THE EFFECT OF STORING RAW MEAT UNDER CO_2 ON THE VISIBLE TEXTURE OF THE COOKED MUSCLE TISSUE

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SUMMARY: A fissured or porous appearance of the muscle tissue developed in steaks cooked after they had been stored under excess CO_2 for 24 h. Extending the storage time to seven days did not obviously increase the degree of porosity. On storage in air after removal from a CO_2 atmosphere, CO_2 was lost from steaks. After four days in air, the CO_2 content of the muscle tissue was the same as that before the steaks were packaged under CO_2. Storage in air for up to seven days after removal from the CO_2 packaging did not affect the development of a porous appearance in the cooked meat. When steaks were stored under CO_2 plus N_2 mixtures, a porous appearance developed on cooking when the equilibrium partial pressure of CO_2 within the pack of raw meat had been more than or about 40% of atmospheric, but did not develop when the partial pressure had been less than or about 30%. The higher CO_2 concentration is attained in some commercial bulk packs of poultry meat, and a porous appearance was observed in such meat when it was obtained from retail outlets and cooked. It is suggested that the porous appearance developing in meat cooked after storage under CO_2 is ascribably to ionic effects of dissolved CO_2, resulting in solubilization of muscle structural proteins.

INTRODUCTION: The storage life of chilled meat can be greatly extended by packaging the product under oxygen-free CO_2, with the CO_2 in sufficient quantity to fully saturate the meat at atmospheric pressure (Gill & Penney, 1988).

Meat from such packaging has good consumer appeal and eating qualities (Gill, 1988a). The only shortcomings that have been identified are reduced colour stability of muscle tissue and exposed bone marrow, an inevitable consequence of prolonged storage rather than an effect of the packaging system itself (Moore & Gill, 1987); a viscous exudate, giving some unaesthetic effects, such as fat staining, that can be controlled by appropriate use of absorbent materials (Gill, 1988b); and a porous or fissured, visible texture apparent when the cooked muscle tissue is cut. That latter characteristic (hereafter referred to as "porous" appearance) has passed unremarked by panellists in extensive consumer trials (Gill & Penney, 1989). However, the porous appearance is obviously different from that usual for cooked, fresh meat and has excited comment from meat industry personnel subjecting product from CO_2-packaging to critical scrutiny (Olsen, O. and Sorensen, R., Personal communication).

Despite the porous appearance of sliced cooked muscle being of little apparent consequence for consumers, it is possible that this effect may have significance in some products in some markets and, undoubtedly, it will continue to be noticed by workers in the food

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industry. We therefore undertook a preliminary study to better identify the storage conditions that give rise to, or enhance, the porous appearance of meat, when it is cooked after having been packed under a CO_2 atmosphere.

MATERIALS AND METHODS: Beef striploins of either normal pH (5.5-5.7) or high pH (6.0-6.5) were obtained from a local meat plant when carcasses were broken down 24 h after slaughter. Muscle pH was determined by the direct application of a glass electrode. The striploins were cut into steaks approximately 5 cm thick and each steak was trimmed to a weight of 750±10 g. Steaks were individually packaged in aluminum foil lamninate pouches using a Captron packaging machine (Challenge-RMF Inc., Industry, CA, U.S.A). The pouches were first evacuated then inflated with 2 litres of CO_2, N_2 or a CO_2+N_2 mixture.

For description of the porous appearance, normal pH steaks were stored for 6 weeks at -1.5° C before they were examined.

For determining the effect of the time of storage under CO_2 on cooked meat appearance, normal-pH steaks were stored at -1.5°C for periods between one and seven days, and examined 2 h after they were removed from the CO_2 atmosphere.

For examination of the effect of storage in air after saturation with CO_2, steaks from a striploin of pH 5.7 were stored under CO_2 for seven days at 3°C. After removal from the CO_2 packaging, the steaks were wrapped in stretch film of high gas permeability and stored at 3°C for periods up to seven days.

