DARK CUTTING BEEF USING MODIFIED ATMOSPHERE PACKAGING (MAP)

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Dark-cutting beef colour is an important and old meat quality issue induced by numerous factors (Murray, 1989) such as: fluctuations or extreme weather conditions, gender, stress, management prior to slaughter, fighting, mounting to re-establish social hierarchy (Warriss et. al., 1984), and use of aggressive implantation (Scanga et. al., 1998). In Canada, between 1997 and 2002, approximately 20,000 to 25,000 head per year were classed as dark cutting (carcasses graded as B4), followed first by a steady increase to a peak of approximately 50,000 head by 2007, and then an immediate drop to a plateau of approximately 35,000 head which in 2010 represented 1.4% of total animals slaughtered (Canadian Beef Grading Agency Data, personal communication, 2013). Colour is the first criterion the consumer uses in the supermarket to evaluate meat quality (Cornforth, 1999) and may be argued to be the most determinant sensory attribute of meat because if colour is deemed unacceptable, the meat will not be purchased or eaten, and consequently, all other sensory attributes lose significance (Sanders *et al.*, 1997) and so economic losses are realized. Until recently, dark cutting beef carcasses were exported to the United States because they were discounted less heavily than in the Canadian grading system. However, changes have now prevented export so now domestic markets must be found for this meat.

In a desirable post-mortem process which produces 'normal' beef, anaerobic glycolysis converts muscle glycogen to lactic acid, lowering the initial muscle pH of ~7.0 to an ultimate meat pH (pHu) of 5.4-5.6. Dark cutting beef occurs in the pHu range of 6.0 to <7.0, which is a range up to five times wider than that of normal meat. As meat pHu increases, proteins are further from their iso-electric point (pH 5.3-5.5), and therefore better able to retain moisture, causing muscle fibres to be more tightly packed; more light is absorbed and is scattered less than from the more open surface of lower pHu meat (as cited by Bate-Smith, 1948; Seideman et. al., 1984) therefore giving rise to a darker colour (MacDougall & Rhodes, 1972). Although myoglobin concentration in dark cutting beef has been shown to be within the normal range (as cited by Lawrie, 1958), dark cutting meat does not bloom well. Egbert & Cornforth (1986) reported that the mitochondrial respiration rate, and therefore oxygen consumption rate, is higher in dark cutting than normal pH beef. Previously, Lawrie (1958) postulated that this could increase the concentration of deoxygenated myoglobin, thus resulting in darker meat colour. Apart from its altered appearance, the generally high pH of dark cutting meat enhances sensitivity to bacterial spoilage (Ingram, 1948; Newton & Gill, 1981). In the upper pH range of dark cutting beef, flavour is reduced (Dransfield, 1981) whereas in the lower pH range it can seem more tender and tends toward greater juiciness (Viljoen et. al., 2002).

Packaging of fresh red meat is carried out to avoid contamination, delay spoilage, permit some enzymatic activity to improve tenderness, reduce weight loss, and to ensure a cherry-red colour in red meats at retail or consumer level (Kerry et. al., 2006). With modified atmosphere packaging (MAP), in which the atmosphere within the package has direct contact with the meat and often has a high oxygen concentration, the shelf life of fresh red meat can be extended (Singh et. al., 2011) beyond that of meat wrapped in oxygen-permeable polychloroethene (also called polyvinyl chloride (PVC)). Vacuum packaging has been reported as the most effective in reducing microbial spoilage, maintaining redness and increasing lipid and protein stability during storage (Gómez & Lorenzo, 2012). Vacuum skin packaging (VSP) is another version of this when the 'skin' used is an oxygen-impermeable film. An upper packaging film is heated and dropped over the meat in a tray where it forms tightly around the contents and adheres to the tray when the vacuum is drawn. Alternately, oxygen-permeable film may be used to permit meat to bloom without compromising the tightness of fit of the packaging.

Research was undertaken to determine if one of the current common retail packaging methods known to be favourable for colour development in normal meat could also be suitable for colour development of borderline or dark cutting meat.

