PACKAGING FRESH AND CURED MEAT

THE COLOUR STABILITY OF VACUUM PACKED WILTSHIRE BACON CURED WITH DIMINISHING QUANTITIES OF NITRITE

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Bacon sides, cured by a nitrate-free Wiltshire process incorporating hand pumping and immersion in brines containing 2000, 1000, 500 and 250 ppm nitrite, were sliced and stored in vacuum packs both in the light and in the dark at 5°C and 15°C for 5 weeks. Bacon cured at the 2000, 1000 and 500 ppm levels had no colour defects; in that cured at the 250 ppm level there were uncured areas which remained after cooking. During storage the lean became more opaque and increased in lightness, and metmyoglobin in areas was converted to nitrosylmyoglobin.

LA STABILITE DE LA COULEUR DU BACON WILTSHIRE MIS EN PAQUETS SOUS VIDE AVEC DES QUANTITES DECROISSANTES DE NITRITE

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Du bacon de flanc, conservé par un procédé du type Wiltshire sans nitrate comprenant le pompage à la main et l'immersion dans des saumures contenant 2 000, 1 000, 500 et 250 ppm de nitrite, fut coupé en tranches et stocké dans des paquets sous vide en pleine lumière et dans le noir à 5°C et à 15°C pendant 5 semaines. Le bacon conservé à des niveaux de 2 000, 1 000 et 500 ppm n'avait aucun défaut de couleur; dans celui conservé au niveau de 250 ppm il y avait des parties non conservées qui sont restées après la cuisson. Lors du stockage le maigre devint plus opaque et plus clair, et la metmyoglobine de certaines parties fut transformée en nitrosylmyoglobine.

DIE FARBFESTIGKEIT VON VAKUUMVERPACKTEM WILTSHIRESPECK, DER MIT ABNEHMENDEN NITRITMENGEN GEPÖKELT WURDE

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Speckseiten, die mittels eines nitratfreien Wiltshireverfahrens unter Verwendung von Handpumpen und Eintauchen in Pökellaugen mit 2 000, 1 000, 500 und 250 ppm Nitrit gepökelt wurden, wurden in Scheiben geschnitten und in Vakuumpackungen sowohl bei Licht als auch bei Dunkelheit gelagert und zwar 5 Wochen lang bei 5° und 15°C. Speck, der bei 2 000, 1 000 und 500 ppm gepökelt wurde, wies keine Farbschäden auf; bei dem bei 250 ppm gepökelten Speck gab es ungepökelte Stellen, die nach dem Kochen blieben. Während der Lagerung wurde das magere Fleisch undurchsichtiger und die Helligkeit verstärkte sich; Metmyoglobin wurde stellenweise zu Nitrosylmyoglobin umgeformt.

ЦВЕТОВАЯ СТАБИЛЬНОСТЬ ВАКУУМ-УПАКОВАННОГО УИЛТШАЙРСКОГО БЕКОНА, СОЛЕННОГО С УМЕНЬШАЮЩИМИСЯ КОНЦЕНТРАЦИЯМИ НИТРИТА

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Беконные половинки, изготовленные уилтшайрским процессом без нитрата с ручным накачиванием и погружением в рассолы, содержащие 2000, 1000, 500 и 250 миллионных долей нитрита, были нарезаны и подвержены хранению в вакуумных упаковках на дневном свету и в темноте при температурах в 5 и 15 °C в течение 5 недель. Бекон, соленный в рассолах с 2000, 1000 и 500 миллионных долей нитрита, не проявил цветовых дефектов, тогда как бекон, соленный в рассоле с 250 миллионных долей нитрита проявил несоленные участки, которые сохранились даже после варки. Во время хранения постное мясо стало менее прозрачным и более светлым, а метмиоглобин в участках преобразовался в нитрозилмиоглобин.

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INTRODUCTION

The concentration of nitrite in cured meats is limited by law in the United Kingdom to 200 ppm (Stat. Inst., 1971) because of possible health hazard, and the concentration of nitrate is limited to 500 ppm because the high level of nitrate traditionally used in cured meats (2000-3000 ppm) represented potentially very high levels of nitrite. Taylor and Shaw (1974) have studied the effect of omission of nitrate and reduction of nitrite level in the curing brine on the storage characteristics of vacuum packed Wiltshire bacon. Back bacon cured in 26 per cent salt brine containing 1000 ppm nitrite but no nitrate gave a product with about 4 per cent salt and 60-100 ppm nitrite in the lean. After 5 weeks storage at 5°C or 2 weeks storage at 15°C the bacon was still bacteriologically and organoleptically acceptable. When the nitrite concentration in the brine was reduced to 500 ppm or less, back bacon was more prone to souring during storage due to lactic acid bacteria.

