I2. PACKAGING FRESH AND CURED MEAT

GAS-PACKAGING : THE EFFECT OF VARIOUS GAS ATMOSPHERES ON COLOUR OF FRESH BEEF

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Colour changes were measured on pieces of the muscles M. Psoas major, M. Semimembranosus, and M. Gluteus medius from primal cuts, aged for 2 weeks in vacuum bags, over-wrapped with air-permeable film and stored in various gas atmospheres at 0°C. Air, pure CO_2, pure N_2, and gas mixtures composed of 10-20% CO_2 + 20-80% O_2 + N_2, were used.

Results:

1. Pure CO_2 has a deteriorating effect on meat colour, even when the meat is stored in the gas for as little as 6 hours.
2. After a storage period of several days in pure N_2, meat re-exposed to air 'blooms' to an acceptable red colour.
3. The colour of meat stored in O_2 + CO_2 enriched atmospheres remains acceptable longer than meat stored in air. The extension of the keeping time of this meat increases with the concentration of O_2 in the gas mixture.

EMBALLAGE AU GAZ : EFFET DE DIVERSES ATMOSPHERES GAZEUSES SUR LA COULEUR DU BOEUF FRAIS

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Les changements de couleur ont été mesurés sur des échantillons des muscles M. Psoas major, M. Semimembranosus, et M. Gluteus medius, prélevés sur des morceaux essentiels, ayant subi un vieillissement de 2 semaines en sacs sous vide, recouverts de film perméable à l'air et conservés à diverses atmosphères gazeuses à 0°C. Ont été utilisés : l'air, le CO_2 pur, le N_2 pur, et des mélanges gazeux composés de 10-20% CO_2 + 20-80% O_2 + N_2.

Résultats:

1. Le CO_2 pur a un effet détériorant sur la couleur de la viande, même lorsque la viande est conservée dans le gaz pour une période n'excédant pas 6 heures.
2. Après une période de conservation de plusieurs jours dans du N_2 pur, la viande réexposée à l'air 's'épanouit' en une couleur rouge acceptable.
3. La couleur de la viande conservée dans des atmosphères enrichies de O_2 + CO_2 reste acceptable plus longtemps que la viande conservée à l'air. La prolongation de la conservation de cette viande est directement liée à la concentration de O_2 dans l'atmosphère gazeuse.

GAS-VERPACKUNG : DIE WIRKUNG VERSCHIEDENER GAS-ATMOSPHAREN AN FARBE VON FRISCHEM RINDFLEISCH

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Farbveranderungen wurden gemessen an Muskelstucken M. Psoas major, M. Semimembranosus, und M. Gluteus medius von ersten Zerlegungen, fur zwei Wochen in Vakuum-Tuten gelagert, eingeschlagen in luftdurchlassigen Bezug und gelagert in verschiedenen Gas-Atmospharen bei 0°C. Luft, rein CO_2, rein N_2, und Gasmischungen zusammengesetzt von 10-20% CO_2 plus 20-80% O_2 plus N_2 wurden gebraucht.

Resultate:

1. Reine CO_2 hat eine herabsetzende Wirkung an Fleischfarbe, selbst wenn das Fleisch nur fur die kurze Zeit von 6 Stunden in Gas gelagert ist.
2. Nach einer Lagerzeit von einigen Tagen in reinem N_2, das der Luft wiederausgesetzte Fleisch nimmt eine annehmbare rote Farbe an.
3. Die Farbe von Fleisch gelagert in O_2 plus CO_2 bereicherten Atmospharen blieben langer annehmbar als Fleisch in Luft gelagert. Die Verlangerung der Erhaltungszeit des Fleisches ist direkt mit der Konzentration von O_2 in der Gas-Atmosphare verbunden.

ГАЗОУПАКОВКА: ЭФФЕКТ РАЗНЫХ ГАЗОВЫХ АТМОСФЕР НА ЦВЕТ СВЕЖЕГО ГОВЯЖЬЕГО МЯСА

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Определялись изменения цвета в кусках мышц **M.psoas major**, **M.semimembranosus** и **M. gluteus medius** из первых отрезков, герметически запакованных в течение двух недель, с дополнительным перекрытием воздухопрницаемой пленки, и храненных в разных в разных газовых атмосферах при 0°C. Были применены воздух, чистый CO_2, чистый N_2 и газовые смеси, состоящие из 10-20% CO_2 + 20-80% O_2 + N_2.

