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The effect of pH on colour and drip loss of lamb chops thawed in air and CO_2

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ABSTRACT

Frozen loins with ultimate pH values between 5.7 and 6.7 were obtained from lambs which had received multiple stresses. Loins were cut into chops and objective colour measurements obtained from the surface of the chops while frozen and after overnight thawing in either air or a CO_2 atmosphere. With frozen chops objective colour measurements showed no change with pH. The thawed chops were darker in colour, but redder than frozen chops. For thawed chops, L, a, b values and calculated values of colour saturation and oxymyoglobin decreased as pH increased. Air-thawed chops tended to show greater decreases than chops thawed under carbon dioxide.

The percentage drip lost on thawing decreased with increasing pH and was on average greater in CO_2 thawed chops than air thawed. The water holding capacity of the thawed chops increased as the pH increased, regardless of thawing method.

The pH of chops decreased on thawing by 0.1 to 0.4, and the decrease was greater in the chops of higher ultimate pH.

Keywords Lamb; frozen; thawing; pH; CO_2; colour; drip loss

INTRODUCTION

Frozen lamb does not compete well in the supermarket with the fresh local product, even though frozen lamb can be of excellent quality. Some New Zealand lamb is shipped fresh, using vacuum packaging or more recently packaging in CO_2 (Gill, 1986). Chilled shipment, however, is expensive, and temperature control must be very precise to achieve the desired results; in the commercial situation such fine control is difficult to achieve.

Much of New Zealand's lamb, although shipped to markets as frozen carcasses or primal cuts, is sold through retail butchery outlets as thawed product. The procedures used by retail butchers are not as easily managed under supermarket operations. However, if frozen lamb cuts could be thawed and packaged for supermarket operations, New Zealand lamb might compete more favourably with local product.

Previous studies have shown that the colour of chilled lamb cuts stored in CO_2 is excellent on blooming. Metmyoglobin formation, which detracts from the colour should not begin in such lamb until the thawed meat is removed from the CO_2 atmosphere. This delay in metmyoglobin formation of CO_2 thawed meat, compared with air-thawed meats, should improve colour and prolong the display life.

The pH of meat generally influences its colour, but dark cutting meat has not been observed in frozen lamb with a high ultimate pH. The effect of pH on the colour of thawed lamb was of interest, as was the influence of CO_2 during thawing. The effect of thawing lamb chops having ultimate frozen pH values between 5.7 and 6.7 in air or CO_2 was examined.

MATERIALS AND METHODS

Meat

Lambs were subjected to multiple stressors, which had the effect of raising the ultimate pH by various amounts (Bray *et al.*, 1989). The animals were slaughtered in an export meat plant, and the carcasses were electrically stimulated and held in a chiller for 7 hours before freezing. The frozen loins were removed, transported frozen to the laboratory, and stored at -20°C for 4 weeks.

Cutting, Packaging, Thawing

Two 25 mm chops were cut from each loin. The chops were weighed, overwrapped in oxygen permeable cling film (Glad Wrap, Union Carbide, New Zealand) and immediately presented for colour measurements. Chops were kept at -20°C.

The cling film wrapped chops assigned to the CO_2 thaw treatment were further packaged in aluminium foil laminate bags of immeasurably low oxygen permeability (Wrightcell, Fielding, New Zealand). The foil bags were evacuated, then inflated with 2 l of CO_2 per kg of meat following the method of Gill (1986). Both sets of chops were held at 1°C for 16 hr to thaw.

Drip and Water Holding Capacity

Drip (% weight lost on thawing) was determined by weighing unwrapped chops while frozen and after thawing. Thawed chops were blotted lightly with a paper towel before being weighed.

The percent free water was measured by removing a small weighed sample (about 400 mg) of meat from the interior of each thawed chop after colour determinations had been made. This was placed on filter paper, pressed between two perspex plates following the method of Grau and Hamm (1953) and the % free water expressed was calculated. The water holding capacity is inversely related to the amount of free water expressed.

pH Measurements

The pH was determined on a small sliver of about 1 g of *longissimus dorsi* (*l.d.*) muscle from each freshly cut frozen chop and a 1 g cube from the interior of the thawed chop. These were homogenised in 10 ml of 5 mM sodium iodoacetate solution, pH 7.0, and equilibrated to 15°C before measurement with a pH meter.

