Effect of packaging on the colour of beef with different α-tocopherol tissue levels

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***Abstract*— This study investigated the effects of tissue α-tocopherol levels on beef colour when using different packaging systems. Meat with four tissue levels of α-tocopherol (<3 μg·g meat^{-1} = low; 3 to 4 = low-medium; 4 to 5 = high-medium and >5 = high) was packaged using overwrap (OVER), modified atmosphere packaging - MAP, vacuum skin packaging with high barrier film – VSP and VSPMAP, a combination of modified atmosphere and oxygen permeable vacuum packaging. Retail attributes assessed by panelists (appearance, lean colour and % surface discolouration), as well as average red (R), green (G) and blue (B) values from digital images were measured over 18 days. A significant interaction (P<0.001) of α-tocopherol×day was found for R as well as a three-way α-tocopherol×day×packaging system interaction for G (P<0.001). Packaging x day interactions were significant (P<0.05) for all studied parameters. VSPMAP had the highest values for retail appearance desirability and showed no change in the % surface discolouration during the first 4 days of retail display, and VSP had better colour stability over time. Packaging type had a major effect compared to the α-tocopherol level in meat, which only showed effects when using high oxygen packaging combined with α-tocopherol concentrations greater than 4 μg·g meat^{-1}.**

***Keywords*— Beef, MAP, Vitamin E**

I. INTRODUCTION

At the retail level, most Canadian customers are influenced by meat freshness and colour [1]. In the mind of the average consumer about to purchase meat, colour becomes synonymous with fresh red meat quality [2]. Consequently, desirable colour must be maintained during retail display to prevent spoilage losses, estimated to cost the industry up to $1 billion each year in the United States, a loss of four to five percent of the wholesale price, while in Canada it is estimated at $200 million per year [3,4]. Beef colour is influenced by packaging system, namely overwrap, modified atmosphere packaging (MAP), as well as vacuum packaging systems. Oxidation of lipids has been linked to oxidation of pigments and meat discolouration [5,6]. The rate of discolouration of meat is believed to be related to the effectiveness of oxidation processes and enzymatic reducing systems in controlling metmyoglobin levels in meat [7]. The enhancement of antioxidant levels in meat may be accomplished by feeding vitamin E to livestock. Several researchers have found that vitamin E not only delays lipid oxidation in beef but also delays myoglobin (Mb) oxidation and, consequently, stabilizes the colour of the product in some selected packaging methods such as PVC-overwrap and vacuum packaging [8,9,10]. Thus, the present study aimed to evaluate the colour of steaks over time in simulated retail conditions when using vitamin E enriched beef packed using different systems: overwrapping packaging, case ready MAP, VSP and the combination of MAP and VSP.

II. MATERIAL AND METHODS

Meat from 48 feedlot steers, fed different vitamin E levels (340, 690, 1040 and 1,740 IU vitamin E·animal^{-1}·day^{-1}) during a 120 day finishing period was used in order to obtain a wide range of tissue α–tocopherol levels. After 24 h *post mortem*, the right *longissimus lumborum* (LL) muscle was collected. Fresh samples were analyzed for muscle α-tocopherol using normal phase HPLC with α-tocopherol acetate as an internal standard [11] adapted for fluorescence detection [12]. The remainder of the fresh muscle was vacuum packaged and aged for 21 days in a cooler at 2°C. Following ageing, the LL was cut into 2.54 cm thick steaks and packaged with a dri-loc pad as follows: 1) Control (OVER) – overwrapping packaging: steaks were placed on polystyrene trays and over-wrapped with oxygen permeable film (8000 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1}$); 2) Vacuum Skin Packaging (VSP): skin-packaging in polyethylene trays in an oxygen non-permeable/high barrier film (1 $cm^3 \cdot m^{-2} \cdot 24h$); 3) Modified Atmosphere Packaging (MAP): packaging in an 80:20 oxygen-carbon dioxide atmosphere on polyethylene trays, with a barrier film (<6.0 $cm^3 \cdot m^{-2} \cdot 24h$); 4) VSPMAP: vacuum skin packaging in an oxygen permeable film

(2000 $cm^3 \cdot m^{-2} \cdot 24h$) on polyethylene trays, filled with an 80:20 oxygen-carbon dioxide atmosphere with a barrier film (<6.0 $cm^3 \cdot m^{-2} \cdot 24h$). MAP, VSP and VSPMAP packaging methods were performed in a Multivac Tray Sealer T200 (Multivac, Germany). The samples were put into a fan assisted, horizontal (chest type) retail display case under fluorescent room lighting supplemented with incandescent lighting directly above the display case to provide an intensity of 1076 lux at the meat surface for 12 $h \cdot day^{-1}$ [13]. Average temperature in the retail display case was 3.5°C. Samples were evaluated every two days until the maximum time of 18 days.