Methods

At 48 h post mortem a total of 33 normal (N), borderline (B) and dark cutting (D) left sides of youthful carcasses identified by pH (pH 5.4 to <5.65, 5.65 to <6.0, 6.0 to ≈ 6.4, respectively) and each with marbling level and yield equivalent to the Canada AA and Y1 categories were selected from a commercial beef grading line over 12 visits from mid-2011 to mid-2012. At 72 h post mortem, at the Lacombe Research Centre, Lacombe, Alberta, the grade site was re-faced and full blue tag grading performed. Meat was permitted to bloom for 20 min and objective colour recorded directly on the steak surface in triplicate then averaged (CIE L*a*b*, C* h; Minolta CR-300, illuminant C and 2° observer; Minolta Canada Inc., Mississauga, ON). Colour was also subjectively assessed and assigned a score between 1 and 8 based on the 1-7 Japanese colour scores for beef, but with an additional score of 8 for very dark meat. Carcass rib eyes and strip loins were removed, cut into 2.5 cm thick steaks, and a steak from each cut randomly assigned to one of four packaging treatments to provide duplicate packages within the side. Packaging treatments were: oxygen permeable overwrap (OVER), oxygen-permeable vacuum skin packaging (VSP), non-permeable or high barrier vacuum skin packaging (VSP-HB), or high oxygen modified atmosphere packaging (80% O_2:20% CO_2; 1 atm; MAP). Packages were monitored over 21 days of storage at 2°C under controlled lighting. Colour was recorded through digital images since the MAP treatment did not allow close contact with the meat. Images were captured under standardized conditions on alternate days and the average red (R), green (G), and blue (B) of each steak was calculated. Ideal meat colour was deemed to be the average of all N OVER samples on Day 1 of storage, and colour change (ΔE) over time was calculated in relation to this target colour:

$$\Delta E = \sqrt{(R_1\text{-}R_2)^2 + (G_1\text{-}G_2)^2 + (B_1\text{-}B_2)^2}$$

where R_1, G_1 and B_1 are the RGB values for the target colour, and R_2, G_2 and B_2 are the RGB values for the colour being compared to the target colour. ΔE is a measure of the magnitude of change, not of the direction of change. Images were also used for subjective assessment of discolouration and an estimate of the % steak area affected, made. Discolouration was defined as a change from sample starting colour, and therefore it applied both to localized and overall colour changes. One additional steak per carcass was weighed into an OVER package, stored with the rest of the packages for 5d, then weighed back for calculation of drip loss.

Results & Discussion

Carcasses were successfully chosen to meet selection specifications (Table 1). Dark cutting meat was deliberately chosen to fall in the bottom of the pH range for dark cutters.

Within N OVER samples, ΔE from the average colour of N OVER on Day 1 was as high as 31, indicating a wide range of acceptable colour, however, statistically meat colour was found to differ from the target colour (black dot in Fig 1) when a ΔE of 22 was reached ($P \leq 0.0001$; solid line in each graph of Fig. 1). Humans are able to distinguish a ΔE of 1 unit when colours are adjacent to one another, however, if colours are separated by time and space they will still be identified as similar even if they differ by up to 10 units (dotted line, Fig 1). The colour of N meat was statistically similar to the target colour for up to 5d when packaged under OVER, for 3d when under MAP, and for less than 3d under VSP. The average colour of N these meats in three treatments changed at similar rates as is evidenced by the similar slope of the line over time. The VSP-HB treatment, which is equivalent to vacuum packaging, of N meat had a ΔE of approximately 49 on Day 1 and was maintained over the full storage period. The colour of both B and D meat under OVER, VSP and VSP-HB was significantly different from the target colour at all points in the study. The colour of B OVER slowly diverged from the target colour while the colour of D VSP slowly approached it. Under MAP, B samples were not significantly different from the target colour for 11 d, whereas D meat remained close to similar to the target colour for the full 21 d of the study at 2°C. Pictorial representation of typical meat samples in each pH range, their packaged colour and colour change over time is in Figure 2.

The percent of the meat surface showing discolouration under oxygenated conditions occurred for N meat after 3, 1, and 9 d under OVER, VSP, MAP respectively (Figure 3), and for B meat after 5, 5, and 13 d respectively. Discolouration of D meat occurred in OVER and MAP after 15 and 17 d, respectively, while no discolouration was recorded for VSP. No discolouration was observed for the anoxic VSP-HB treatment for any meat type.