For steaks stored under CO_2 and N_2 mixtures containing 80, 60, 40 or 20% CO_2, both normal and high-pH steaks were stored at -1.5°C for two days before they were examined 2 h after they were removed from the CO_2 and N_2 atmospheres.

Determination of CO_2 in Muscle Tissue

When steaks were stored in air before being examined, a quarter portion was sliced from the end of each steak before it was to be cooked. Three samples, each weighing between 1 and 2 g, were removed from the centre of each portion and accurately weighed. Each sample was placed in a 100 ml Buchner flask containing 5 ml of 6% perchloric acid. The flask was then closed with a neoprene bung. The side arm of the flask connected with the side arm of a second stoppered flask containing 3 ml of standard 0.05 M $Ba(OH)_2$. After standing overnight to allow for absorption of evolved CO_2, the residual $Ba(OH)_2$ was titrated with standard 0.1 M HCl as previously described (Gill, 1988c).

Examination of Steaks

Steaks were grilled at 180°C, for 3 to 5 minutes on each side, in a covered electric frying pan. Each steak was then cut into 5 cm wide slices and the texture of the cut surfaces assessed by five panellists

on a three-point scale where 1 = no porous texture, 2 = porous texture evident on close inspection, 3 = markedly porous texture. Slices judged to be typical of the appearances perceived were photographed.

Examination of Chicken Muscle

Chickens of a brand stated by the producers (Tegel Poultry Co., Auckland, New Zealand) to be packed for bulk storage under an atmosphere of 93% CO_2 and 7% O_2, added at 1 ± 0.2 litres/carcass, were purchased from a local retail store. Two each of the largest (1.6 kg) and smallest (0.8 kg) size available were purchased. The entire breast muscles were removed from each carcass. The breast fillets were grilled, and assessed in the same manner as the beef steaks.

RESULTS AND DISCUSSION: When samples were cooked soon after removal from a 100% CO_2 atmosphere, the cooked meat surfaces appeared as normal, but cut surfaces showed a markedly porous texture. The porosity was most pronounced in muscle tissue that had been moderately cooked. Porosity was less pronounced in well cooked outer layers of tissue and did not appear in any central tissue that remained raw.

The porous appearance of muscle tissue cooked after storage under CO_2 was due to the development of fissures between muscle fibre bundles. Fissure dimensions were highly variable. Maximum dimensions in the samples studies were approximately 50 x 10 x 3 mm (length x depth x width). The cut surface appearance resulting from the fissuring was obviously dependent on the angle at which the fissures were transected, and the diameters of fibre bundles. Longitudinal sections showed fissures, and dished areas where fissures were widest. Transverse and oblique sections showed round, oval and spindle shaped pores (Plate 1). The maximum separation of bundles was greater between coarse than between fine muscle fibre bundles.

When first cut, the pores in some moderately cooked tissue appeared to be filled with fluid rather than gas. In longitudinal sections, a membrane free of the fissure walls could be observed in some fissures (Plate 1a). In transverse sections, a few pores were bridged by such membranes to cut off a fluid-filled section behind the membrane.

Although the presence of fluid in some pores suggested that gas evolution during cooking of CO_2-saturated tissue might not be involved in fissure formation, it was necessary to further examine that possibility.

When steaks were stored under CO_2 for varying periods, a markedly porous appearance was evident after 24 h storage, and the appearance did not substantially alter with storage up to seven days.

Muscle tissue samples removed before packaging under CO_2 evolved 210 ± 30 ml CO_2/kg when placed in perchloric acid. Samples from steaks that had been in air approximately 2 h after removal from a CO_2 atmosphere evolved somewhat less CO_2 than would be expected from fully CO_2-saturated tissue. The amount of CO_2 evolved from the tissue declined as the time in air extended until, by the fourth day, the amount of CO_2 obtained was similar to that evolved from the tissue

before it was exposed to CO_2 (Fig. 1).

Despite the decrease in dissolved CO_2, the porous appearance of cooked steaks was judged to be similar at all times of storage in air up to seven days after the meat was removed from the CO_2 atmosphere.