ВЫВОДЫ

1. Чистый CO_2 имеет неблагоприятный эффект на цвет, даже при хранении мясе в газе не больше чем за 6 часов.
2. При хранении в чистом N_2 после нескольких дней, мясо снова подверженное действию воздуха, "расцветает" до приемлого красного цвета.
3. Цвет мяса, храненного в атмосферах обогащенных O_2 и CO_2 сохраняет свою приемлемость за более длительный срок времени по сравнению с мясом, храненным в воздухе. Удлинение срока хранения этого мяса имеет непосредственное отношение к концентрации O_2 в газовой атмосфере.

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Introduction

There is an increasing interest in the use of atmospheres, other than air, for the storage, transport and selling of fresh meat. Modified gas atmospheres can extend the time during which meat remains of good quality and retains an acceptable appearance and colour. Development of such a system is economically desirable since it favours centralised packaging and marketing of fresh meat.

Fresh beef, when first exposed to air, develops a bright red colour due to the layer of oxymyoglobin pigment at the surface of the meat. This colour deteriorates with storage in air because of oxidation of the myoglobin to brown metmyoglobin. The oxygen partial pressure at the meat surface largely determines the quality and duration of the bright red colour of fresh beef; a high oxygen partial pressure gives a deep layer of red oxymyoglobin which masks the underlying brown metmyoglobin. With reduction in the oxygen partial pressure at the meat surface, the red layer narrows and the underlying brown metmyoglobin, which forms maximally at low oxygen pressures (4 m.m. Hg or 0.5% O_2), becomes visible. When all oxygen is excluded from the meat surface, the reduced myoglobin (purple) is visible. This pigment converts to red oxymyoglobin on re-exposure to oxygen.

Fresh beef, stored at temperatures ranging from -1°C to +5°C, in atmospheres containing O_2 at levels higher than atmospheric, retains an acceptable red colour longer than meat stored in air at similar temperatures (Georgala & Davidson, 1970; Daun et al., 1971; MacDougall, 1971; Naumann et al, 1971; Clark & Lentz, 1973; Taylor & MacDougall, 1973). These atmospheres also require a level of CO_2 higher than atmospheric to inhibit the bacterial growth due to the high O_2 levels (Georgala & Davidson, 1970; Naumann et al, 1971; Taylor, 1971; Clark & Lentz, 1973; Taylor & MacDougall, 1973). While CO_2 is useful as a bacteriostatic agent in gas-packaging of fresh meat, high concentrations of the gas have an adverse effect on meat colour (Brooks, 1933; Georgala & Davidson, 1970; Partmann & Frank, 1971). It has been suggested (Ledward, 1970) that the effect of high concentrations of CO_2 on meat colour may be due to the consequent reduction in O_2 partial pressure at the meat surface.

The use of the inert gas N_2 as a storage atmosphere for fresh meat has been favourably reported; the meat pigment is in the reduced myoglobin form during storage in N_2 but 'blooms' to a bright red colour on re-exposure to air (Partmann & Frank, 1970).

The aim of this work was to examine the effect of a variety of gas atmospheres on fresh beef which had been aged as primal cuts in vacuum bags. Various mixtures of O_2 + CO_2, recommended as suitable for storage of fresh beef, and N_2, and CO_2, were used; the colour of the meat was compared with that found for meat stored in air. The work was designed especially to investigate the effect of these gas atmospheres on a range of muscles of the hind-quarter known to have varying colour stability. In previously reported work meat is often from an unspecified muscle or from a muscle such as M. Semitendinosus, whose colour stability is intrinsically good, and due account is not taken of the variation in colour stability in different muscles (Georgala & Davidson, 1970; Ledward, 1970; Naumann et al, 1971; Partmann & Frank, 1971).