Three to 5 days is the generally accepted appearance-based shelf-life of normal beef displayed for retail sale, and was also seen in this study. Based on appearance only, the MAP treatment showed excellent promise for altering the colour of both B meat and of D meat in its lower pHu range to a colour similar to freshly cut N meat with a favourable appearance maintained for up to 11 d for the former, and 21 d for the latter. Although the colour was perceptibly different from N OVER on Day 1, the appearance may be similar enough to be considered desirable by the consumer if not displayed adjacent to N meat.

These results are very promising, however before adoption of the packaging treatment for D meat, the effect of storage temperature, the ultimate eating quality of the meat, and the propensity for microbial growth in an enriched oxygen atmosphere must also be considered. Storage temperatures have a strong detrimental effect on the keeping qualities of meat, and an increase of as little as 2° C could appreciably decrease the appearance shelf lives realized in this study. Borderline meat has recently been shown to be significantly tougher than either N or D meat (Holdstock *et al.*, 2013, submitted), and so on that account may not be desirable for retail sale. Storage of N meat under MAP has reportedly increased toughness and warmed over flavour (Clausen *et al.*, 2009). If this also occurs for D meat, possibly its inherent tenderness would provide a counterbalance for a net toughening of zero in relation to normal meat. Highly marbled meat in high oxygen MAP may develop off-flavours more rapidly under high oxygen conditions than meat with lower levels of marbling. Finally, the microbiological safeness must be determined for high pH meat in a high oxygen environment for extended periods.

Conclusions

The appearance of both borderline and a narrow pH range of dark cutting beef were successfully favourably altered using a commonly existing 80% O_2:20% CO_2 MAP packaging method and appearance shelf life extended beyond that of normal beef. Future research must include determining the applicability of the method to the full pH range of dark cutting beef, the microbiological safety at extended storage times, and the eating quality.

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Table 1. Descriptive statistics of carcass and meat characteristics. (Mean ± SD)

	Normal	Borderline	Dark	P
	n=11	n=12	n=10	
Trimmed loin wt (kg)	7.3 ± 2.00	7.2 ± 1.03	6.9 ± 1.48	0.8501
Grade fat thickness (mm)	6.5 ± 1.75	7.0 ± 2.13	6.2 ± 2.04	0.6275
USDA Marbling score[1]	343 ± 53	354 ± 35	357 ± 39	0.7153
Carcass pHu	5.54^{a} ± 0.05	5.81^{b} ± 0.10	6.23^{c} ± 0.17	<0.0001
CIE L* a* b* recorded before packaging				
L*	38.0^{a}± 3.28	31.7^{b} ± 1.60	31.6^{b} ± 1.64	<0.0001
a*	18.1^{a} ± 1.73	13.9^{b} ± 1.83	12.1^{c}± 1.85	<0.0001
b*	12.6^{a} ± 1.52	8.4^{b} ± 1.06	7.4^{b} ± 0.95	<0.0001
JMGA beef colour score[2]	4.3^{b} ± 0.36	6.8^{a} ± 0.35	7.6^{a} ± 0.38	<0.0001
5d retail drip loss (%)	3.95^{a} ± 0.83	2.11^{b} ± 0.81	1.53^{b} ± 0.47	<0.0001

[1] Small (Sm^{0}) = 400 USDA.
[a,b,c] Differing superscripts within a row indicate significant difference
[2] JMGA: Japanese subjective colour; 1 = pale 7 = dark. In-house addition of one dark category for very dark meat

