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COLOUR STABILITY OF VACUUM SKIN PACKED FROZEN BEEF

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INTRODUCTION

Current commercial interest in prolonging the attractive appearance of packaged fresh meat cuts to allow their centralised preparation has concentrated on the use of modified gas atmospheres to achieve good colour and microbiological stability. Greater stability can be achieved with meat which is frozen but, hitherto, poor appearance has limited retailing largely to specialised freezer outlets. The attractive red colour of meat is due to oxymyglobin, the oxygenated form of the muscl pigment and, in frozen meat, this is stable only in the dark. In presence of light, the pigment is oxidised to metmyoglobin, which is brown and much less attractive to the consumer.

Several studies have investigated the colour changes in frozen meat held under different conditions (Sandberg, 1970; Santamaria, 1970; Lentz, 1971; 1979; Tuma et al., 1973; MacDougall, 1974; Kropf, 1980; 1982;). They have established, in general, that the rate of colour deterioration is affected by muscle type, is less at lower frozen temperatures, and is increased by more intensive illumination. Tuma et al (1973) recommended that, for reasonable display life, illumination should be no higher than 1000 lux, but even with these conditions at -18^{o}C, Lentz (1971) found appreciable changes in colour after 1-3 days and pronounced changes by two weeks.

In recent years the packaging of frozen meat has improved greatly, mainly with the introduction of vacuum skin packing with Surlyn (Du Pont) films. These moderately gas-permeable films are applied in such a way that they form a skin tight package which prevents internal frosting and allows presentation of frozen meat in the red oxygenated state. As long as the meat has been allowed to

oxygenate sufficiently before freezing, its colour resembles that of overwrapped chilled meat. However, the necessary presence of oxygen in the meat surface also means that it is susceptible to light-induced discolouration.

Exploratory trials with vacuum skin packed frozen meat have confirmed that the rate of discolouration is related to illumination level (MacDougall, 1982). They have also indicated that it varies with different muscles and may be affected by exposure time before freezing and oxygen availability. This study was designed to evaluate the colour changes during simulated commercial display of skin packed frozen sirloin and rump steaks which had been exposed to air or oxygen for different periods before freezing.

EXPERIMENTAL

Material

Striploin (M. longissimus dorsi) and rump (M. gluteus medius) primal joints were removed from coventionally slaughtered and chilled Hereford x Friesian steers and vacuum packed in Cryovac BB1 bags (W.R. Grace). After 10 days' storage at 1°C the packs were opened and 20mm thick steaks cut from each joint and exposed to either air or pure oxygen for 0.5, 1, 2, 4 and 24h before being blast-frozen for 20 min in air at -40°C.

The crust-frozen steaks were then vacuum skin packed on a Parnavac Model VFM 1 Skin Packer (EDL, Farnborough) using 75u Surlyn Film with an oxygen permeability of 950 $cm^3 \cdot m^{-2} \cdot day^{-1} \cdot atm.O_2$ at 25°C. All samples were then frozen completely and stored in the dark at -20°C for 5 days before display.

Display

The skin packed steaks were displayed in a domestic deep-freeze cabinet running at -18°C with an illumination level of 1000 lux (Natural, Atlas) to simulate retailing conditions.

Assessment

Colour was measured with a Hunter D25D2 Colour Difference Meter. No sample was removed from the display case for longer than three minutes, and care was taken to avoid frosting of the surface during measurement. The colour space used was Hunter L, a, b. Saturation, S, is a measure of colour intensity or colourfulness, and is calculated: $S = (a^2 + b^2)^{\frac{1}{2}}$. It is a uniform scale and appropriate for reporting the results of this study.

As the samples were measured instrumentally, they were also visually assessed on a scale from 'very bright red' (RR) through 'red' (R), 'brownish-red' (bR), 'brown-red' (BR), 'reddish-brown' (rB), 'brown' (B) to 'greenish brown' (gB). In the daylight viewing conditions used, S >20 was judged as 'red' and S <16 as 'brown'.

RESULTS

Effect of air or oxygen exposure on initial colour

Initial redness of the steaks before freezing increased with exposure to air. There was no measurable loss of redness during 5 days dark frozen storage, so that before display, saturation (S) ranged from 18 to 22 for both LD and GM which had been exposed for up to 4 hours (Table 1). The value S = 18 for zero exposure is higher than that of a freshly cut meat surface because some oxygenation and reddening of the surface had occurred during crust freezing. Longer exposure to air for a total of 24h increased S by more than 2 units as the oxymyoglobin layer thickened. The colour of frozen meat exposed for 1 hour was similar to that of unfrozen.

The effect of oxygen exposure on initial colour was similar to that of air for short exposure times (Table 2), but 4h to 24h oxygen treatment produced a layer of oxymyoglobin more than 5mm thick and was described as 'very bright red' (RR).

Loss of redness during display

The relative effects of air or oxygen pre-treatment coupled with the slow (LD) and fast (GM) oxidative muscle types, on the decrease in S during illuminated display can be seen in Tables 1 and 2. An S value of 20 can be considered as the visual limit between red and the start of discernible brown (bR) when assessment is carried out in overcast daylight. Red-enhancing fluorescent tubes, typical of these employed for displaying meat, improve redness by at least 2 saturation units. When viewed under typical retail display conditions therefore, an S value of 18 might be considered as the point on which brown just becomes discernible in frozen meat.