With meat stored under CO_2 and N_2 mixtures, the porous appearance was evident in meat cooked after storage under atmospheres initially containing 60% or more CO_2, but not in meat cooked after storage under atmospheres initially containing 40% or less CO_2 (Plate 2). Although the degree of porosity varied between samples, variation was obviously due to differences in fibre bundle dimensions and the angle at which they were cut, rather than a graded response to variation of the CO_2 concentration, as the porous texture was judged to be discernible without close inspection in all samples showing such texture.

No distinction could be made between high and low pH muscle in the effects of exposure to CO_2.

The observation that development of fissures was not dependent on the amount of CO_2 dissolved in muscle tissue at the time it was cooked, and the presence of much fluid in fissures, would seem to establish that fissuring is not a consequence of gas pockets forming within the tissue when it is warmed. The presence within fissures of free membranes, presumably perimysia, indicates that adhesion between the muscle fibre bundle and the perimysium is disrupted as a result of CO_2 dissolution in muscle tissue.

It can therefore be suggested that the porous appearance of meat cooked after exposure to CO_2 is a gross consequence of the ionic effects of CO_2 dissolution on muscle tissue structure. Such ionic effects, swelling of muscle fibres and solubilization of myofibrillar/cytoskeletal proteins, have been described for NaCl and NaCl/polyphosphate mixtures (Offer & Trinick, 1983; Parrish & Patterson, 1988). As with cured meats, the resulting disruption of muscle structure would give rise to a porous texture on cooking because of differential shrinkage of structural elements uncoupled by protein solubilization. The porosity is probably due to the lateral shrinkage that occurs most rapidly at about 60°C (Offer et al., 1988), because fissure dimensions are reduced in outer layers of tissue that would experience the higher temperatures at which longitudinal shrinkage occurs. The enhanced viscosity of exudate from CO_2-saturated meat would be another consequence of protein solubilization.

As CO_2 is highly soluble in meat tissues, the equilibrium partial pressure of CO_2 in packs containing CO_2 + N_2 atmospheres will differ from that of the initial atmospheres (Gill, 1988c). From the gas volume and meat sample weight used in this study it appears that storage under equilibrium CO_2 concentrations of up to 30% will have no effect on the visible texture of cooked meat, while equilibrium CO_2 concentrations of 40% or more should result in an obviously porous cooked meat texture. High-CO_2 bulk packages in current commercial use to extend the storage life of chilled poultry (Hotchkiss et al., 1985) should therefore cause a porous appearance in at least some of the product so packaged when it is cooked. Examination of samples of such

a product on local retail sale confirmed that expectation. After cooking, breasts from small carcasses showed a porous appearance, but breasts from large carcasses did not (Plate 3). As poultry and pork packaged under that type of high-CO_2 atmosphere has been extensively traded for several years, the findings in consumer trials that consumers do not react to a porous apperance of cooked meat would seem to be confirmed by commercial experience.

Therefore, the development of a porous texture in the cooked meat need not be considered a substantial reason for rejecting the use of high-CO_2 atmospheres to preserve chilled meat, unless there is evidence from particular markets of adverse consumer reaction to the condition.