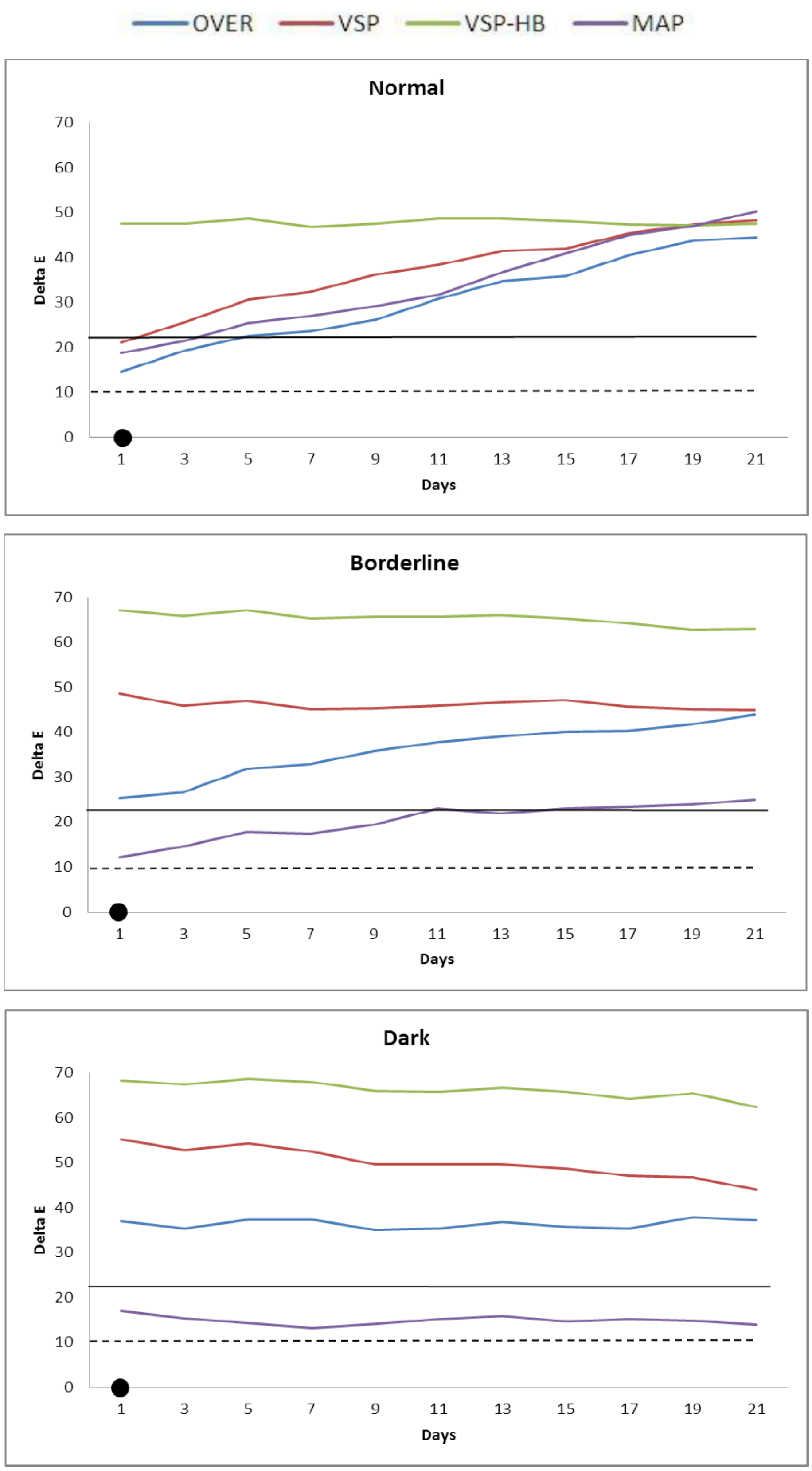

Figure 1. Mean colour change over time in relation to the average colour of normal overwrapped meat on Day 1 of storage (black dot) at 2°C, by meat type. Above solid black line: mathematically significantly different from N OVER D1 ($P < 0.0001$). Above dotted black line: colours seen to be similar by human vision when separated by time and space. OVER: oxygen-permeable overwrap; VSP: oxygen permeable vacuum skin packaging; VSP-HB: high barrier (oxygen impermeable) vacuum skin packaging; MAP: modified atmosphere packaging - 80% O_2: 20% CO_2

