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MEAT COLOR CHANGES UNDER HIGH PRESSURE TREATMENT

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INTRODUCTION: High pressure (above 100 MPa) technology is of common use in a variety of industrial processings (diamonds, ceramics, alloys, electronics...). Effects of high pressure on biological materials have been reported long ago, at the dawn of this century, regarding egg white coagulation or microorganisms destruction but practical application to the food industry was not considered until the last 10 years. In the present time, outcomes are expected mainly in the field of food texturization, using the potential of high pressure to promote protein gelling and in food preservation with the aim of minimizing changes in organoleptic and nutritional properties that currently result from thermal treatments.

It has been reported that pressurization of meat above 150 MPa not only reduce bacterial counts but may also induce color changes in the sample (Carlez *et al.*, 1993). This latter effect can be seen as likely to reduce the scope of applications of the treatment.

The aim of the present work is to pin-point the mechanism responsible for color changes. Three hypothesis have been considered:

- Cleavage of heminic ring.
- Precipitation of proteins.
- Oxidation of myoglobin.

MATERIAL AND METHODS:

Studied meat products: - Fresh minced meat: Pork (m. *Gluteus superficialis*) and Beef (m. *Semimembranosus*).
- Cured minced meat: (muscles: as above, salt: 20 g/kg, sodium ascorbate: 300 mg/kg, Sodium nitrite: 120 mg/kg)
- Cooked ham: (curing as above, cooking: internal temperature 68°C)

Treatment: Samples (150 g portions) are vacuum-packaged in polyethylene pouches (residual pressure : 20 hPa) and stored in the dark (wrapped in aluminum foil) at + 4°C until use.

High pressure treatments (20°C, 30 mn, 600 MPa) were applied, using a pilot-scale prototype designed by Ateliers et Chantiers de Bretagne, Nantes, France. Water was used as the pressure-transmitting fluid to a high pressure vessel with a 3.3 l capacity (h = 0.3 m, D = 0.12 m). Maximum admissible pressure was set to 650 MPa. It takes about 2 minutes to reach the operating 600 MPa pressure and one minute to depressurize to ambient atmosphere.

Measurements:

Color: L*, a* and b* color values were measured using a Micro-color Dr Lange (Berlin, Germany). Each measurement was repeated 9 times.

Total pigments were determined according to Hornsey (1956) and non heminic iron according to Schricker *et al.* (1982).

Protein extractibility: Sample (15 g) is homogenized (Polytron, 10,000 t/mn, 1 mn) with 150 ml phosphate buffer 0.04 M, pH 7.2, stored 24 h at + 4°C and then centrifuged (10.000 g, 30 mn, + 4°C). Residues, homogenized (Polytron, 10.000 t/mn, 1 mn) with 150 ml Weber-Edsall solution, were left 24 h at + 4°C and then centrifuged (40.000 g, 1 h, + 4°C). All the supernatants are frozen as soon as collected and stored for later freeze-drying and nitrogen determination. Three replicates were studied in any set of experimental conditions.

Further investigations have been carried out on myoglobin: oxymyoglobin and nitrosylmyoglobin solutions were prepared from metmyoglobin (Sigma, horse muscle) stock solution. Metmyoglobin, dissolved (2 mg/ml) in sodium phosphate-citrate buffer, pH 5.2, reduced with sodium dithionite, was either oxygenated by air bubbling or treated by addition of sodium ascorbate and nitrite (molar ratio ascorbate+nitrite/myoglobin 100/1). Derivatives formation was checked spectrophotometrically. Myoglobin solutions were poured into 15 ml polyethylene flasks and subsequently submitted to high pressure (150 MPa, 300 MPa, 450 MPa and 600 MPa, 30 mn, 20°C). Absorbance spectra of control and pressurized samples were recorded from 400 to 700 nm (spectrophotometer Cary 1/3, Varian). Three replicates were studied in any set of experimental conditions.

RESULTS AND DISCUSSION:

Excepted cooked ham, which color proved stable, samples turned to paler colors under high pressure treatment. Beef samples and fresh pork showed a more or less brownish/greyish tone while cured pork remained red. The color change can be traced from parameters L*, a* and b* as shown in Fig. 1. Whatever pork or beef is considered, L* increase is noticeable, ranging from 45 up to more than 70 for the former and from 38 up to 55 for the latter. All samples but cured pork yielded higher values for a* and b*.