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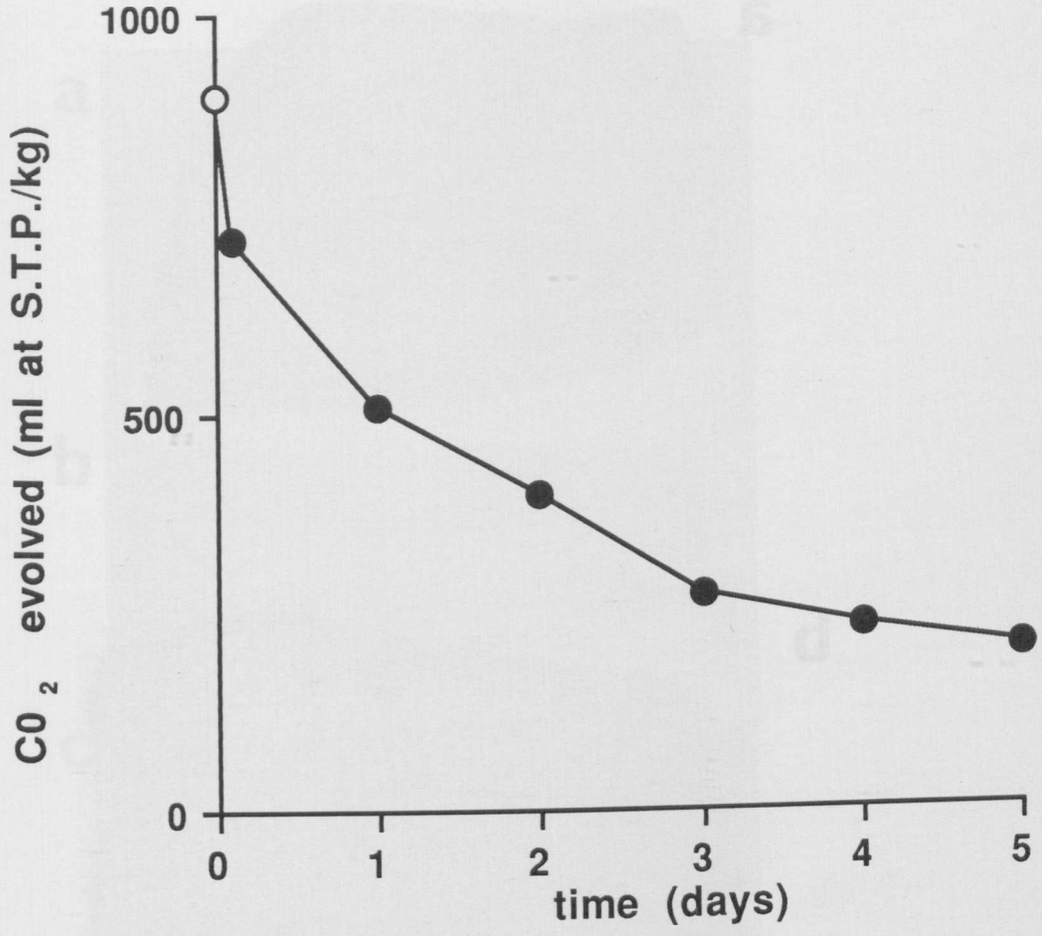

Figure 1. The effect of storage in air on the quantity of CO_2 in beef muscle tissue that had previously been stored under CO_2. (○) Estimated quantity of CO_2 in CO_2-saturated tissue. (●) Experimentally determined quantities of CO_2.

