THE EFFECTS OF OXYGEN SCAVENGERS ON THE COLOUR STABILITY OF FRESH BEEF MEAT PACKAGED UNDER PURE CARBON DIOXIDE ATMOSPHERE

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Background

Packaging atmosphere can effect the colour of meat. Its colour is dependent on the oxidation state of muscle pigment myoglobin, and metmyoglobin is the major pigment responsible for meat discoloration. The colour of meat storage under pure CO_2 is maintained in the purple reduced form of myoglobin (Isdell et. al. 1999). However optimum conditions for metmyoglobin formation occur at low partial pressures of oxygen (Gill, 1996). The including sachets of oxygen-scavenging chemicals in the pack might to prevent discoloration in master-packaged beef steaks. Commercial O_2 scavengers are based on iron powders ('activated iron oxide') which are mixed with acids and/or salts and a humectant, to promote oxidation of iron (Gill and McGinnis, 1995; Labuza and Breene, 1989). The humectant may be dry or pre-wetted according to chemical reaction type. Smith et. al. (1995) reported the relationship between the types of O_2 scavengers, reactions speed and their specific use. Tewari *et al.* (2001) reported that the prevention of metmyoglobin formation might be affected by the type and the capacity of O_2 scavenger employed, storage temperature, pack atmosphere (air/N_2/CO_2), and initial O_2 concentation. But the information about performance of oxygen scavengers types and their scavenging behaviour is limited, and essentially non-existent at low O_2 concentrations, causing some confusion on their application.

Objective

The objective of this study was to evaluate the uptakes of O_2 from pure carbon dioxide atmosphere by two types of oxygen scanvengers based on iron chemical reactions and by the meat with inherent low stability colour, such as *Gluteus medius* muscles, to extend the storage life of the fresh beef steaks.

Methods

The *Gluteus medius* (GM) muscles from chilled carcasses of Nelore breed (*Bos indicus*) were excised one day after slaughter. Two steaks (390±40g) sliced into approximately 10-15mm were placed in a expanded polystyrene tray (3RR, Cryovac) on a soak pad (DryLock, Cryovac). Each tray was over-wrapped with clear polyolephinic shrink film presenting an O_2 transmission rate of about 12,232 cm^3 (STP)/m^2/day at 25°C, 75% R.H. and 1atm. The film was perforated along the two largest sides of the tray to allow for free exchange of atmospheres during gas flushing and the reblooming. After sealing, eight trays were distributed in ten masterpacks (3.1±0.1 kg) with an O_2 transmission rate of 19mL(STP)/m^2/day at 25°C and 75% R.H. and 1atm. Taking in a count that the rate of oxygen uptake by commercial scavengers declines exponentially with the decresing oxygen concentrations below 1% (Gill, 1996), the scavenging capacity of scavengers was overestimated approximately 20%. Both oxygen scavengers used in this study are composed an iron-based chemical system and moisture-dependent. In the first four masterpacks was added a scavenger which is formulated to reduce 300mL of O_2 (S_1), whereas in the other four masterpacks were adicionated another type (S_2) that rated capacity of scavenger is 420mL of O_2. Two control masterpacks (C) without O_2 scavengers were also carried out. The masterpacks were evacuated using 'double vacuum-flush' cycle, filled with 3,5L of pure CO_2/kg of meat, and sealed using a gas flushing machine (A300, CVP Systems Ltd., USA). Control packs without O_2 scavengers were also packaged in the same way. All packs were stored in a cold chamber in the dark for up to 14 days at 4 ± 1°C. After 7 and 14 days of storage, the O_2 concentration was analysed immediately before opened of masterpacks using an O_2 analyser, based on a solid state O_2 ion conduction material, zirconium oxide. After gas analysis two masterpacks for each type of scavenger tested and one having no O_2 scavenger were opened and all trays were placed in an illuminated (incandescent light) display case in air at 5±1°C for up to 48h. After retail pack opening, the pH of the meat surface was measured directly with a combined glass electrode. Samples (25g) were removed from the steaks with a sterile scalpel and ground with 225mL 0.1% peptone saline water. Aliquots (0.1mL) of appropriate dilutions were then spread on duplicate plates of Plate Count Agar (Merck). The plates were incubated for 2 days at 35°C for growth of bacterial mesophiles and 3 days at 20°C for growth of aerobic e anaerobic psychrotrophic bacteria (Vanderzant & Splittoesser, 1992). Subjective and objective colour evaluations of the steaks were made through the transparent shrink film. Meat colour (purple, red or brown) was assessed visually by a six-member trained panel. The of purple, bright red and brown colour were evaluation on a non structured scale of 9cm where 0 cm = none colour and 9 cm = intense colour. Discoloration was scored on a six-point scale where 1 = no discoloration, 2 = 5% discoloration, 3 = 5-15% discoloration, 4 = 15-25% discoloration, 5 = 25-35% discoloration, 6 = 35-100% discoloration The overall steak quality was scored on a seven-point scale where 1 = very poor and 7 = excellent. Colour coordinates (L, a, b) were measured in the CIELab system (C, 10°, specular excluded) with a portable spectrophotometer (Minolta Co., Ltd. – CM508d). The average of eight readings was recorded for each steak. For each type of scavenger were assessment four trays of two masterpacks. The results were analysed using the analysis of variance (ANOVA). Scheffe´s test was used to compare the means at a level of 0.05%.

