PE4.36 Effect of high pressure processing, temperature, and storage on the color of pork longissimus dorsi 129.00

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***Abstract*—Color is one of the most important quality attributes for the consumer when purchasing meat. High pressure processing (HPP) has the ability to preserve flavor and nutrients better than thermal processing. The effect of HPP on meat color is therefore an interesting area of research. In the present study, the effect of HPP on the color of pork *longissimus dorsi* (*LD*) was investigated via CIE 1976 L*a*b* values and reflectance spectra for pressures in the range 200-800 MPa in combination with the effect of processing temperature (5 or 20 °C), during a storage period of six days after pressurization. There seemed to be a threshold at around 400 MPa. Samples treated at pressures above this threshold obtained almost similar L*a*b* values, being lighter, more red, and slightly more yellow than meat samples treated at lower pressures. HPP at 20 °C compared to 5 °C resulted in meat samples which were less red and with a tendency towards being lighter in color. A clear effect of storage was seen, most notably within the first day of storage. From immediately after HPP to one day after treatment, samples became significantly darker, less red, and more yellow. The reflectance curves showed – regardless of pressure and temperature of treatment – that an unknown, short-lived myoglobin form with a peak at about 540 nm formed as a result of HPP. The myoglobin species disappeared again within only one day of storage. There appeared to be a spectral shift of about 20 nm downwards compared to oxyMb. Further investigations into the nature of this myoglobin compound are to be conducted in the near future.**

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***Index Terms*—Color, High Pressure Processing, LD, Pork, Storage, Temperature.**

I. INTRODUCTION

HIGH pressure processing (HPP) is an emerging technology in food science with a great potential within the area of meat science. The effect of HPP is different from that of thermal processing since HPP is said to affect only non-covalent bonds. The method thus has the ability to preserve flavor and nutrients while inactivating spoilage bacteria and pathogens.

Color is one of the most important quality attributes for the consumer when purchasing meat [4]. The effect of HPP on meat color is therefore an interesting area of study. Meat color is determined by the amount and chemical state of the hemoproteins present as well as by the structure of the meat. The main hemoprotein in meat is myoglobin, which in raw meat is present in the three forms: the bright red oxymyoglobin (oxyMb), the purple deoxymyogloin (deoxyMb), and the brown metmyoglobin (metMb). The former two have iron in the ferrous (Fe^{2+}) state, while metMb has iron in the ferric (Fe^{3+}) state [3]. In fresh meat, there is a constant interconversion between the three myoglobin forms [3].

Meat color is traditionally measured by the tristimulus parameters L*a*b* in the CIE 1976 (Commission International de l'Éclairage) color space. In this color space, L* designates lightness, positive a* values mean red, negative a* values green, positive b* values yellow, and negative b* values blue color [2]. Even though the L*a*b* values describe a specific point in the color space, they do not reveal the relative amount of each myoglobin species on the meat surface. This can be done using reflectance spectra.

In this paper, the effect of HPP on the color of pork *longissimus dorsi* (*LD*) was investigated via L*a*b* values and reflectance spectra for a wide range of pressures in combination with the effect of processing temperature, and a storage period after pressure treatment.

II. MATERIALS AND METHODS

A. Pork meat samples

Four vacuum packed pork *LD* of normal pH were purchased from a local meat market (Inco,

Copenhagen, Denmark) on four different occasions, resulting in four experimental runs with a total of 16 *LD* muscles. The meat was kept at 2 °C for three days until commencement of experiments. The *LD* muscles were trimmed from fat and epimysium. The middle part of each *LD* was then cut into ten slices of approximately 2 cm in thickness. The samples were vacuum packed individually into vacuum bags. Samples were kept at 2 °C in the dark for one day until HPP in order to promote development of deoxyMb. The initial color of the meat samples was expected to be more similar than without this day of storage prior to HPP.

B. High pressure processing

One sample from each *LD* was randomly assigned to one of the nine pressure levels (200, 250, 300, 350, 400, 500, 600, 700, and 800 MPa) and unpressurized control (0.1 MPa). The vacuum packed meat samples were submerged in the pressurizing chamber of a QUINTUS Food Processing Cold Isostatic Press QFP-6 (Avure Technologies AB, Västerås, Sweden) with a pressure chamber of 0.9 L and a maximum operating pressure of 900 MPa reached in two minutes. The pressure transmitting medium was water thermostated at either 5 °C or 20 °C. Automatic depressurization took place after 10 minutes of HPP.