As an integral part of the investigation the colour of bacons cured with different levels of nitrite were measured. The changes in colour during storage in vacuum packages are reported in this paper.

MATERIALS AND METHODS

Bacon manufacture. Bacon was produced at a local factory from carcasses subjected to normal Wiltshire dressing procedure. The sides were stitch-pumped by hand to gain 8 per cent of their trimmed weight, immersed in brine (26 per cent NaCl) for 5 days and then removed from the tank and stacked for 7 days at 5°C as recommended in the Code of Practice for Wiltshire Curing. Sides cured in nitrate-free brines containing 1000, 500 and 250 ppm $NaNO_2$ were compared with companion sides cured in nitrate-free brines containing 2000 ppm $NaNO_2$. The 1000 ppm and one of the 500 ppm brines (and their companion 2000 ppm brines) had been matured for use for 12 and 8 weeks respectively before the experimental sides were cured. The other 500 ppm brine and the 250 ppm brine (and their companion 2000 ppm brines) were freshly made before use.

Sample selection and storage. Portions of bacon from between the 5th and 8th ribs from 6 sides from each treatment were cut into 4 slices 1.5 cm thick after removal of the rind and the slices vacuum packed in Metathene X pouches. 5 cm thick pieces of bacon from each side, with the exception of those cured in the 500 ppm mature brine, were vacuum packed in nylon-polyethylene pouches and heated in a water bath for 1 hour at 80°C and then cooled. The pieces of cooked bacon were cut into 4 slices 1 cm thick and vacuum packed in Metathene X pouches. The packages of raw and cooked bacon were stored at 5°C and 15°C both in the dark and under fluorescent tube illumination (80 to 100 decalux).

Colour measurement. The uniform lightness ($L = 10Y^{\frac{1}{2}}$) of the lean of each sample was measured on a Gardner Colour Difference Meter. It was not possible to measure the chromaticness of the colour with this instrument because the 45° incident illumination produced directional iridescence.

The reflectance spectra of the centre of the M.longissimus dorsi of the two most typical sets of samples from each treatment were measured on an Optica CF4DR recording spectrophotometer with normal illumination and diffuse viewing. The spectra were measured relative to pressed barium sulphate calibrated to the ideal uniform diffuser (Wyezecki, 1973). The C.I.E. (1931 standard observer, source C) tristimulus values X, Y, Z and the chromaticity coordinates x and y were calculated by the weighted ordinate method at 10nm intervals between 400 and 700nm. The dominant wavelength λd (a measure of hue) and the per cent excitation purity Pe (a measure of saturation) were obtained from the chromaticity coordinates (Wyszecki and Stiles, 1967).

The Kubelka-Munk absorption coefficient K and the scatter coefficient S (unit thickness of 1 mm) were calculated from the values of Y of 2 mm thick slices mounted on a white background and of optically infinitely thick slices (MacDougall, 1970).

Chemical analyses. Nitrite and nitrate were estimated by the method of Follet and Ratcliffe (1963). Sodium chloride was estimated by precipitating the chloride with excess of silver nitrate and titrating the excess with potassium thiocyanate.

Total pigment was measured as haematin by a modification of the method of Hornsey (1956).

pH was measured in a 1 : 10 distilled water macerate.

RESULTS

Initial colour. Table 1 shows the mean values of pH, total pigment, salt, nitrite and colour of the raw lean at the beginning of storage. NaCl concentrations ranged from 3.5 to 4.5 per cent and $NaNO_2$ concentrations in the bacon were in approximate proportion to the concentration in the brine, ranged from 5.6 to 9.4 per cent of that in the brine. 12 of the 16 samples whose colour was measured by the spectrophotometer had their luminous absorption (K) and scatter (S) coefficients determined. K increased with increase in pigment concentration with values between 0.30 and 0.38 for haematin concentrations between 30 and 50 ppm and values >0.39 for haematin concentrations >50 ppm. The values of S, range 0.10 to 0.19, were unrelated to the bacon's final pH. S in bacon varies with the paleness of the pork from which it is manufactured (MacDougall, 1970) and depends on the rate of post-mortem glycolysis. Variation in S would account for most of the differences in lightness between samples.

With the exception of the bacon cured in the 250 ppm nitrite brine, there were no colour differences attributable to nitrite level. The chromaticity coordinates x and y and the values of dominant wavelength λd and excitation purity Pe show that the hue and saturation of all samples were similar. Of the 6 sides cured in the 250 ppm nitrite brine, 4 had uncured circular cores approximately 2 cm in diameter in the centre of the M. longissimus dorsi. The uncured areas were lighter (larger values of L and Y), their chromaticity coordinates were different (x was smaller) and λd was considerably less red. Values for both cured and uncured areas are given in Table 1.