Results and Discussion

All steaks had a normal pH (<5.8) independent of storage time or use of O_2 scavenger. Variations in pH after each storage period were explained mainly by the pH directly measured on the steaks. After 14 days, the steaks packaged with or without O_2 scavengers showed small pH variations (5.59-5.45 and 5.62-5.45). Initially, the microflora was composed of approximately 10^2 CFU/g of mesophiles and 10^4 CFU/g of aerobic and anaerobic psychrotrophic bacteria. After 14 days, all steaks with or without O_2 scavengers had comparable counts of aerobic and anaerobic bacteria (<10^6 CFU/g). The O_2 concentration in the masterpacks was dependent of use and type of O_2 scavengers (Table 1). It is obvious from the results that the O_2 residual in the masterpack may initially increase drastically after packaging. The O_2 concentration increased from 0.16% to 1.84% on the 1st day of storage in the masterpack with no O_2 scavenger, whereas in masterpacks with S_1 or S_2 scavengers types, O_2 increased to 2.31 and 1.46, respectively (Table 1). The inevitable increase of O_2 concentration shortly after masterpack sealing may be attributed to O_2 entrapment during evacuation either in the absorbent pad, at the corners of the tray, inside the expanded polystyrene tray, underneath the steaks or under the over-wrap film, and ingressing oxygen through the masterpack that had a measurable gas transmission. Oxygen concentration decreased continuously until 14 day in masterpacks without oxygen scavengers (1.59%) and with S_1 type (1,04%), and reached 0.01% in the masterpack containing S_2 scavenger type. In the present study, the redness a* was a good index of reblooming. After

1h of masterpack-opening, the a* values on steak surface from the masterpacks with S_2 scavenger type increased from a*=16.15 after 7 days to a*=21.18, after 14 days (Table 2). The steaks packaged with S_2 scavenger type showed the least discoloration (0-5%) and the highest red intensity (8.0), when compared to the steaks of masterpack containing S_1 type or no oxygen scavenger. The overall steak quality for product stored in the S_2 scavenger type was 4 (neither good nor poor) or 5 (good) after 7 days, and increased to 5 (good) or 6 (very good) for all steaks after 14 days. Scores of 1 (very poor) or 2 (poor) were recorded to overall steak quality for all steaks stored without oxygen scavengers or with S_1 type after 7 days or longer. These steaks had comparable brown areas and failed to bloom. The irreversible discoloration observed in those steaks was probably a result of excessive residual O_2 in those packs as compared to the product stored in masterpack with S_2 scavenger type.

Conclusions

The results indicated that the type and the reaction speed of O_2 scavengers will determine the capacity of scavenging activity that would be required to remove the oxygen at faster rate than can the meat itself. It is probable that the self-activating type of oxygen scavenging used in this study will prevent the metmyoglobin formation in beef steaks with higher colour stability, such as *Longissimus dorsi* stored under similar conditions for 14 days or longer. With about a dozen different oxygen scavenging systems in or near the commercial market, similar studies on the other types of scavengers and beef cuts must be executed to determine the practical applicability to extend the shelf life of fresh beef meat.

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Table 1 – Modified atmosphere inside masterpacks of beef steaks for up 2 weeks at 5 ± 1°C.

Storage time	Gas concentration (%v/v)					
	Control (C)		S_1		S_2	
	O_2	CO_2	O_2	CO_2	O_2	CO_2
0h	0.16	99.9	0.16	99.9	0.16	99.9
2.5h	0.53	99.9	1.33	99.9	-	-
22h	1.74	99.9	2.26	98.2	1.48	99.9
1 day	1.82	99.9	2.30	98.5	1.55	99.9
2 days	1.84	99.0	2.31	96.2	1.46	97.7
5 days	1.60	97.5	1.67	92.3	1.02	94.8
1 week	1.49	92.3	1.67	96.1	0.91	95.2
2 weeks	1.59	94.6	1.04	93.3	0.014	94.3

Table 2. Mean values for lightness (L*), redness (a*) and yellowness (b*) obtained from steak surfaces (GM), stored in masterpacks under a CO_2 atmosphere for up to 14 days at 4 + 1°C.

Sample	Colour evaluation					
	7 days			14 days		
	L*	a*	b*	L*	a*	b*
Control (C)	36.98^a	11.80^a	3.10^a	37.05a	9.23^a	7.27^a
S_1	38.02^a	11.00^a	5.02^a	36.95a	9.62^a	5.85^a
S_2	34.34^b	16.15^a	3.84^a	35.59b	21.18^b	8.36^a

^{a,b} Means within a column with no common superscript are significantly different (P<0.05)