Experimental

1. Meat

Beef was obtained from 14 heifers, aged about 1½ to 2 years (0-2 teeth). The animals were slaughtered, under hygienic conditions, in the Meat Research Department abattoir and hung as sides in the chill (+2°C) for 48 hours. After chilling, the hind-quarters were broken into primal cuts. Fillet, Sirloin and Inside Round cuts were vacuum packaged in polythene/nylon laminate bags and these vacuum packs were stored at 0°C for a further 13 days.

After ageing the muscles M. Psoas major, M. Semimembranosus, and M. Gluteus medius were dissected out from the Fillet, Inside Round and Sirloin, respectively. Median portions from each pair of muscles were cut into steaks of approximately 1.5 cm. thickness. A random selection of samples, measuring approximately 4 x 3 cm, were cut from these steaks and placed on perspex trays. The samples from each of the muscle pairs were placed in groups of 8 (4 from each muscle) on fibreboard trays. After holding in the dark at 0°C for 1 hour, all the meat samples were individually overwrapped with PVC meat grade film.

The preparation of these meat samples was carried out under aseptic conditions. The muscles were dipped in boiling water for a few seconds before cutting into steaks, and sterile knives were used both for dissecting out the muscles and for cutting the samples. All cutting of the meat was on metal surfaces, previously scrubbed with hot water, sterilised with chloros solution, rinsed with cold water and allowed to dry.

2. Measurements

The pH of the different muscles was measured on their removal from the vacuum packages (15 days post slaughter) and all muscles had a normal pH value, lying between pH 5.4 and pH 5.8.

Colour change was measured by reflectance spectrophotometry, using a Unicam SP 800 Spectrophotometer fitted with an SP 890 diffuse reflectance attachment. The reflectance spectra of all the meat samples, stored in the various gas atmospheres, was measured periodically during storage. From these reflectance spectra, $(K/S)_{572}/(K/S)_{525}$ ratios were calculated and used to determine the changes in the meat pigments during storage. The methodology has been described at length elsewhere (Stewart, Zipser & Watts, 1965; Hood, 1971; Hood, 1973).

The trays of 8 meat samples, for each of the 3 muscles, were stored in air, pure CO_2, pure N_2, and various gas mixtures of CO_2, O_2 and N_2. In the case of the gas atmospheres other than air, the trays of meat samples were placed in vacuum dessicators, which were evacuated and flushed with the desired gas atmosphere. This evacuation and flushing cycle was repeated twice and, then, all samples were stored at 0°C. A Wösthoff Gas-Mixing Pump, Model M301/a-F, was used to prepare the gas mixtures.

After over-wrapping with PVC film the samples stored in air were allowed to 'bloom' for 2 hours at 0°C and the spectra of these samples recorded on the spectrophotometer. These $(K/S)_{572}/(K/S)_{525}$ ratios were taken as representing 0% metmyoglobin (100% oxymyoglobin) for each of the 3 muscles.

Before each measurement of the spectra of the meat samples stored in the gas atmospheres, samples of the gas in the dessicators were analysed using a Pye 104, Model 44 Gas Chromatograph. Meat samples stored in CO_2, O_2 and N_2 were removed from the dessicators, their spectra recorded on the spectrophotometer, and then replaced in the dessicators, which were evacuated and reflushed with the correct gas mixture. Samples of meat were stored in pure CO_2 and pure N_2 for a number of days and then exposed to air to allow the meat to 'bloom'. After 24 hours in air the reflectance spectrum of these samples was recorded and then, periodically during their continued storage in air at 0°C.

Results & Discussion

A decrease in $(K/S)_{572}/(K/S)_{525}$ ratio of approximately 0.16 from the initial value (0% metmyoglobin) is equivalent to a metmyoglobin concentration of about 20%, and this level of discolouration has been found to be close to the limit for acceptability (Hood & Riordan, 1973). On this basis, when the $(K/S)_{572}/(K/S)_{525}$ ratio for the meat samples decreased by 0.16 from the initial, we judged the meat to be unacceptable and rejected it.

Meat from different muscles varies considerably in colour stability. Of the 3 muscles we selected for this work, M. Psoas major is by far the most unstable and M. Semimembranosus is the most stable, M. Gluteus medius having an intermediate stability (Hood, 1971). The meat samples stored in air were treated as control samples, the test gas atmospheres being adjudged better or worse than air according as meat samples stored in them remained acceptable for longer or shorter than the controls.

