OxyMb levels over time, which were most pronounced at Day 15 and OxyMb concentrations, were significantly, negatively correlated to the treatment $O_2$80%. This trend was also observed for total myoglobin (Mb) concentration and concluded that the high oxygen atmospheres had a greater effect in reducing OxyMb concentrations compared to the lower oxygen atmosphere packs ($O_2$0%, $O_2$10% and $O_2$20%).

Effect of Modified Atmosphere

Modified atmosphere is a very effective tool for packaging fresh beef. In this technique, beef is commonly displayed under high oxygen concentrations in modified atmosphere packs (MAP) in order to promote colour stability. Such conditions, however, may also cause quality deterioration through lipid oxidation and decreased tenderness [15]. MAP requires the use of films with low gas permeabilities and, after air evacuation, employs a gas or a mixture of gases (i.e. carbon dioxide, nitrogen and oxygen) to control the microbial growth or to prevent colour deterioration [81,83]. As reported by some researchers [84-86], MAP packs usually contain mixtures of two or three gases: O_2 (to enhance colour stability), CO_2 (to inhibit microbiological growth) and N_2 (to maintain pack shape). O'Grady *et al.* [44] reported that the presence of high O_2 concentrations promote the formation of oxymyoglobin (OxyMb), the cherry red form of myoglobin. However, other investigators reported that the presence of high O_2 may impact negatively on the oxidative stability of muscle lipids and lead to the development of undesirable flavours [87, 88].

Several researches were justified to inestigate the effect of modified atmosphere packaging (MAP) on meat quality attributes and the purchasing preferences of consumers [15, 45, 89]. Recently Lund *et al.*[90] investigated the effect of combination of solutions of rosemary extract and ascorbate/citrate (1:1) in combination with modified atmosphere packaging (100% N_2, 80% O_2/20% N_2) on protein and lipid oxidation in minced meat. They found that in 80% O_2/20% N_2, a significant effect of antioxidant was found after 1 day of storage. After 3 days of storage only ascorbate/citrate preserved the red colour compared to no addition of antioxidant and addition of rosemary extract. This finding was in good agreement with the studies reported by many researchers who demonstrated previously the preserving effect of both ascorbate and rosemary extract on red meat colour [64, 67, 91]. The researchers also found that ascorbate/citrate combination treatments were found to protect the red meat colour better than the rosemary extract. However, after 6 days of storage, no effect of antioxidant or packaging atmosphere was found. The level of oxygen was found to be 0% throughout the entire storage period in 100% N_2 packaging. The level of carbon dioxide increased from 0 to 7% both with and without addition of antioxidant, indicating microbial growth in the meat. For meat stored in 80% O_2/20% N_2 a decrease in oxygen level and increase in carbon dioxide level were found during the storage period both with and without addition of antioxidant, and the change in gas composition was most marked from 3 to 6 days of storage. However, without addition of antioxidant lower levels of oxygen and higher levels of carbon dioxide were observed compared to addition of antioxidant even though this effect was non-significant. This indicates that the antioxidant systems employed also reduce microbial growth, which was previously reported [68].

For red meat, Bell [2] described high-oxygen MAP systems typically utilize atmospheres containing from 70 to 80% of oxygen and from 20 to 30% of carbon dioxide. In this way, the high oxygen concentration enhances the bright-red colour, as well as carbon dioxide inhibits the growth of aerobic spoilage microorganisms, ensuring a long shelf-life (5–10 days).

Conclusions

The present review was done to evaluate the colour of beef as an effective critical parameter influencing the quality attribute of the meat. The main factors that affect this attribute include autoxidation of myoglobin to metmyoglobin (MetMb) and reduced oxymyoglobin (MbO_2) and lipid and protein oxidation. To protect the colour of beef against these negative effects, antioxidants and good packaging techniques as well as the combination of antioxidants and packaging can approved good positive result in prolonging the storage life of beef.

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