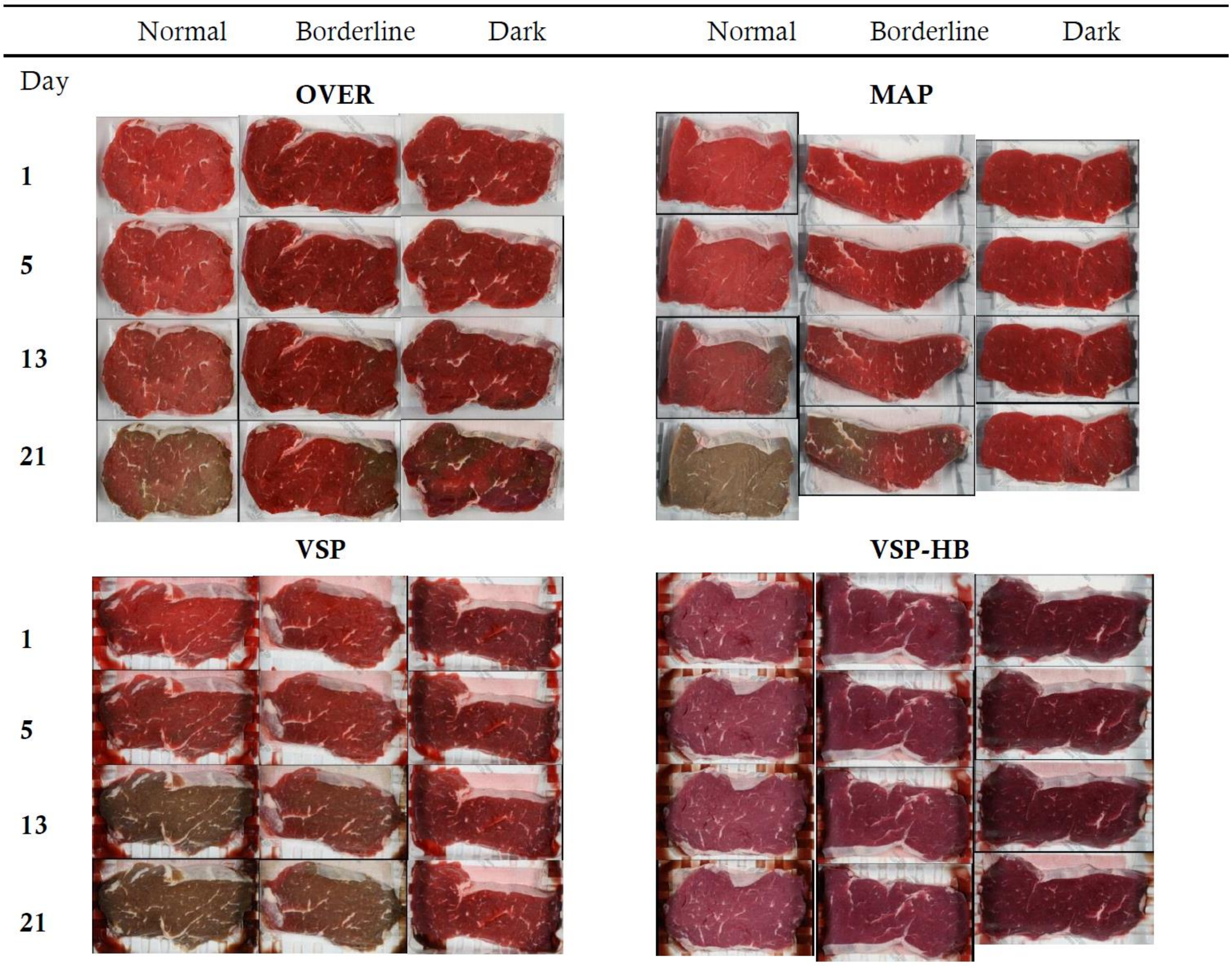

Figure 2. Pictorial representation of meat colour on days 1, 5, 13, and 21 of storage at 2°C. OVER: oxygen-permeable overwrap; VSP: oxygen permeable vacuum skin packaging; VSP-HB: high barrier (oxygen impermeable) vacuum skin packaging; MAP: modified atmosphere packaging - 80% O2: 20% CO2