The cooked bacon, with the exception of the uncured areas in the bacon cured in the 250 ppm nitrite brine, was also uniform in colour, particularly in hue and saturation. Y ranged from 37.4 to 44.3, λd ranged from 587 to 591 nm and Pe ranged from 13 to 15 per cent. The uncured cooked area was lighter (Y of 48.3) and much less red (λd of 582 nm).

Colour changes during storage. Nitrite loss during storage has been described in detail by Taylor and Shaw (1974); after 5 weeks at 5°C or 2 weeks at 15°C bacon cured with 2000 ppm nitrite brine contained 100 ppm, bacon cured with 1000 ppm nitrite brine contained 25 ppm, bacon cured with 500 ppm nitrite brine contained 10 ppm and in bacon cured with 250 ppm nitrite brine nitrite was hardly detectable.

With the exception of the uncured areas, there were only small changes in the chromaticity of the raw bacon during storage either in the dark or under flourescent tube illumination; after 5 weeks at 5°C λd ranged from 589 to 603 nm and Pe ranged from 17 to 20 per cent, and after 5 weeks at 15°C λd ranged from 587 to 596 nm and Pe ranged from 13 to 20 per cent. Although the hue and saturation remained virtually unchanged the colour became lighter and this rate of increase in lightness was temperature dependent; after 5 weeks at 5°C Y had increased by 1.5 units and at 15°C Y had increased by 3.9 units. Since x and y remained constant it follows that all three tristimulus values increased concomitantly (Figure 1). Examination of the reflectance spectra showed that the state of the pigment in the centre of the M.longissimus dorsi did not change. Conversion of reflectance to the ratio K/S (Judd and Wyszecki, 1963) indicated that the increase in lightness with storage was due to increase in the light scattered by the tissue. Figure 2 shows the mean initial, 2 weeks and 5 weeks spectra for the 16 samples stored at 15°C. The shape of the curves are almost identical indicative of no change in absorption, but after 2 weeks S increased by 15 per cent and after 5 weeks by 35 per cent. The visual size of these colour differences would be quite distinct in side by side comparison but because of the constancy of hue and saturation they are of no importance.

The uncured areas in the bacon cured with 250 ppm nitrite became greyer on storage; Pe decreased to 10 per cent with the formation of strong metmyoglobin absorption at 630 nm.

The colour of the cooked bacon hardly changed during storage; after 5 weeks at 5°C or 15°C λd increased by approximately 2 to 4 nm and Pe decreased by approximately 1 to 3 per cent. The uncured areas, which were easily distinguishable after cooking and packing, shrank to half their size after 1 week's storage and by 2 weeks it was impossible to measure them accurately.

Metmyoglobin conversion to nitrosylmyoglobin. Before vacuum packing, there were small brown areas on the ventral edge of the M.longissimus dorsi caused by oxidation of the pigment to metmyoglobin during curing and maturation. After packing these discoloured edges disappeared within 4 days at 5°C or 1 day at 15°C. The muscle became uniform in chromaticity across its entire area. To confirm that metmyoglobin formed by exposure to oxygen is subsequently converted to nitrosylmyoglobin, samples of bacon were first vacuum packed and held at 5°C for 2 days until the brown edges became pink. The bacon was then wrapped in polyvinylchloride film to prevent moisture loss and exposed to air for 2 days at 5°C under 100 decalux until the surface was predominantly metmyoglobin (strong absorption at 630 nm). It was again vacuum packed and stored for a further 2 days at 5°C when the surface colour became pink and the absorption band at 630 nm disappeared.

DISCUSSION

This investigation has clearly demonstrated that the complete development of cured colour is not assured when bacon is manufactured by the Wiltshire process with brine containing only 250 ppm nitrite. At this level the bacon also spoiled. Using brine containing 500 ppm nitrite, bacon colour was indistinguishable from that made in brine containing 2000 ppm nitrite, but in the bacon made in the 500 ppm nitrite brine there was the risk of spoilage by lactic acid bacteria. It is bacteriological stability and not colour stability which defines the lowest limit of nitrite to be used in curing (Shaw, 1974).

When bacon was vacuum packed residual metmyoglobin was converted to nitrosylmyoglobin and thus the vacuum packed product had a more uniform appearance than freshly cut material. This uniform bright pink-red colour was found to be stable under flourescent tube illumination of the intensity encountered in shop display; moreover the colour was stable for the entire 5 weeks storage period although by the end of the period much of the bacon had obviously spoiled. The consumer buys vacuum packed bacon on its colour and price but since the colour is so stable it cannot be considered a good indicator of shelf-life or quality, except in the case of punctured or torn packs where the colour deteriorates to brown due to metmyoglobin formation. This emphasises the necessity for defining a realistic shelf-life, for date stamping for last day of purchase and for good refrigeration practice at the point of sale.