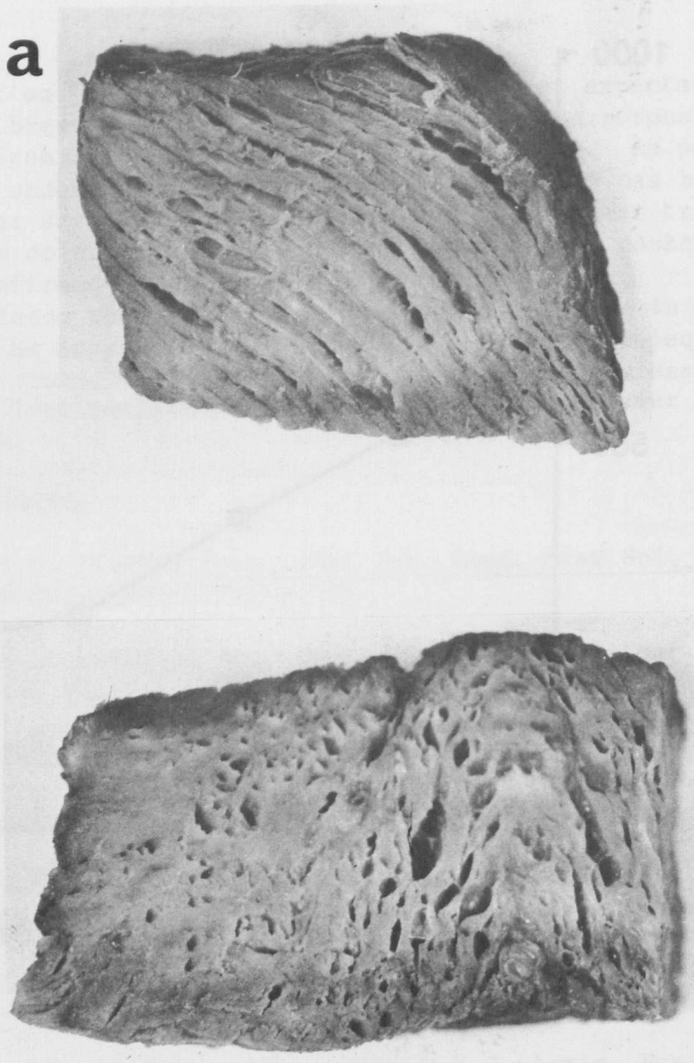

Plate 1. Porous texture in beef muscle cooked after storage under CO_2 in sufficient quantity to saturate the tissue. a) Longitudinal section; b) transverse section. Magnification x 2.