Colour Measurements

Hunter *L, a, b* values and reflectance spectra for each frozen and thawed chop were measured with a Gardner Spectrogard reflectance spectrophotometer. Measurements were made through the cling film. *L* measures the brightness of the chops, a the redness, and b the yellowness. Hue (*f/b*) and saturation of colour ($a^2 + b^2$) were also calculated. From the reflectance curves, myoglobin, oxymyoglobin, and metmyoglobin were estimated by the method of Claus *et al.* (1984).

Statistical Analysis

An analysis of variance was performed on the data to determine significant effects. The interaction of pH and values from the spectral curves were analysed for linear or quadratic components.

RESULTS

TABLE 1 Drip (% weight loss) and percent free water of lamb chops thawed overnight in air or CO_2 at 1°C.

Frozen pH	No. of carcasses	% Weight lost on thawing in Air	% Weight lost on thawing in CO_2	% Free water on thawing in Air	% Free water on thawing in CO_2
5.7	3	4.53	4.85	27.0	30.8
5.8	8	3.22	4.30	30.6	32.0
5.9	7	4.10	4.12	31.4	31.2
6.0	4	3.57	3.02	28.4	32.1
6.1	3	2.54	6.25	32.1	30.3
6.2	7	3.32	3.46	27.0	30.2
6.3	4	2.65	3.86	31.7	26.2
6.4	7	2.59	3.69	24.6	26.8
6.5	1	1.41	1.07	23.2	31.2
6.6	2	4.54	2.57	24.4	27.7
6.7	2	1.76	2.45	24.2	24.0
Effects of:					
pH		**		***	
Thawing		**		NS	
pH x thawing		**		*	
SEM		0.462		1.250	

SEM = Standard error of the mean

Drip and Water Holding Capacity

When chops were thawed, the drip decreased linearly as the muscle pH increased in both air-thawed and CO_2-thawed chops ($P<0.01$, Table 1). Chops thawed in CO_2 had a greater mean drip than those thawed in air (CO_2 = 3.86%; air = 3.25%, $P<0.01$). A significant pH x thawing treatment interaction ($P<0.01$) was also found.

The % free water decreased (i.e., the water holding capacity increased) linearly as pH increased ($P<0.001$) and this relationship was independent of the thawing method (Table 1).

TABLE 2 Summary of significant effects on objective colour measurements.

	pH	Effect of Thawing method	pH x Thawing method	SEM
Myoglobin				
Frozen	NS	NS	NS	0.021
Thawed	NS	***	*	0.019
Difference[1]	NS	*	NS	0.037
Oxymyoglobin				
Frozen	NS	NS	**	1.063
Thawed	*	NS	NS	1.214
Difference[1]	**	NS	NS	1.600
Metmyoglobin				
Frozen	NS	NS	NS	0.086
Thawed	NS	NS	NS	0.135
Difference[1]	NS	NS	NS	0.135
L				
Frozen	NS	NS	NS	1.351
Thawed	*	NS	NS	0.757
Difference[1]	NS	NS	NS	1.666
a				
Frozen	NS	NS	NS	0.636
Thawed	***	**	**	0.476
Difference[1]	NS	*	*	1.074
b				
Frozen	NS	NS	NS	0.455
Thawed	***	*	NS	0.304
Difference[1]	**	NS	NS	0.609
Hue (a/b)				
Frozen	NS	NS	NS	0.057
Thawed	NS	NS	***	0.046
Difference[1]	NS	*	**	0.078
Saturation $\sqrt{(a^2 + b^2)}$				
Frozen	NS	NS	NS	0.743
Thawed	***	**	**	0.521
Difference[1]	**	*	*	1.211

[1] Difference between values for the frozen and thawed chop.

