MODIFIED ATMOSPHERE STORAGE OF ACCELERATED PROCESSED BEEF RESTRUCTURED WITH AN ALGIN/CALCIUM SYSTEM.

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INTRODUCTION

Meat restructuring technology allows products to be formed into any desired shape or size, giving portion control, customer convenience, interest and added value. The process may also utilize mincing or flaking which help to upgrade poorer, tougher cuts of meat. Restructuring is generally accomplished through the addition of salt and often polyphosphates to extract salt-soluble proteins which form a heat setting gel after cooking and bind the meat pieces together. The products must therefore be sold pre-cooked or frozen. In 1986, Schmidt and Means patented the use of an alginate/calcium gel system for making restructured meat products. This novel technology produces structured steaks which bind in both raw and cooked states, resemble fresh, intact muscle cuts, and, as no salt or polyphosphate is used, retain a natural fresh meat colour. (Means and Schmidt, 1986; Means et al, 1987; Clarke et al, 1988).

The ability of the alginate/calcium system to bind meat in the raw, chilled state could have a particular application in the accelerated post-slaughter processing of fresh meat. Whilst various studies have demonstrated the economical and quality advantages of hot boning of beef carcasses (Taylor et al., 1980), uptake of this novel technology has been restricted (Kastner 1982; Taylor 1987), one of the reasons being that the soft nature of hot pre-rigor meat makes it difficult to cut into retail portions before cooling. Alginate binding could allow hot meat to be moulded in casings to uniform shapes, which could then be rapidly and efficiently chilled, for instance, by immersion in refrigerated brine. The resulting product could be readily sliced to retail portions within 4 to 5 hours of slaughter. Electrical stimulation would of course, be an essential pre-requisite to avoid the possibility of cold shortening.

The objectives of this study were to evaluate the effectiveness of algin/calcium technology for restructuring pre-rigor meat, establish whether natural tenderization occurs in a fabricated product and to determine the shelf-life of such products in M A packages.

MATERIALS AND METHODS

Preparation of restructured beef logs

Experiment 1

Four Hereford x Fresian heifers approximately 18 months of age, were slaughtered and subjected to high-voltage electrical stimulation (ES; 700V 25Hz for 2 min) 50 min after death. Within 30 min, six large muscles from the forequarter of the left side, (M. *serratus ventralis,* M. *longissimus thoracis,* M. *triceps brachii,* M. *infraspinatus,* M. *supraspinatus,* M. *subscapularus*) were seamed out intact. Temperature and pH of these muscles were measured at five sites by inserting a temperature probe (RS Components Limited, No 611234) and pH probe (Digital Orion Research pH meter, model 211, Russell spear electrode probe CMS WL/6) Muscles were then demembraned by machine (Townsend 700 PA, Townsend Engineering Company, USA) and large sheets of internal connective tissue removed. The muscles were combined and coarsely minced through a kidney plate (3 x 22 cm consecutive holes). Twenty percent of this meat was then re-minced through a 4 mm plate and added to the coarse mince in a paddle-mixer (Stalberk Mixer, Equipment Limited, Oxted, Surrey). The meat was premixed for 30 sec and then sodium alginate (0.4% Manugel GHB, Kelco International Limited, Westminster House, London) and encapsulated calcium lactate (0.4% 135E-75, Balchem Corporation, State Hill, NY) containing c. 75% calcium lactate and 25% emulsifiable coating, were added and mixing continued for a further 4 min. The meat was stuffed into a 100 mm diameter casing (Clear Saran, Viskase Limited, Swansea, UK) with an oxygen permeability of 8 ml/m^2/24h/atm. at 25°C and 0% RH. After sealing, the meat logs were placed in a chiller at 1°C to cool and stored for one week.

Four days later, the corresponding muscles from the right side of the carcass which had been conventionally chilled, were removed and the process repeated, to provide the cold-boned samples.

One week after the meat was hot-boned, half of each log was cut into steaks, 12 mm thick. The remaining portions of the logs were vacuum

packed and stored for a further two weeks (c. 1°C) before slicing. Modified atmosphere (MA) packing of individual steaks was performed on a Multivac thermoforming machine using standard commercial MA packs with an atmosphere of 75% O_2 and 25% CO_2. The ratio of gas headspace to meat was c. 3:1 v:v. The MA packed steaks were displayed under 1000 lux illumination at either 2°C or 6°C. These samples were assessed for changes in colour, odour and microbial load.