C. Minolta color measurements

Meat color of control and pressurized samples was measured using a Konica Minolta Spectrophotometer CM-600d and the corresponding Color Data Software CM-S100w SpectraMagic™ NX (Konica Minolta Sensing, Inc., Japan). The instrument is capable of producing both the traditional L*, a*, and b* values as well as reflectance curves. Color was measured through the vacuum bags immediately after pressure treatment (day 0), as well as on days 1, 2, 3, and 6 of refrigerated storage (2 °C in the dark). Measurements were conducted five times on each sample on every occasion, and the average was used in the calculations.

D. Data analysis

Statistical analysis was carried out with SAS version 9.1 (SAS Institute Inc., Cary, North Carolina, USA). The mixed procedure was applied to calculate least squares means (LSM) and standard errors (SE) and the option Pdiff was used to calculate significant differences between LSM. The statistical model included treatment pressure, length of storage period (day), processing temperature and all two-way interactions as fixed effects and *LD* as random effect. With $P < 0.05$, the effect is considered significant, while $0.05 < P < 0.10$ indicates a trend. After concluding that there was a clear effect of treatment (control vs. pressurized samples – results not shown), control samples were omitted from further analyses.

III. RESULTS AND DISCUSSION

Results of the analysis of variance are given in Table 1.

Table 1. Effect of pressure, day (storage), and temperature on L*, a*, and b*

Variable	P-value		
	L*	a*	b*
Day	0.0029	0.0001	0.0001
Pressure	0.0001	0.0001	0.0001
Temp	0.0519	0.0392	0.5156
Day*Temp	0.0044	0.0001	0.1667
Day*Pressure	0.8431	0.0001	0.0001
Pressure*Temp	0.0001	0.0001	0.0095

It is seen that lightness was affected by pressure and storage, and there was a trend towards an effect of processing temperature as well (higher temperature resulting in lighter meat samples). Significant interactions of temperature with both storage (Fig. 1) and pressure (Fig. 2) were observed. The L* value was significantly higher after HPP at 20 °C than at 5 °C immediately after pressurization. This difference was not seen during the following storage period (Fig. 1). An increase in L* up to 350 MPa, and a slight decrease after 400 MPa was observed. Below 300 MPa, pressure was more significant for L* than temperature. Pressurization at 20 °C resulted in significantly higher L* values than 5 °C at 300-500 MPa and at 700 MPa (Fig. 2).

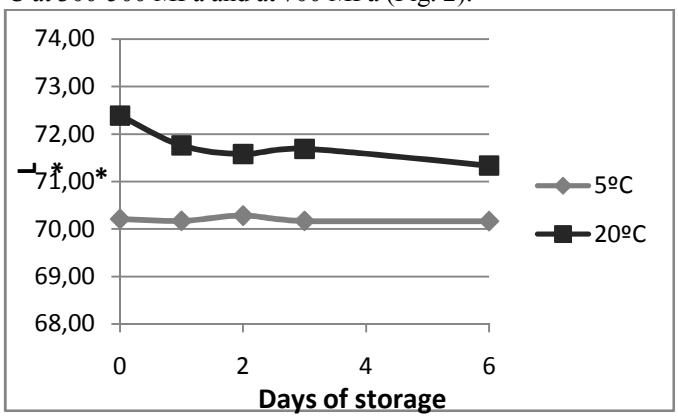

Figure 1. L* value during storage after HPP at 5 and 20 °C. Significant difference ($P < 0.05$) between temperatures in L* is seen on the day marked with *. Pooled standard error = 0.53, n = 8.

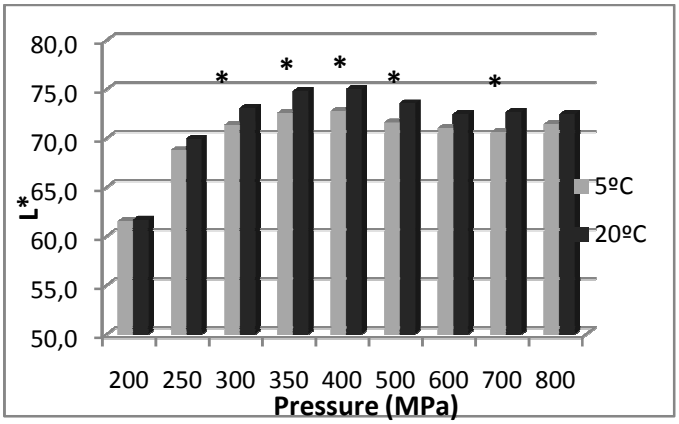

Figure 2. Effect of pressure and temperature on the L* value. Significant difference (P < 0.05) between temperatures at the various pressure levels (average for all days) in L* is seen at the pressures marked with *. Pooled standard error = 0.54, n = 8.

