EFFECT OF CALCIUM CHLORIDE, ZINC CHLORIDE AND WATER INFUSION ON FRESH MEAT COLOUR.

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Background:

Consumers equate the colour of meat to freshness and rely on colour as a visual measure of quality[1]. Furthermore, colour is probably the most significant appearance factor that determines whether a retail cut of meat will be purchased[2]. Consequently, maintaining the cherry red colour of bloomed fresh meat will increase its shelf life and desirability. Benefits to retailers are a reduction in losses due to discolouration [3] and elimination of re-packaging costs[4]. Application of calcium chloride to meat has become a popular method for tenderisation[5]. However, $CaCl_2$ has a negative effect on colour and colour stability which is an obstacle for the utilisation of the process in the meat industry. Infusion of water into animal muscles has also been reported to improve tenderness[6], whilst the infusion of zinc chloride toughens meat [7,8]. There have been no reports on the effects of $ZnCl_2$ and water on colour and colour stability. Despite, the negative effect of $ZnCl_2$ on meat tenderness, zinc can induce changes in other acute phase proteins and enzymes[9]. Moreover, zinc is well-known membrane stabiliser and contributes to the maintenance of membrane structure and function[10]. There is, therefore, a potential opportunity to use zinc to investigate the factors which influence colour and colour stability.

Objectives:

To investigate the effects of pre-rigor infusion of water, zinc chloride and calcium chloride on colour and colour stability.

Material and methods:

Twenty four lambs (9 months old, average live weight 36.3± 3.3 kg) were assigned randomly to four groups of six. These groups were; water infusion (W), 50 mM $ZnCl_2$ infusion (ZN), 0.3 M $CaCl_2$ infusion (CA) and no infusion (CON). Animals were slaughtered using standard captive bolt stunning procedures, using the university facilities, on three consecutives days in which two animals from each group were killed. Vascular infusion was performed as described[7] . After dressing, the carcasses were held at 5°C. The right *longissimus dorsi* (LD) muscles were excised at 24 h postmortem and the muscles were divided into two sub-samples. One part was used to examine colour and colour stability at 24 h postmortem and the other part to examine the treatment effects after 3 weeks vacuum storage at 2°C. Colour and colour stability determinations were performed as described earlier[11] over 6 days of retail display period on the meat held at 2°C.

Results and discussion:

All the meat samples had normal pH values of 5.72±0.14, 5.81±0.12, 5.72±0.07 and 5.77±0.14 for W, ZN, CA and CON respectively.

Lightness (L*): After allowing 2 h for blooming, L*-value of CA was significantly ($p<0.001$) lower than W for 24h postmortem samples (Fig.1A). Treatment CA and CON reached their maximum L*-values after 24h of display at 2°C and their L*-values decreased as the display time progressed. Water treatment (W) reached maximum L*-value after 3 days of display and started to decrease from that time onwards. The L*-value for $ZnCl_2$ treatment continued to increase throughout the display period. The differences between treatments were more pronounced after 3 weeks of vacuum packaging (Fig. 1B). Treatment CA had significantly ($p<0.001$) lower L*-value than the other treatments including the control from 0 time until the end of the display. Treatments W and CA and the control CON reached their maximum L*-values after 3 days of display while treatment ZN continued to increase during the display time. Such significant differences in L*-values and the rate of change of L* can contribute to differences in the visual perception of the meat colour.

Redness (a*): The data from ZN treatment for both 24h postmortem and 3 weeks vacuum packed samples were best fitted to a different mathematical model from those of W, CA and CON as shown in Fig. 2A and Fig. 2B, respectively. Treatments W and ZN were significantly ($p<0.001$) higher in redness than CA and CON during the display period. The effect of the various treatments was consistent between W, CA and CON after 3 weeks of vacuum packed storage at 2°C. Only ZN exhibited a different rate of change of redness, indicating that the differences between W, CA and CON were mainly due to the differences in the initial a*-values. In agreement with an earlier report[12], the 3 weeks vacuum packed samples had higher initial a*-values and higher rate of redness change than 24h postmortem samples.

Yellowness (b*): The yellowness and the rate of change of yellowness were affected by treatments in the 24h postmortem and 3 weeks vacuum packed samples (Fig. 3A and 3B). Treatment CA and CON showed significantly ($p<0.001$) darker colour as determined by their lower b*-values than treatments W and ZN.