Evidenced increase of L* can result either from lower concentration of active pigment in treated samples, suggesting that porphyric ring could have been damaged to some extend, or from protein coagulation, affecting structure of the sample and surface properties, that in turn may have increased the share of reflected *vs* absorbed light.

Data obtained on samples contents in total pigments and non heminic iron (not displayed here) are very close for control and pressurized samples ruling out hypothesis involving ring breakdown. On the contrary, extractibility of sarcoplasmic and myofibrillar proteins appears to be highly depressed by high pressure (results obtained at 600 MPa are shown Fig. 2 and 3). Drop in protein extractibility is higher for pork than for beef meat while ham looks totally different. Recorded variations for L* show an inverse relationship with variations of solubility of sarcoplasmic proteins. Heat coagulation of ham proteins on cooking accounts for their low solubility indexes that were found to fit with the literature (Rougié *et al.*, 1976). Whilst absence of effect on heat-sensitive sarcoplasmic proteins was expected, the apparent increase in solubility of myofibrillar proteins remains questionable.

Studies carried out on oxymyoglobin and nitrosylmyoglobin solutions make clear that recorded variations for a* and b* can be related to changes in the chemical state of myoglobin and support the assumption that high pressure trigger two concomitant procedures (Fig. 4 and 5). According to the proposed scheme, a noticeable part of the pigment precipitates that is grossly connected with applied pressure (for instance, rising pressure from 150 to 300, 450 and 600 MPa leaves respectively 100, 64, 48 and 37% of oxymyoglobin and 100, 96, 84 and 48% of nitrosylmyoglobin in the soluble state), while oxidation of oxymyoglobin to metmyoglobin takes place progressively. At the difference of oxymyoglobin, owing to the antioxidant capacity of nitrite (Zubillaga *et al.*, 1984), nitrosylmyoglobin is left unaffected.

Experimental data recorded for a* and b* can be considered in the light of this proposal :

Increases of a* (red) and b*(yellow), recorded on fresh meat samples, are consistent with formation of metmyoglobin both on the qualitative (color shifts toward brownish tones) and the quantitative grounds (beef meat contains five times as much pigment as pork meat). Considering experimental values of nitrite/pigment molar ratio in cured samples, it is not surprizing that nitrite affords total protection against oxidation to pork meat (25/1) wheras protection is only partial for beef meat (5/1). Cooked ham contains nitrosated pigment in the form of heat stabilizated nitrosylmyochromogen (Lee and Cassens, 1976) on which high pressure has obviously no effect.

CONCLUSION:

High pressure induces changes in the color of meat according to an ubiquous scheme involving coagulation of proteins responsible for a shift toward lighter tones and myoglobin oxidation to metmyoglobin yielding a brownish/greyish turning that can be prevented by means of nitrite.

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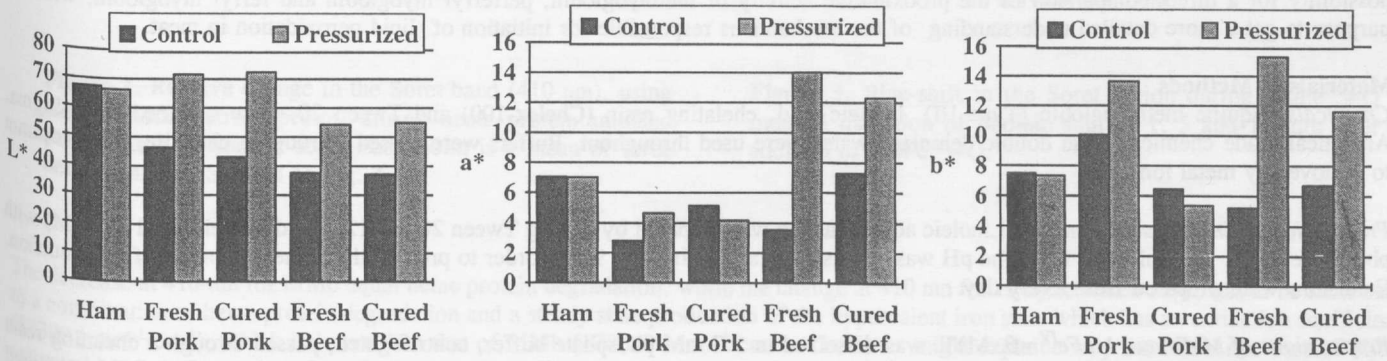