Experiment 2

Two further animals were slaughtered, stimulated and hot-boned as in Expt 1, but cold-boning took place 24h after slaughter. Samples from hot- and cold-boned meat were cut daily, cooked to an internal temperature of 80°C and assessed by taste panel consisting of eight people familiar with meat testing. Tenderness was also assessed instrumentally with a Stevens Materials testing machine, fitted with 1 cm Volodkevitch jaws (Rhodes et al., 1972).

Instrumental Colour

Daily colour measurements were made only on meat samples from Expt 1 using five unopened MA packs, for each temperature and treatment. Colour was measured by inverting each pack over the 1 cm viewing port.of a Minolta Chroma Meter (CR-200) tristimulus colour analyzer. The data were obtained as Hunter L, a and b values from which saturation (S) was calculated (MacDougall, 1977).

Gas analyses, microbiological analyses, odour and visual colour assessment were made on 2 further packs from each treatment after 0, 2, 4, 7 and 9 days' display at 2°C and after 0, 2, 4 and 7 days at 6°C.

Headspace gas analyses

Four samples were withdrawn from the packs via a needle inserted through a patch of silicone rubber sealant on the container lid. Composition was measured on a gas chromatograph (Series 150 Thermal conductivity detector; GOW-MAC Instruments, Shannon, Ireland).

Odour and visual colour.

Odour and colour were assessed by a small group of experts, immediately after packs were opened. Odour was scored on a 6 point scale ranging from "no off-odour" = 1 to "extreme off-odour" = 6. Colour was scored on a 6 point scale from "bright red" = 1 through to "brown" = 6.

Microbiological evaluation

A 25 mm diameter core was removed aseptically from each sample and weighed. This was homogenized in a Stomacher 400 (A J Seward Limited, UAC House, Blackfriars Road, London SE1) with saline diluent (pH 7.0; volume = 3 x sample mass) containing 0.1% (w/v) peptone. Counts were obtained as follows: total viable count on Tryptone Soya Yeast Agar (TSY; Oxoid), incubated for 5 days at 25°C, anaerobic viable count (to recover facultative anaerobes growing poorly in air) on TSY, incubated at 25°C for 5 days in an anaerobic jar containing 10% CO_2 + 10% H_2 + 80% N ; *Brochothrix thermosphacta* on Streptomycin-Thallous Acetate agar (STAA; Gardner, 1966), incubated at 25°C for 2 days; lactic acid bacteria on MRS agar (de Man et al., 1960) adjusted to pH 5.7, incubated for 5 days at 20°C in an anaerobic jar containing 10% CO_2 + 10% H_2 + 80% N_2; *Pseudomonas spp.* on Cetrimide Fusidin Ceporin agar (CFC; Mead and Adams, 1977) incubated at 25°C for 2 days; *Enterobacteriaceae* using pour plates of Violet Red Bile Glucose Agar (VRBG; Oxoid) overlaid with the same medium and incubated at 30°C for 24h. Initially only total counts were determined and those on selective media from the onset of spoilage until an advanced stage of spoilage.

RESULTS

Headspace gas analyses

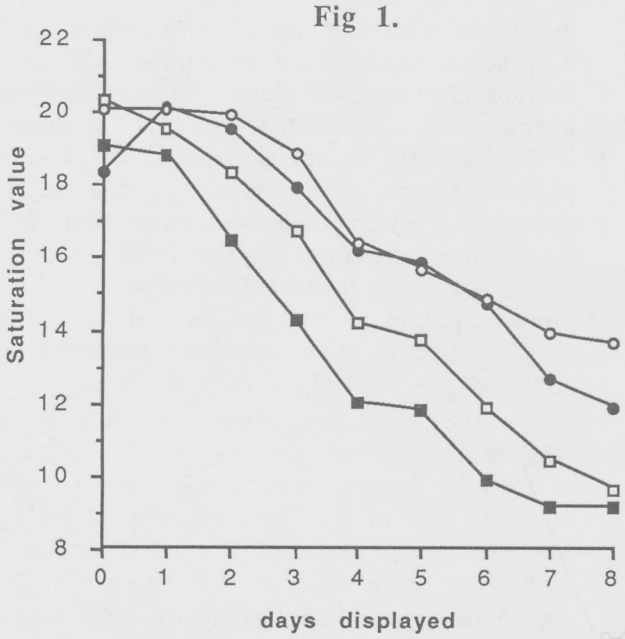
The CO_2 concentration remained between 17 and 25%. The gas space was large enough to cope with the depletion of oxygen whose concentration did not fall below 50% during the storage period.