Colour parameters and colour stability of LD muscles were significantly affected by pre-rigor infusion treatments. The negative effect of $CaCl_2$ infusion on colour in our study are in accordance with those in other reports.[8,12] However, Harris et al.[13] reported that post-rigor $CaCl_2$ injection resulted in beef meat that was lighter and redder than control beef over 3 days of retail display at 4°C. The differences in the induction technique (infusion vs injection), species (lambs vs beef) and $CaCl_2$ induction time (pre-rigor vs post-rigor) between our study and Harris et. al[13] cannot explain the differences in the effect of $CaCl_2$ on meat colour in the two studies. Since another study[8], which employed the same conditions as Harris et al.[13] did not find any positive effect of injecting $CaCl_2$ on beef meat colour, maybe these parameters do not account for all of the observed inconsistencies in colour in $CaCl_2$ treated meat. The negative effect of $CaCl_2$ on meat colour may be due to the acceleration of metmyoglobin formation[8] through Ca^{2+} stimulation of lipoxygenase.[12] The autooxidation of myoglobin and oxymyoglobin can be accelerated by lipid peroxidation.[14] Another possible explanation is the inhibition of metmyoglobin reductase by calcium ions.[15] The role of reactive oxygen species (ROS) in promoting the oxidative processes is well-known. Water quenches both the high and low energy states of singlet oxygen and it constitutes a very effective primary defence against this oxidant[16]. This quenching function of water may explain its positive effect on colour in the present work. There are reports on the antioxidant properties of zinc and its effect on antioxidant enzymes in biological systems (for review see[10]). Zinc ions, in this study, may maintain and/or enhance meat colour through one or more systems. For instance, zinc was found to bind to myoglobin and increase the oxygen affinity of myoglobin (oxygenation).[17] Zn^{2+} also inhibits mitochondrial respiration.[18] Thus, diminishing the mitochondrial oxygen consumption rate should maintain meat colour. Furthermore, zinc has been reported to prevent the formation of ROS through a mechanism that may involve protection of sulfhydryl groups against oxidation[10] and/ or displacement of redox transition metals from site-specific loci.[20] In addition, it has been reported that zinc has synergistic action with lipid-soluble antioxidant (α-tocopherol) and water-soluble antioxidant (epicatechin) to prevent lipid oxidition.[21]

Conclusion:

Pre-rigor water and $ZnCl_2$ infusions improved the colour and colour stability of ovine LD muscle. $CaCl_2$ infusion decreased the colour of the muscle. The effects of water, $ZnCl_2$ and $CaCl_2$ on colour seem to be due to of their effects on the oxidative processes in meat.

Pertinent literature:

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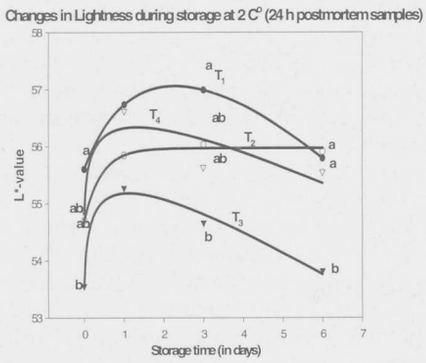
Figure 1.

A



B

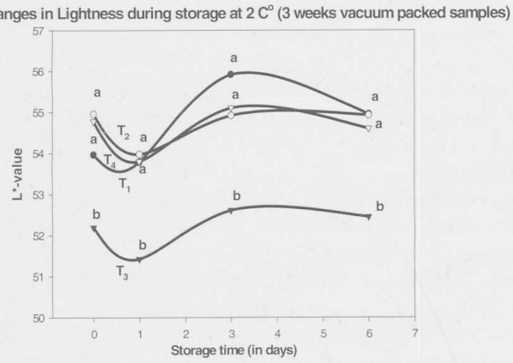
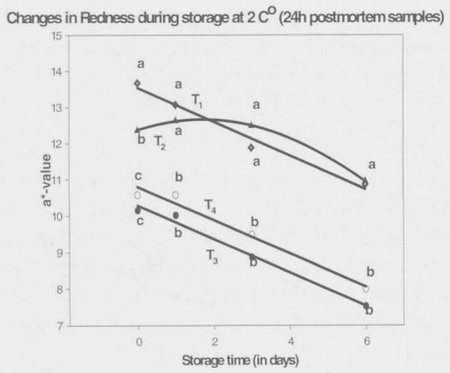


Figure 2.

A



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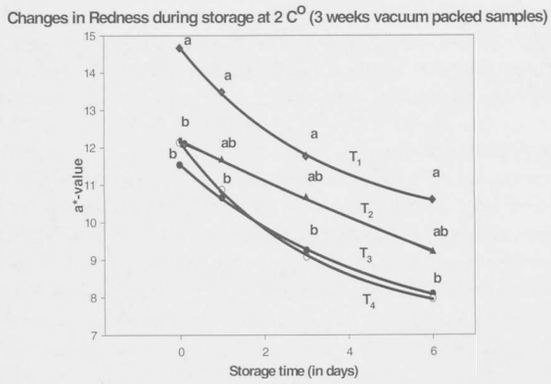
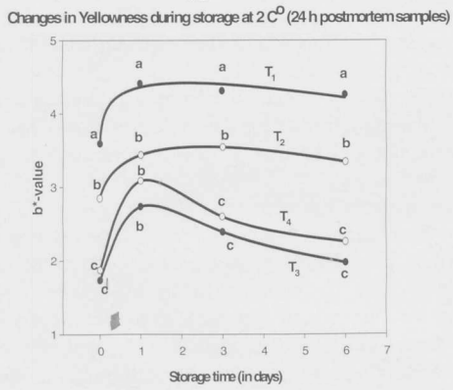


Figure 3.

A



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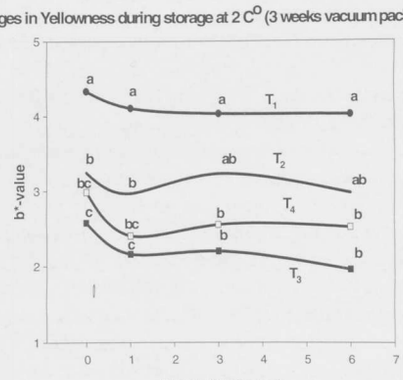

- a,b and c= treatments do not have same letter per day are significantly different ($p<0.001$).
- T_1 = water infusion $T_2 = ZnCl_2$ infusion $T_3 = CaCl_2$ infusion T_4 = control