Table I shows the time for which meat samples stored in the various atmospheres retained an acceptable colour.

1. CO_2, O_2 and N_2 mixtures.

A marked increase in keeping time of fresh beef was found with storage in atmospheres contining 50% - 80% O_2; 50-60% O_2 maintained meat in an acceptable condition for much longer than air and a further increase in keeping time was achieved by using 70-80% O_2. This increase in keeping time was most marked for M. Psoas major meat (100-200%) but was less marked for the more stable muscles; an increase of 50-60% in keeping time was found for M. Gluteus medius. When the meat samples were stored in an atmosphere composed of 20% O_2 + 20% CO_2 + 60% N_2, a noticeable decrease in keeping time was observed, compared with keeping time in air. Since this atmosphere contained a similar concentration of O_2 as air, the increased level of CO_2 in this gas mixture may be the factor responsible for the faster deterioration of the meat colour (Georgala & Davidson, 1970).

2. Pure N_2

Meat samples were stored in atmospheres of 100% N_2 for periods of 3 and 6 days and stored subsequently in air during which time reflectance spectra of the samples were recorded. On exposure to air, the meat 'bloomed' to an acceptable red colour; the keeping time of the meat was increased in proportion to the period of storage in N_2. As in the case of atmospheres containing increased levels of O_2, the increase in keeping time was most marked for M. Psoas major meat; the keeping time was increased by the length of time that the meat samples were stored in N_2. The keeping time of the more stable M. Gluteus medius and M. Semimembranosus meat is also increased, but by a shorter period. The colour of meat stored in an atmosphere of 100% N_2 does not deteriorate during this storage period because the myoglobin pigment is not oxidised to metmyoglobin.

3. Pure CO_2

Meat samples from a total of 10 animals were stored in 100% CO_2 for periods of 6, 24, 48 and 96 hours before exposure to air. The results, generally, showed a deterioration in meat colour which was characterized by

1. being greater in proportion to the length of time of storage in CO_2, and
2. being greater in muscles of unstable colour (M. Psoas major) compared with the more stable muscles (M. Semimembranosus & M. Gluteus medius) (Figs 1 & 2).

However, the results from some trials were not consistent with these findings, the meat in these trials 'blooming' to an acceptable colour on re-exposure to air.

The deterioration in colour of the meat samples stored in CO_2 is possibly the result of metmyoglobin accumulation due to the presence of traces of oxygen in the gas atmosphere surrounding the meat but further work is necessary to establish the exact cause of this phenomenon. This deteriorating effect of CO_2 on meat colour has been observed by other workers (Georgala & Davidson, 1970).

These preliminary investigations indicate that at 0°C:-

1. The colour of meat stored in O_2 + CO_2 enriched atmosphere remains acceptable longer than meat stored in air, the extension of the keeping time increasing with the concentration of O_2 in the atmosphere.
2. The keeping time of meat may be extended by storing in 100% N_2 for several days and then exposing the meat to air when it 'blooms' to an acceptable red colour.
3. Modified gas atmospheres markedly increase the keeping time of meat from muscles which have unstable colour characteristics, such as M. Psoas major.

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TABLE I

Keeping time of meat samples stored in gas atmospheres at 0°C

Atmospheres	Time (days) to decrease of $(K/S)_{572}/(K/S)_{525}$ ratio by 0.16 (20% metmyoglobin)		
	M.Psoas major	M. Gluteus medius	M. Semimembranosus
1) Air	3 - 5	10 - 12	14 - 16
2) 20% O_2+20% CO_2 + 60% N_2	2 - 4	7 - 9	10 - 12
3) 80% O_2+20% CO_2	11 - 13	16 - 18	> 20
4) 70% O_2+10% CO_2 +20% N_2	10 - 12	15 - 17	> 20
5) 60% O_2+20% CO_2 + 20% N_2	8 - 10	15 - 17	> 20
6) 50% O_2+20% CO_2 + 30% N_2	8 - 10	14 - 16	> 18
7) 100% N_2 (for 3 days)	6 - 8	12 - 14	15 - 17
8) 100% N_2 (for 6 days)	9 - 11	15 - 17	> 17