On each testing day, steaks were subjectively evaluated by a trained 5-member sensory panel for retail appearance, lean colour and % surface discolouration using an 8-point hedonic (1=extremely undesirable and 8= extremely desirable), 8-point descriptive (1=white, 2=pale pink, 3=pink, 4=pale red, 5=bright cherry red, 6=slightly dark red, 7=moderately dark red and 8=extremely dark red) and 7-point descriptive (1=no surface discolouration and 7= complete surface discolouration) scale, respectively.

Evaluation of colour in MAP and VSPMAP packages by traditional methods using the *L*a*b** system provided by colorimeters and spectrophotometers was not suitable, since direct contact with the meat sample without compromising package integrity and atmosphere [14] was not possible. Hence, in this study, repeated images were captured as an alternative method [15] for measuring meat colour in the different packages. On each testing day, an image of each package was captured with a digital camera (Canon EOS Digital Rebel with a 28-105mm Canon Zoom EF lens, Canon Canada Inc., Mississauga, ON, Canada) fitted with a circular polarizer and standardized to an 18% grey card which was used as a reference for a white balance. Packages were illuminated at 45° with two pairs of incandescent lights fitted with linear polarizing film. To ensure consistent lighting, all other lights in the room were turned off while the pictures were taken. Average R, G and B (Red, Green and Blue respectively) were calculated by image processing for the entire surface of the steak. A change from the colour of the fully oxygenated steak surface constituted discolouration.

Data were analysed using the mixed model repeated measures procedure with compound symmetry (CS) covariance structure [17]. Individual animal nested in α-tocopherol level was included as the random effect and the effects of four different levels of tissue α-tocopherol and four different packaging systems and their interaction were included as fixed effects. Least square means separation for significant ($P \leq 0.05$) treatment and interaction effect differences were calculated by linear contrasts.

III. RESULTS AND DISCUSSION

In the present study, a packaging system by display day interaction ($P<0.001$) was found for all parameters. An α-tocopherol by display day interaction was also found for R ($P<0.001$) and a three-way interaction (packaging system x α-tocopherol x display day) was found for G ($P<0.001$). For the packaging system by display day interaction for retail appearance, OVER, MAP and VSP started at the same point and VSPMAP had the most desirable appearance at the beginning (day 0), but ended with the lowest score (Fig. 1).

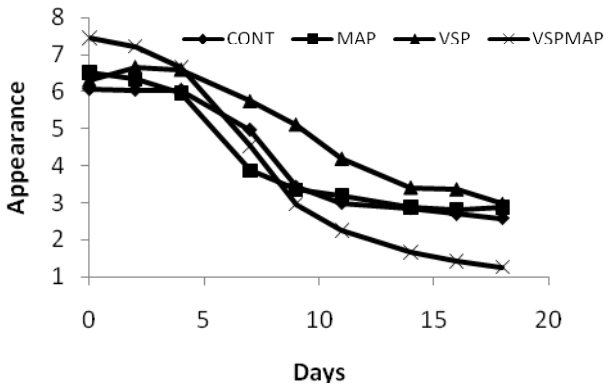

Fig. 1. Packaging×day interaction for beef appearance.

Lean colour scores ranged from 5=bright cherry red to 7=moderately dark red. Although lean meat colour changed during the trial, no sample showed complete surface discolouration. (Figure 2).

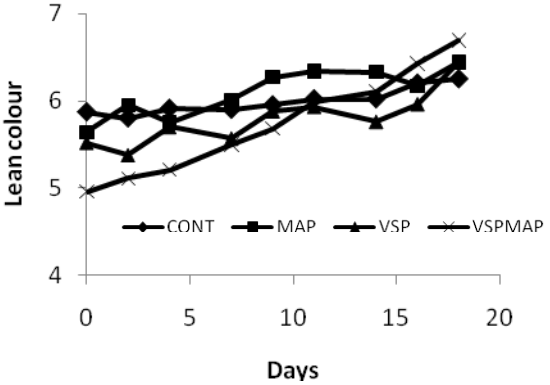

Fig. 2. Packaging×day interaction for beef lean colour

As expected, all samples started with no surface discolouration (Figure 3).