Redness was significantly affected by pressure, storage time, temperature, and their interactions (Table 1). Pressure increased a* with the most red samples at 500-700 MPa. There was a decrease in a* with increasing storage time. A temperature increase caused a decrease in redness. The difference between temperatures in a* was significant only immediately after pressure treatment, not during storage, with samples pressurized at 5 °C having higher a* values (Fig. 3). Up to 400 MPa, there was a large effect of temperature on a*, but up to about 300 MPa, pressure was still very influential as seen from Fig. 4.

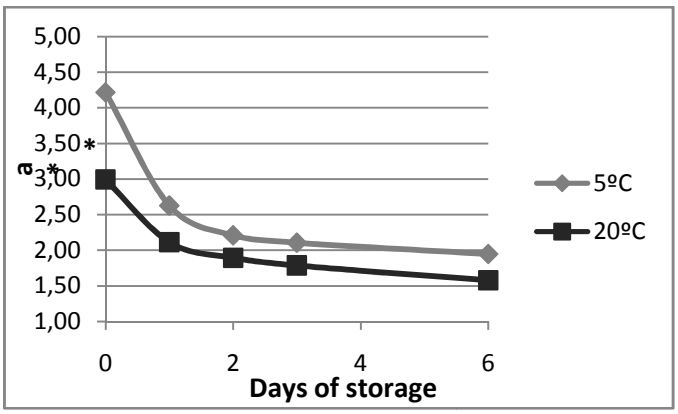

Figure 3. Significant difference (P < 0.05) between temperatures on the different days of storage after HPP in a* is seen on the day marked with *. Pooled standard error = 0.18, n = 8.

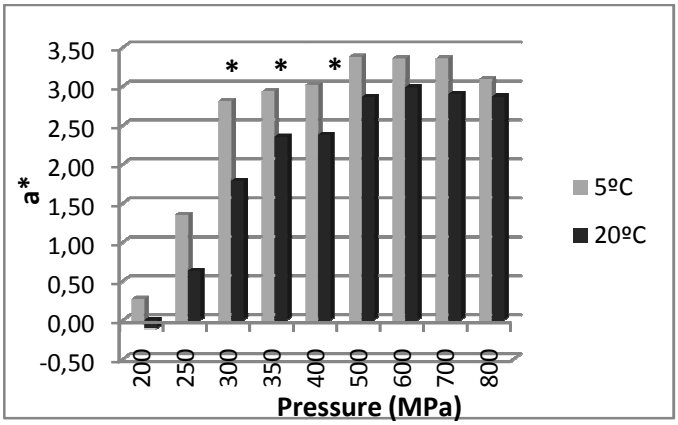

Figure 4. Significant difference (P < 0.05) between temperatures at the various pressure levels (average for all days) in a* is seen at the pressures marked with *. Pooled standard error = 0.18, n = 8.

Yellowness was significantly affected by pressure. At 200 MPa, b* was significantly lower than for the remaining pressures, with maximum b* being found at 350-600 MPa (data not shown). Increasing storage time lead to an increase in b*, with maximum on days 3 and 6. The interaction between pressure and storage time was also significant, as was the interaction between pressure and temperature (Table 1).

Carlez *et al*. [1] found for minced beef, that L*-values increased significantly in the range 200-350 MPa, the meat going from red to pink. They suggested this whitening effect to be due to globin denaturation and/or heme displacement or release. At pressures of 400 MPa and above, they saw a decrease in a*-values and the meat turning gray-brown. They ascribed this effect to be due to oxidation of ferrous myoglobin into the ferric metMb. The latter effect was not observed in the present study, probably because the starting point was with myoglobin mainly in the deoxy-form, which tends to give low a*-values. Furthermore, HPP of deoxyMb results in a bis-His coordinated ferrous myoglobin, which may result in different color changes than those caused by the formation of metMb [5]. The low myoglobin content in pork compared to beef may also be at least part of the reason why no change in a* is seen at the highest pressures in the present experiment.