Colour

The saturation (S) values of 2°C and 6°C after 1 weeks pre-storage are shown in Fig. 1. All the samples had S-values as measured > 18 on the first day after MA packing, and were regarded as acceptably red (MacDougall, 1982).

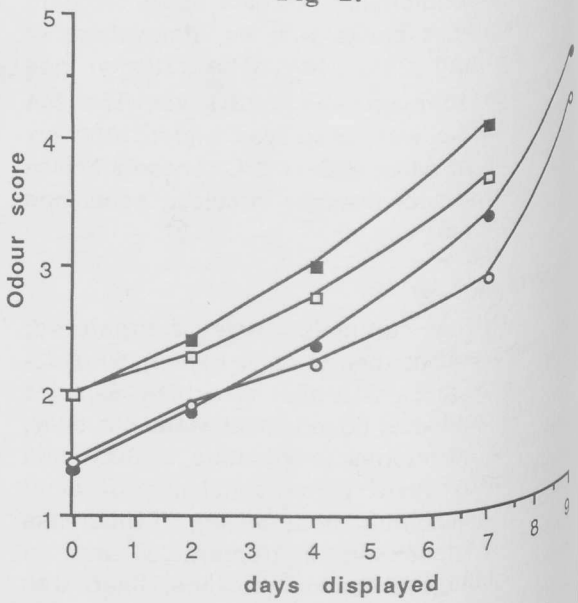
The one week aged samples stored at 2°C discoloured to a measured S-value of < 18 after 3 days and were considered to be fading in colour by the panel after 4 days (panel score = 3; MacDougall, 1982). The 3 week aged samples (results not shown) had lower initial saturation values and higher visual colour scores than those given the 1 week storage treatment and remained lower and higher respectively throughout storage. After 7 days display, all

Fig 1.



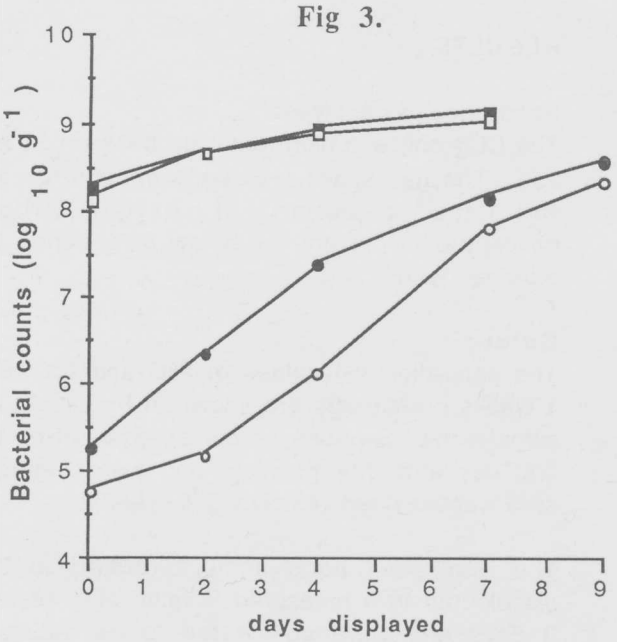
Colour (as saturation) of alginate restructured beef displayed in MA packs at 2 (o) or 6 (□) °C after 1 week anaerobic pre-storage. Closed symbols are for hot-boned meat, open symbols for cold boned meat.

Fig 2.