Colour Characteristics

For convenience the significance levels obtained from the analysis of variance of myoglobin, oxymyoglobin, *L, a, b,* hue, and saturation data are given in Table 2.

Because the two frozen chops from each carcass were not significantly different for any characteristic, values for the two frozen samples were averaged to give one curve relating pH and colour characteristics for frozen chops in Fig. 1. Curves relating colour characteristics and pH of chops thawed in air and thawed in CO_2 are presented separately.

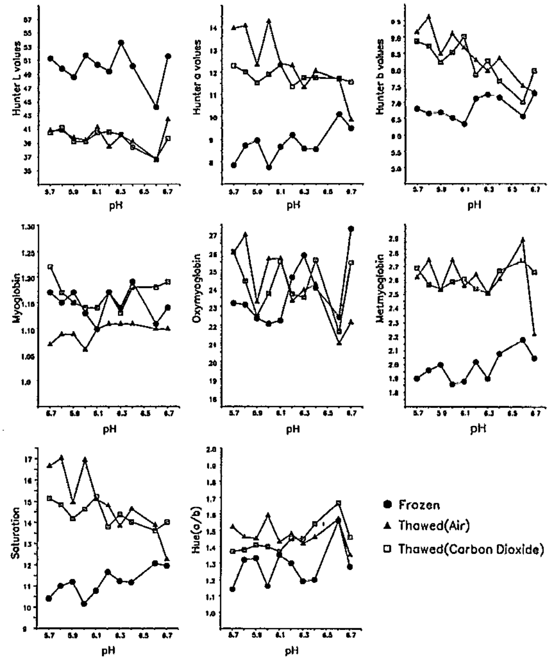

FIG. 1 Changes in objective colour measures due to ultimate pH in frozen and thawed lamb.

Myoglobin, Oxymyoglobin and Metmyoglobin

The values of myoglobin and oxymyoglobin and metmyoglobin on the meat surface were determined from the spectral curves and are presented in Figure 1. In frozen or thawed samples, myoglobin values varied only slightly, but values tended to be lower for the air-thawed chops. Meat pH had no effect on myoglobin values, but thawing method ($P<0.001$) did. Oxymyoglobin values decreased in thawed samples as the pH increased ($P<0.05$). The decrease occurred regardless of thawing method. Metmyoglobin values were lower in frozen chops compared with thawed chops ($P<0.01$), and did not change significantly with pH or thawing method.

Hunter *L, a, b,* Hue, and Colour Saturation

Hunter L values, which measure the lightness-darkness component of colour, were not affected by pH when the chops were frozen, but they decreased linearly with increasing pH in thawed samples ($P<0.05$) regardless of thawing method.

Hunter a values (redness) of frozen chops were not affected by pH (Fig. 1), but in thawed chops, they decreased linearly as pH increased ($P<0.001$). Hunter a values were significantly higher for air thawed samples ($P<0.001$). The rate of decrease in a due to pH was greater in air thawed samples than in CO_2 thawed samples ($P<0.01$) due to the higher values of a at the lower pH values. From pH 6.1 upwards, the a values of air-thawed and CO_2-thawed samples were similar.

Hunter b values (yellowness) shown in Figure 1 decreased in thawed chops as pH increased ($P<0.001$). On average chops thawed in air had higher b values than those thawed in CO_2.

Saturation of colour of frozen chops was unchanged over the pH range investigated, but saturation of colour of thawed chops decreased linearly with increasing pH ($P<0.001$). Chops thawed in air were more saturated in colour than those thawed in CO_2 ($P<0.01$). The significant