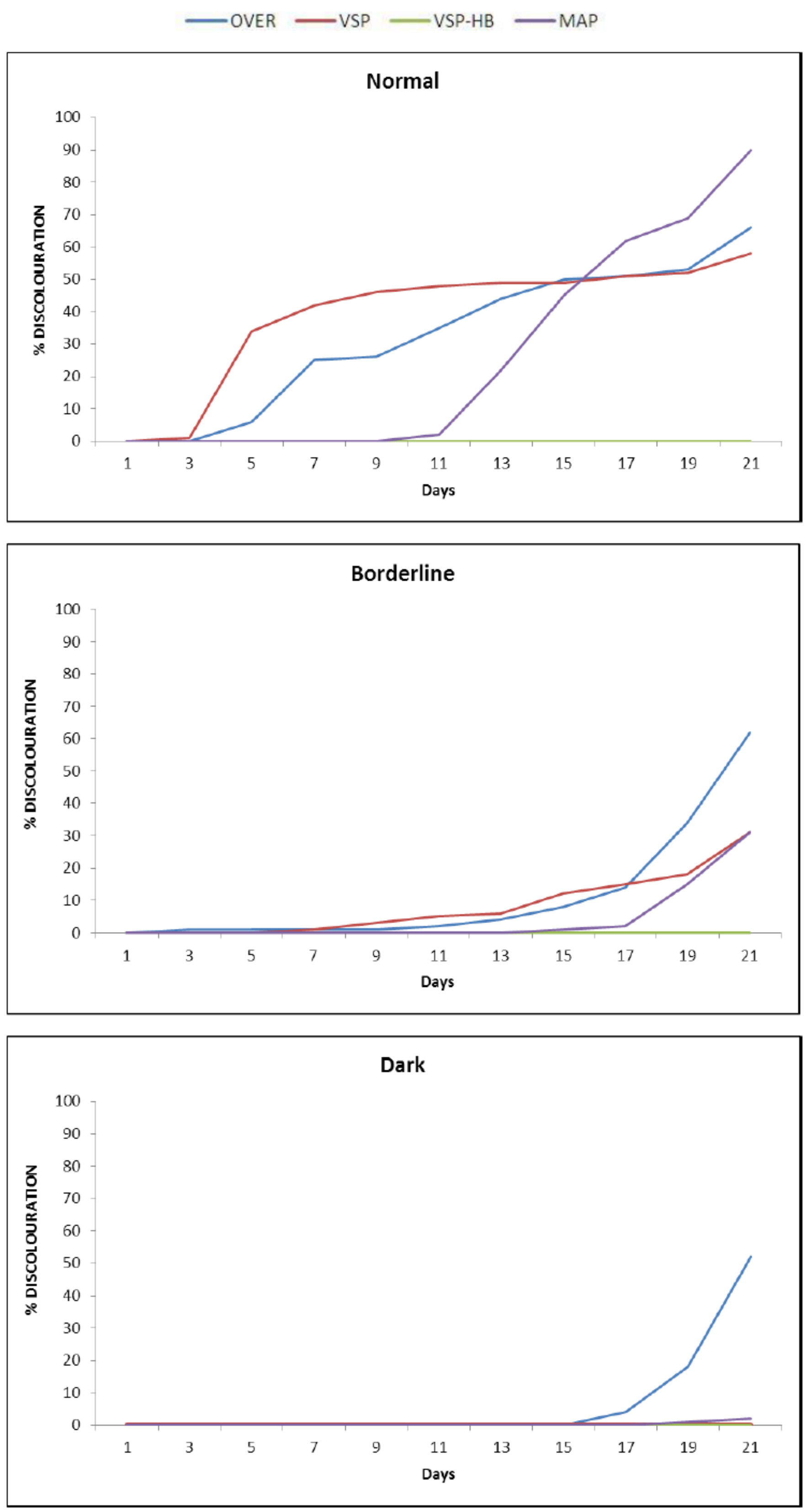

Figure 3. Subjectively assessed mean percentage area meat discoloured over time, by meat type under four packaging conditions at 2°C. OVER: oxygen-permeable overwrap; VSP: oxygen permeable vacuum skin packaging; VSP-HB: high barrier (oxygen impermeable) vacuum skin packaging; MAP: modified atmosphere packaging - 80% O_2: 20% CO_2