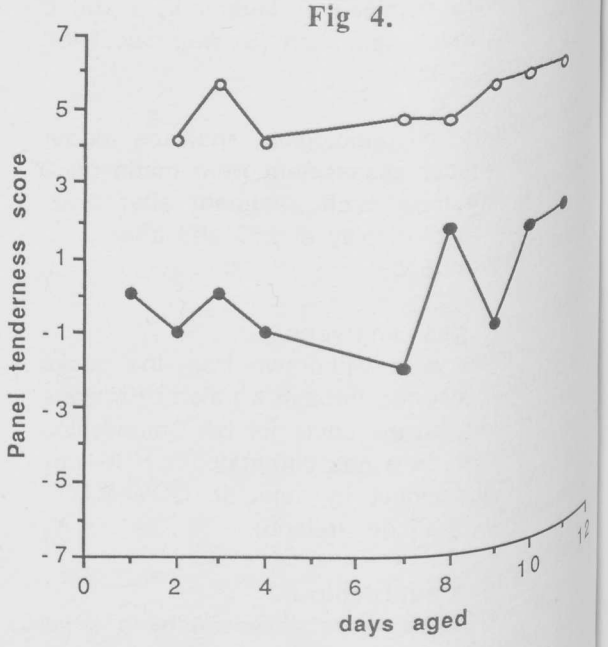
Odour of alginate restructured beef displayed at 2°C in MA packs after 1 (o) and 3 (□) weeks anaerobic pre-storage. Closed symbols are for hot-boned meat and open symbols are for cold-boned meat

Fig 3.



Total viable count of alginate restructured beef displayed at 2°C in ma packs after 1 (o) and 3 (□) weeks anaerobic pre-storage. Closed symbols are for hot-boned meat and open symbols for cold-boned meat.

Fig 4.



Panel tenderness scores (on a scale of 7= extremely tender to -7=extremely tough) for alginate restructured beef aged anaerobically. Closed symbols are for hot-boned meat and open symbols for cold-boned meat.

the samples were distinctly brown according to saturation values (S = 14) and were scored by the panels as being slightly brown.

For all treatments, saturation values were lower in the three week aged samples compared to the one week aged samples, in the hot-boned compared to the cold-boned samples and declined more rapidly at 6°C than at 2°C. All the samples were distinctly brown after 4 days at 6°C and this was confirmed by the panel.

Odour

Mean odour panel scores for restructured steaks during MA display of 2°C are shown in Fig. 2. Steaks from samples aged anaerobically for 3 weeks in log form initially had a higher off-odour score than those from 1 week aged logs (2.0 vs 0.9), with the panel detecting slight off-odours (score = 3) after 4 days of MA display at 2°C and c. 2.5 days at 6°C respectively. Off-odours were detected earlier on hot-boned samples than on cold-boned counterparts, for both ageing and temperature treatments. The cold-boned samples scored <3 after 7 days at 2°C and 4.5 days at 6°C. The panel described the odours as 'buttery, 'sickly sweet' or sometimes 'cheesy'. The odours were never described as offensive or putrid, but at the end of storage some panelists detected rancid, ammoniacal and alcoholic smells (7 days).

Microbiology

The mean total aerobic counts on the MAP sampes stored at 2°C are shown in Fig. 3. The counts of some of the other examined groups of bacteria are shown in Table 1. At the commencement of MA storage the total viable aerobic counts were relatively acceptable for cold-boned 1 week stored samples ($< 10^5$ g^{-1}), relatively high ($>10^5$ g^{-1}) for the hot-boned counterparts and extremely high ($> 10^8$) for the 3 week stored samples.

The total viable aerobic count remained higher on the hot-boned samples throughout the storage period for 1 week aged samples, while the counts on 3 week aged samples were similar, although much higher, at both storage temperatures. Maximum total counts on samples stored at 2°C were between 10^8 and 10^9 g^{-1} and $> 10^9$ g^{-1} at 6°C. *Brochothrix thermosphacta* were more prolific on cold-boned samples reaching maximum levels $> 10^6$ g^{-1} when stored at 2°C and $> 10^8$ g^{-1} at 6°C. *Pseudomonas spp.* and *Enterobacteriaceae* grew more readily on hot processed samples, with both reaching levels $> 10^6$ g^{-1} in the case of 2°C storage and $> 10^7$ g^{-1} in the case of 6°C storage.

The selective counts demonstrated that lactic acid bacteria were the predominant group on all the MA stored samples at both storage temperatures and showed that the higher total count on the 3 week aged samples could be attributed to this group of bacteria.