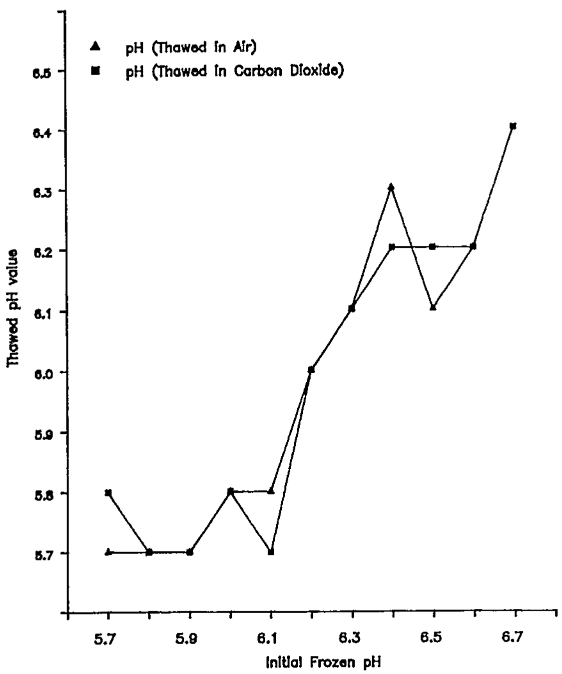

FIG. 2 Relationship of pH of thawed chops to their pH in the frozen state.

pH by thawing method interaction ($P<0.01$) is due to the greater difference in saturation between air-thawed and CO_2-thawed chops at lower pH than at higher pH values.

Hue (*a*/*b*) was not affected by either pH or thawing method. A highly significance thawing x pH interaction was due to the crossover between pH 6.1 and 6.3.

pH

The pH decreased with thawing ($P<0.01$) (Fig. 2). The decrease in pH from the frozen to the thawed state ranged from 0.1 at the lower pH range (<5.8) and 0.3 at the higher levels (>pH 6.5).

DISCUSSION

An increase in muscle pH is associated with a decrease in drip (Sair and Cook, 1938). The pH of rigor meat can be changed by injection of solutions such as ammonia or lactic acid into the muscle (Sair and Cook, 1938) or pH can be influenced by more natural means associated with animal stress, as in the present experiment. In the present study, not only did increased pH result in reduced drip during thawing, but also drip in chops thawed in CO_2 was slightly greater than that of chops thawed in air. The present study did not resolve whether this difference was due the CO_2 environment acting on the meat tissues to reduce pH slightly. The water that could be pressed from the thawed meat also decreased at higher pH values, consistent with the view that high pH meat has an increased water holding capacity.

A decrease in pH during thawing has not been reported consistently with lamb at low ultimate pH, and a decrease of 0.1 could be due to experimental error in measurement at different time periods. Decreases of 0.2, however, are not likely to be due to experimental error. In the present study the *l.d.* had reached its ultimate pH before freezing. The fact that the decrease in pH occurred with chops in air or CO_2 indicates that the phenomenon is anaerobic, suggesting further breakdown of glycogen.

In a commercial sense, thawing will give a more uniform product as regards pH. Most New

Zealand lamb is below 6.0 (Petersen, 1983), and lamb with even this marginally high pH would be 5.8 when thawed, no longer high pH meat.

As the ultimate pH increased, the oxymyoglobin at the surface of thawed chops tended to decrease, a trend which was paralleled by a decrease in Hunter a values (redness) and Hunter b values (yellowness). Lightness (Hunter L values) and saturation decreased also, consistent with the darker colour of high pH meat. Hunter a and b values in thawed chops never reached the low levels of frozen samples. The objective measurements suggest that below pH 6.1, lamb *l.d.* blooms more readily when exposed to oxygen than is the case above pH 6.1.

This experiment shows that there were no changes in the objective colour measurements of frozen meat with an increasing muscle ultimate pH; thus the dark colour of high pH meat cannot be detected visually in the frozen product. It is therefore not unexpected, as the earlier observation by Moore and Duganzich (1985) showed that colour display life of frozen chops is unaffected by muscle ultimate pH. Such is not the case with thawed lamb, where chops with a low muscle ultimate pH were redder as determined by objective colour measurement and appeared to bloom more readily in the presence of oxygen. The thawing environment is important, since chops thawed in air had higher Hunter values than those thawed in CO_2, but these higher values may have been due to the longer exposure times of the surfaces to the oxygen atmosphere in the former.

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