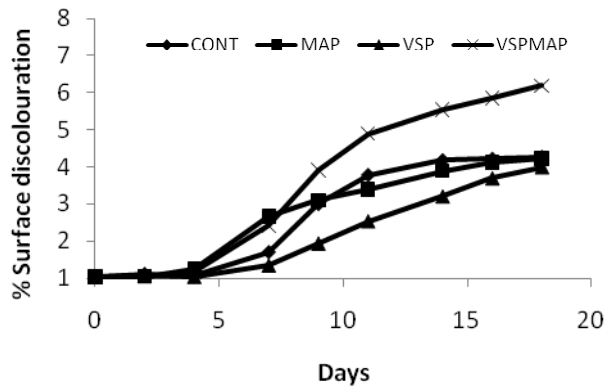

Fig. 3. Packaging×day interaction for beef % discolouration

The effects of packaging system over time on steak R, G, and B are shown in Figure 4. Over time, a decrease in R was observed for OVER, MAP and VSPMAP. The G when using VSPMAP and MAP increased slightly whereas when using OVER G remained relatively stable. There were small changes in B over time. The changes over time in RGB appeared to be related to a combination of the type of packaging material and the package atmosphere, as meat was exposed to oxygen in different conditions. For traditional retail display of fresh meat, high oxygen permeability is desired with oxygen transmission rates greater than 5000 $cm^3 \cdot m^{-2} \cdot 24h$ needed for oxygenation [19]. This permeability is achieved in OVER packaging, but not in VSPMAP.

The interaction of α-tocopherol with display day for R was due to a shift in R among the different levels of over time. Regarding to the three-way interaction for G, this may be explained by shifts between the extremes of in each packaging type over time (Figure 5).

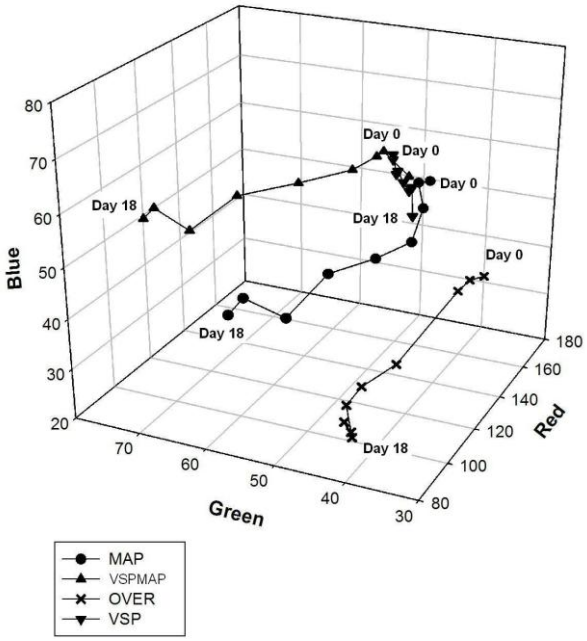

Fig. 4. Packaging x day interaction on average R,G, and B of imaged beef steaks over time

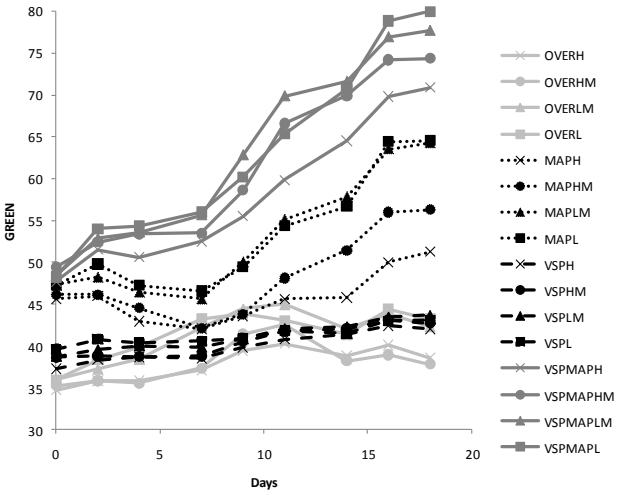

Fig. 5. Packaging×tocopherol×day interaction for G values

Higher average G always occurred at lower α-tocopherol levels. Sufficient levels of α-tocopherol should be present to delay lipid oxidation particularly in high-oxygen packaging methods [20]. In the present study, α-tocopherol levels did not appear to be high enough to delay pigment oxidation over the entire

studied time, although some positive effects in high-oxygen packaging methods were observed.

IV. CONCLUSIONS

Packaging type had more influence in this study than α-tocopherol levels in meat, although α-tocopherol levels greater than 4 μg·g meat^{-1} had a significant impact on G in MAP and VSPMAP packages. VSPMAP seems to be promising for short retail display, as it had the highest values for retail appearance desirability and the same % surface discolouration in the first 4 days of retail display. However, no further advantage was found after 8 days of ageing. VSP showed greater colour stability, but because of the purple colour, it is not acceptable for most North American consumers.

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