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Table 1. Analysis of raw bacon at beginning of storage

	Nominal concentration of $NaNO_2$ in brine (ppm)								
	2000	1000[a]	2000	500[a]	2000	500[b]	2000	250[b]	
Brine, $NaNO_2$ (ppm)[c]	1870	960	1980	490	1980	500	2130	270	
Lean, $NaNO_2$ (ppm)	170	81	150	34	144	28	143	17	
Lean, NaCl (%)	4.5	4.5	4.5	4.5	3.7	3.9	4.2	3.5	
Lean, pH	5.95	5.90	5.70	5.75	5.60	5.60	5.70	5.80	
Haematin (ppm)[d]	46	45	34	33	44	43	41	36	Uncured areas
Uniform Lightness, L	35	36	35	35	32	32	35	35	40
CIE colour co-ordinates Y	16.0	16.1	16.7	16.8	13.1	12.7	15.1	13.7	22.4
x	0.366	0.360	0.362	0.362	0.369	0.365	0.372	0.373	0.349
y	0.339	0.335	0.340	0.336	0.330	0.329	0.335	0.332	0.342
Dominant wavelength λd (nm)	590	591	588	591	597	597	594	596	583
Exitation purity Pe (%)	21	18	21	19	19	18	21	21	18

a. Mature brine, b. Fresh brine, c. 1000 ppm = 14.5 μ mol/g, d. 100 ppm = 153.5 n mol/g.

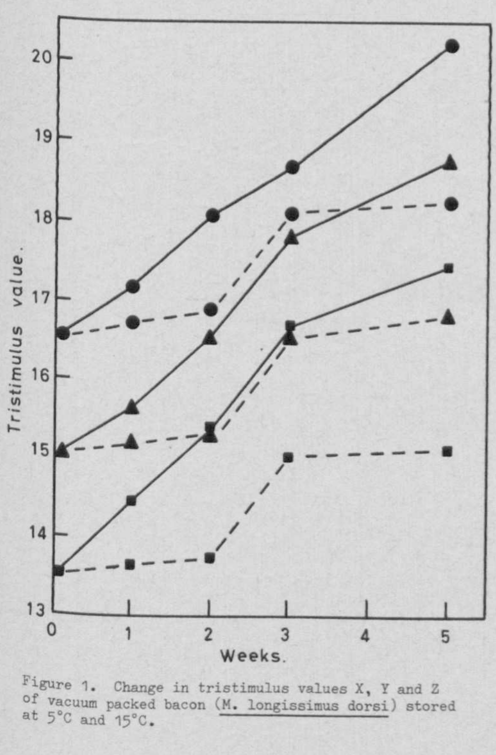

Figure 1. Change in tristimulus values X, Y and Z of vacuum packed bacon (M. longissimus dorsi) stored at 5°C and 15°C.

● X, ▲ Y, ■ Z, - - - - 5°C, —— 15°C.

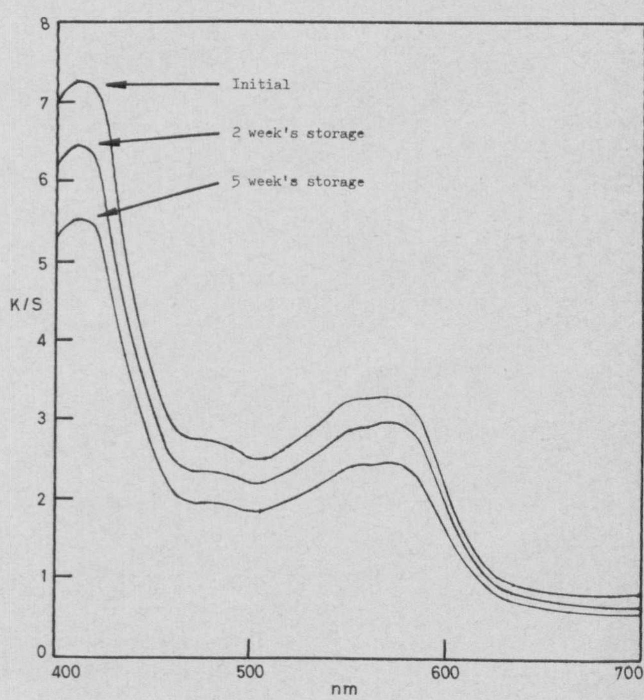

Figure 2. Change in K/S function of reflectance of vacuum packed bacon (M.longissimus dorsi) stored at 15°C.