Fig.1: Effect of high pressure (600 MPa, 30 mn, 20°C) on color values L*, a* and b*

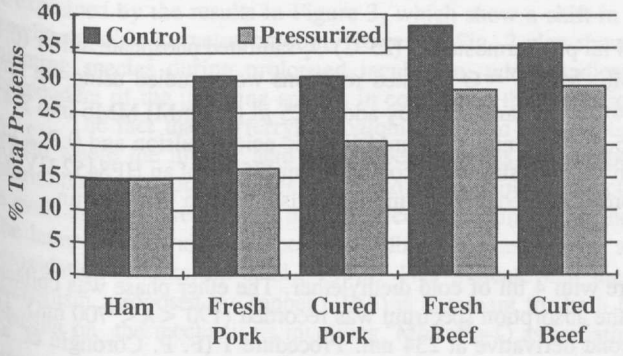

Fig. 2: Extracted Sarcoplasmic Proteins (+ NPN)

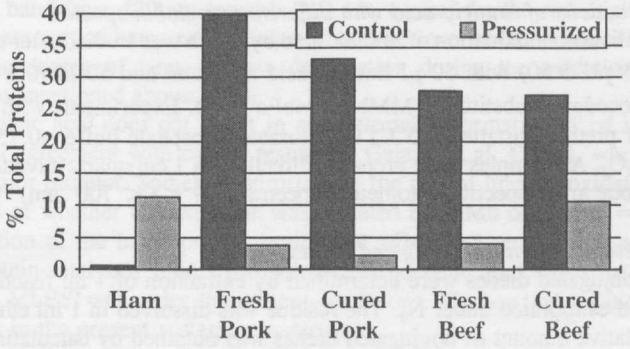

Fig. 3: Extracted Myofibrillar Proteins

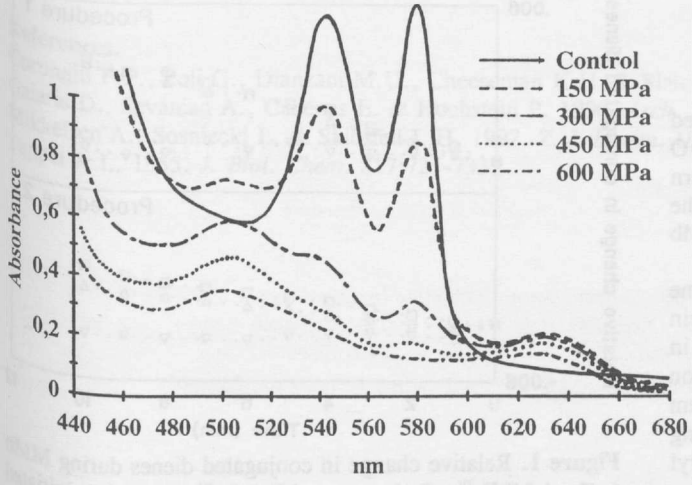

Fig. 4: Effect of high pressure on oxymyoglobin.

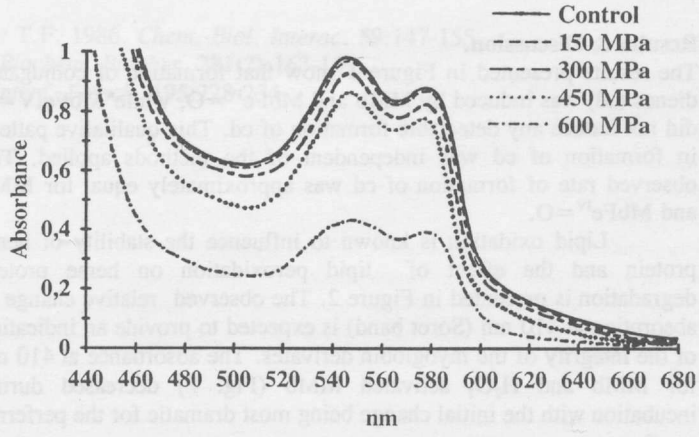

Fig. 5: Effect of high pressure on nitrosylmyoglobin.