Prolonging redness by oxygen treatment was most effective for LD exposed for more than 4 hours. The effect of prolonged treatment with air or oxygen was different for the 2 muscles, the GM fading much more quickly than the LD. Two hours' exposure to air extended colour stability of the LD from 2 days to at least a week, whereas the GM showed no improvedment even with 24 hours' treatment. The effect of oxygen was similar, but more consistent, with meat exposed for up to 2 hours. Longer exposure, however, gave a marked extension with the LD, at least 3 weeks from 4 hours' treatment; again the GM was less stable, requiring 24 hours' treatment with oxygen to reach 1 week.

Just as a saturation value of 20 indicates the first signs of brown in meat viewed in daylight, a value of 16 can be considered the point at which the meat is predominantly brown with only a slight amount of red remaining (rB). At this level of saturation, colour is not enhanced by illumination, and therefore, for comparative purposes, a value of 16 can be regarded as the limit of acceptability. Colour deteriorated to this stage most rapidly with the air treated GM steaks, most reaching S ≤ 16 in 3 to 7 days, with the longer exposed samples paradoxically becoming completely brown first. The air treated LD was more stable with no values below 16 until after 2 weeks. Oxygen treatment delayed S < 16 for 10 days for the GM and throughout the period of the experiment for the LD.

TABLE 1

Colour saturation (S) during illuminated display at -18°C of frozen skin packed sirloin and rump steaks, exposed to air for different periods before freezing.

		Days Displayed								
	Pre-freezing exposure (h)	Initial	1	2	4	7	10	14	21	28
		Saturation (S)								
Sirloin (LD)	0	18	18	18	17	17	17	17	17	16
	0.5	20	21	18	17	18	18	17	17	16
	1	21	19	18	16	16	17	15	14	14
	2	24	23	21	19	19	18	18	17	17
	4	22	22	19	16	16	17	15	15	15
	24	24	25	23	19	20	19	18	18	17
Rump (GM)	0	18	17	17	16	17	17	16	15	15
	0.5	22	18	16	15	15	16	16	14	14
	1	21	18	16	16	16	16	15	14	14
	2	19	17	14	14	14	14	14	13	13
	4	22	17	16	14	15	15	15	14	13
	24	26	18	16	15	15	15	15	13	13

TABLE 2

Colour saturation (S) during illuminated display at -18°C of frozen skin packed sirloin and rump steaks exposed to oxygen for different periods before freezing.

	Pre-freezing exposure (h)	Days Displayed: Initial	1	2	4	7	10	14	21	28
		Saturation (S)								
Sirloin	0.5	23	20	19	17	17	17	17	16	16
	1	22	24	22	18	17	17	17	17	17
	2	22	24	24	22	18	17	17	16	17
	4	25	25	25	24	24	23	20	19	18
	24	24	24	25	24	24	23	23	21	18
Rump	0.5	23	17	16	16	16	16	16	15	14
	1	24	18	16	16	16	16	15	14	14
	2	24	20	18	16	16	16	14	13	12
	4	27	23	19	17	17	16	16	15	15
	24	24	26	26	23	20	19	18	17	16

DISCUSSION

Correctly packaged frozen meat can be stored in the dark for up to 3 months with negligible colour deterioration, but its attractive appearance is quickly lost when exposed to light, as in display. Depending on illumination level and muscle type, unsightly surface discolouration can develop within a few days with pre-packed frozen beef (MacDougall, 1982). However, Lentz (1979) reported that colour shelf-life of meat stored at -40°C was unaffected by light levels below 2000 lux but, at -7° to -18°C with 500 to 1000 lux, life is no more than 1 to 3 days. In our experiment, LD exposed to air for minimum time to oxygenate before freezing had a discernible colour difference after 3 days display at 1000 lux.

Oxygen treatment improved initial colour saturation and delayed onset of visual brown, especially with exposure beyond 4 hours. The most stable sample was LD which had been exposed longest in oxygen, but even with 24 hours treatment, the GM was still more susceptible to oxidation. Oxygen treatment might appear attractive to the frozen food packer, but there are drawbacks in addition to the prolonged time required to produce the thick oxygenated layer on the meat surface. Although the surface of the LD remained red for > 4 weeks, this was only in the outer 2mm. The underlying 5mm thick oxygenated layer became dark brown during this period. Consequently, the most stable surface colour from the longest oxygen exposure produced potentially the brownest colour, especially if the meat is thawed prior to cooking. This raises the question of mechanism of metmyoglobin formation during display. Clearly, high oxygen tension in the surface following long exposure to oxygen, with continuing replenishment from air through the packaging film, produces an oxidation resistant layer, but at the lower oxygen tension in the meat interior, complete oxidation occurs, with or without light. Presumably, an auto-catalytic process, unaffected by light, is involved in the region furthest from the surface.

Nevertheless, skin-packed frozen meat, even with minimal exposure to air before freezing has an initial appearance equivalent to fresh chilled meat. If the consumer would accept an attractive frozen product sold in an opaque package, then the industry could guarantee a bright red appearance for up to 3 months. Alternatively, skin-packed frozen meat would not be rejected on the basis of colour where turnover was rapid as with chilled meat i.e. 1 to 2 days. In this case, however, rotation of stock would be important since different cuts would discolour at different rates. Although skin packing can give frozen meat a period of attractive display similar to that for conventionally overwrapped chilled meat, this is a shorter time than can be achieved with modified atmosphere packing in mixtures of carbon dioxide and oxygen where, at a temperature of 1°C, the meat surface retains its bright-red colour for a week after packing (Taylor & MacDougall, 1973). The advantage of vacuum skin-packed frozen meat must therefore lie in its long-term colour stability in

dark storage before open attractive display.

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