Fig. 5 shows the reflectance curves for meat samples treated at the various pressures at 5 °C on day 0, i.e. immediately after HPP, on a relative scale. Samples pressurized at 200 and 250 MPa were seen to stand out from the rest of the samples in that they had no peak at about 540 nm. For all the pressures where the peak at about 540 nm occurred, it was seen to have disappeared already on day 1 of storage, exemplified in

Fig. 6. The shape of the reflectance curve resembles that of oxyMb, but the maxima and minima have shifted (Fig. 6).

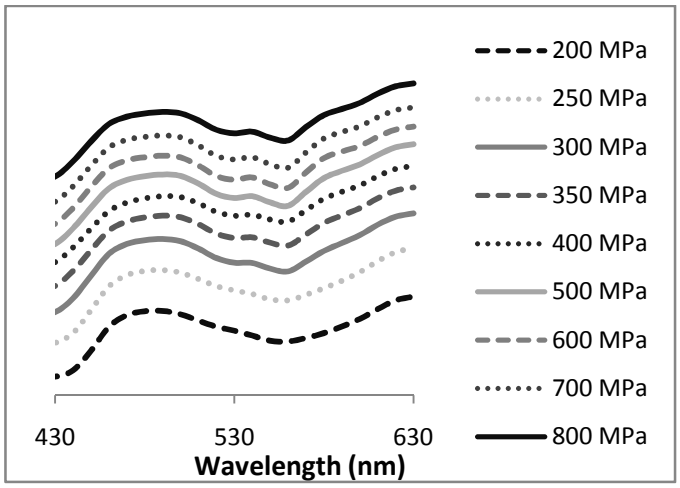

Figure 5. Reflectance curves from 430 nm to 630 nm on a relative scale for all pressures (200-800 MPa) immediately after HPP at 5 °C. Similar curves were seen for samples pressurized at 20 °C.

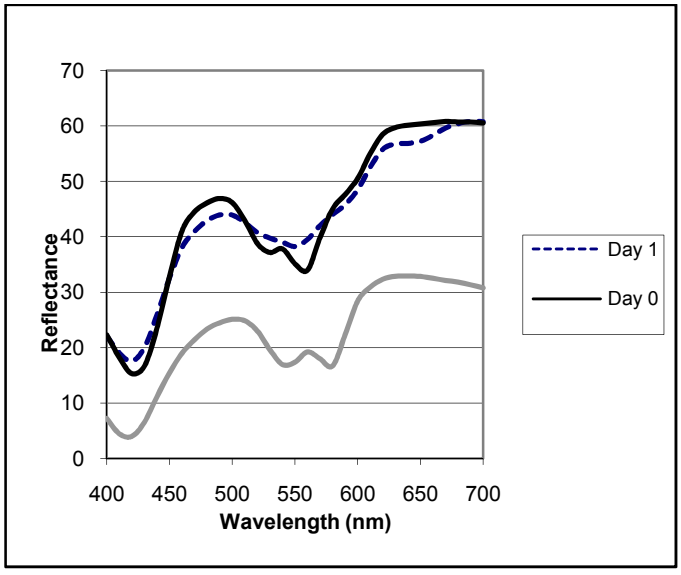

Figure 6. A typical reflectance curve on days 0 and 1, here seen for samples pressurized at 800 MPa and 20 °C. The reflectance curve for oxyMb is included as a reference.

IV. Conclusion

The effect of HPP on the color of pork *LD* was investigated via CIE 1976 L*a*b* values and reflectance spectra for pressures in the range 200-800 MPa in combination with the effect of processing temperature (5 or 20 °C), and a storage period of six days after pressurization. There seemed to be a threshold at around 400 MPa. Samples treated at pressures above this threshold obtained almost similar color attributes in the form of lightness, redness, and yellowness. HPP at 20 °C compared to 5 °C resulted in meat samples which were less red and with a tendency towards being lighter in color. A clear effect of storage was seen especially within the first day. From immediately after HPP to one day after treatment, samples became significantly darker, less red, and more yellow. The reflectance curves showed – regardless of pressure and temperature of treatment – that an unknown, short-lived myoglobin form with a peak at about 540 nm formed as a result of HPP, but disappeared within only one day of storage. There appeared to be a spectral shift of about 20 nm downwards compared to oxyMb. Further investigations into the nature of this myoglobin compound are to be conducted in the near future.

References

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