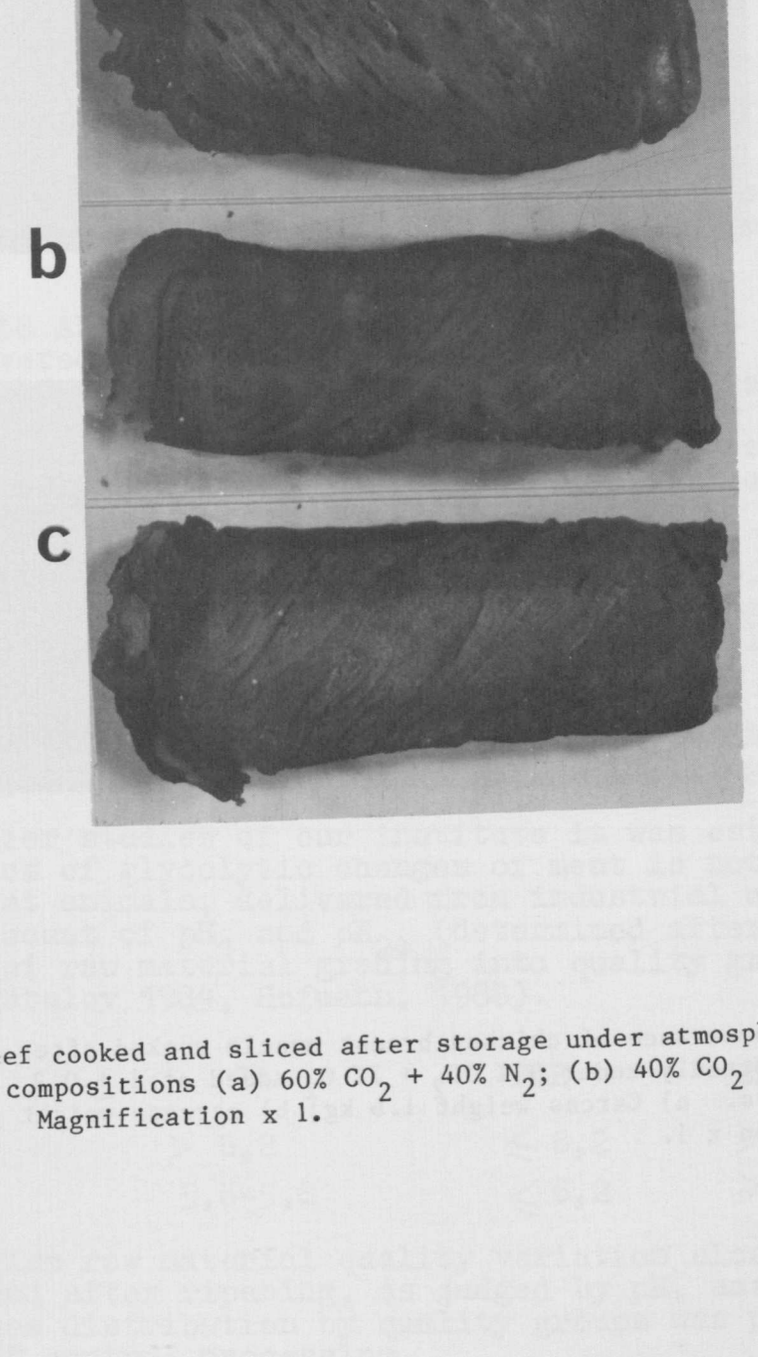

Plate 2. Beef cooked and sliced after storage under atmospheres with the initial compositions (a) 60% CO_2 + 40% N_2; (b) 40% CO_2 + 60% N_2; (c) 100% N_2. Magnification x 1.

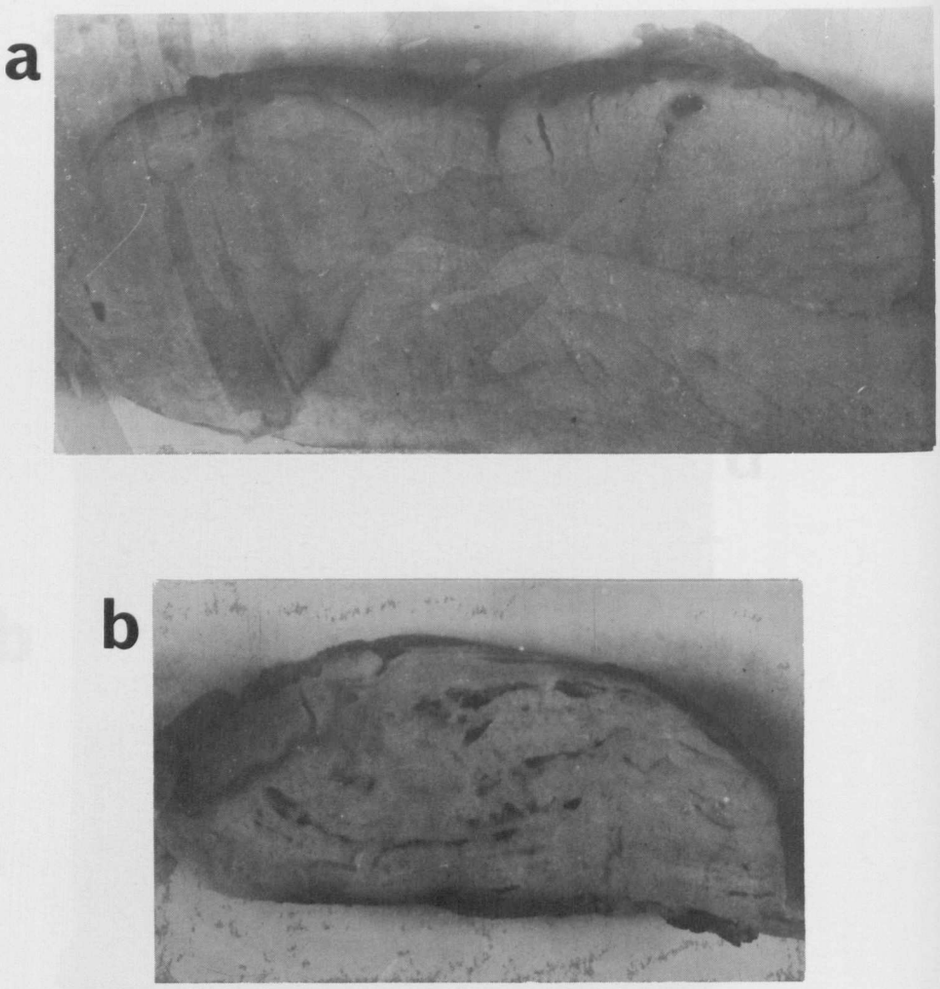

Plate 3. Appearance of chicken breast muscle cooked after commercial storage reportedly under 93% CO_2 + 7% O_2 added at 1 $\pm$ 0.2 litre/carcass. a) Carcas weight 1.6 kg; b) carcass weight 0.8 kg. Magnification x 1.