Texture

Taste panel tenderness scores from Expt 2 are shown in Fig. 4. All the samples had mean taste panel tenderness scores between +2 and -2 with mean shear forces values between 2.5 and 4Kg (results not shown). Cold boned samples were more tender with mean taste panel scores between +4 and +6 and mean instrumental values between 2 and 3 Kg. Only a minor tenderizing effect could be demonstrated over an 11 day period.

DISCUSSION

The higher pH and temperature of the hot-boned meat did not affect the raw or cooked alginate bind strength compared to products made from cold-boned meat and so the concept of making alginate restructured products from hot-boned meat is feasible.

The hot-boned products were neither as tender as the cold-boned products, when assessed by either taste panel or instrumentally, nor did they tenderize to the same score as the cold-boned samples over an 11 day period. Although electrical stimulation reduced the mean pH of the hot-boned muscles, shortly after excision, to 6.07 ± 0.04 (n=36), which would avoid cold-shortening in meat cooled to less than 10°C within 8h post-mortem (Lawrie, 1985), the logs in these experiments were cooled to 1°C within 8h post-mortem. A more recent experiment (unpublished observations) has suggested that mincing the hot meat may have cause toughness since hot-boned muscles, cooled individually under the same regime as the logs and then minced and restructured the next day, were as tender as cold-boned samples.

Samples from logs stored for 3 weeks before MA packing had shorter shelf-lives than samples from logs stored for 1 week in terms of colour, odour and microbiology. Since little, or no, tenderization occurred during storage,

there is no benefit from a period of ageing before packing and distribution.

Instrumental colour, visual colour and odour values showed only small differences in the shelf-life of hot- and cold-boned products with a slight advantage to the cold-boned products. The differences in initial microbial load between these samples would explain these results. Previous studies have shown that if hot-boning is done on the rail then TVCs are lower than when it is done on a table (Eikelenboom and Smulders, 1987). In our experiments, considerable contamination could have been introduced during trimming, pH measurement, mincing, and stuffing operations and the higher temperature of the hot-boned meat would have allowed microbial proliferation during product preparation and cooling. Initial colour saturation values were lower and declined faster than has been seen in other trials with alginate restructured products (Richardson in preparation) and is probably due to the extra handling and the pre-storage period before MA packing described above. However, we have also observed that higher S values are obtained, which remain higher for longer, if the colour is measured directly on the surface of the meat product rather than through the covering film of an unopened pack of the type as used in these experiments. Strict adherence to good sanitation practice during hot-boning operations improves product quality and shelf-life (Taylor et al., 1980; Kotula, 1981; Kennedy et al., 1982) and would also give a greater shelf-life than the three to five days noted in these experiments.

Overall, this work shows that alginate products can be made from hot-boned meat, but a longer time period before mincing may be required to allow the pH to drop further so that irreversible toughening does not occur. The fabrication of uniformly shaped products from hot-boned meat would allow not only more efficient processing in terms of energy for cooling and for storage space, but using alginate as binder could conceivably lead to the production of fresh reformed chilled products with natural colour, packed ready for distribution on the day of slaughter.

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Table 1.

Microbial counts (log_{10} count g^{-1}) on algin/calcium restructured beef steaks displayed in MA packs at 2 and 6 °C after one weeks storage.

Treatment	Total aerobes		*Brochothrix thermosphacta*		*Pseudo-monadaceae*		*Entero-bacteriaceae*		Total lactics	
	HB	CB	HB	CB	HB	CB	HB	CB	HB	CB
Displayed at 2°C										
0 days	5.27	4.78	-	-	-	-	-	-	-	-
2 days	6.34	5.18	-	-	-	-	-	-	-	-
4 days	7.37	6.13	3.52		3.87	5.36	4.73	5.76	3.83	6.88
7 days	8.13	7.77	4.12	5.50	5.41	4.88	6.06	4.47	8.00	7.74
9 days	8.55	8.32	5.40	6.84	6.61	6.08	6.56	4.96	8.59	8.27
Displayed at 6°C										
0 days	5.27	4.78	-	-	-	-	-	-	-	-
2 days	7.27	6.59	-	-	-	-	-	-	-	-
4 days	8.55	8.27	4.76	6.76	7.20	5.38	7.29	5.37	7.91	7.46
7 days	9.03	9.13	6.41	8.12	7.93	7.38	7.92	7.11	8.88	8.95