Effect of light and temperature on the colour stability of frozen minced beef

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SUMMARY

The object of the present study was to evaluate the effect of light (in a display cabinet) and temperature on the colour stability of frozen minced beef.

Frozen minced beef was produced at six different commercial meat processing plants. The product was extended with approximately 20% hydrated soy protein; the fat content was approximately 25%. The minced beef was packed in polyethylene chubs and frozen in a blast-freezer, either in cartons (about 25 in each) or individually. After freezing the samples were stored for 4 - 5 months in the dark in a freezer storage room at -24°C, after which some of the samples were displayed for a period of four weeks in the top layer of a freezer cabinet fitted with commonly used fluorescent tubes (Philips TL 18W/36). During this period the remaining samples were kept in the freezer storage room. To prevent the effect of light half of each sample in the display cabinet was wrapped in heavy black paper. To simulate a temperature abuse during transport some of the samples were stored two days in a refrigerator (+2°C) before display. During frozen storage and display the surface colour of the frozen samples was evaluated visually by trained panellists as well as measured objectively with a Hunter Colour Difference Meter.

The main discoloration on the surface of the product occur in the display cabinet, while the changes in colour during freezer storage (-24°C) for 4-5 months were quite small. Discolorations in the display cabinet was caused primarily by the light catalyzing the oxidation of oxymyoglobin to metmyoglobin. In addition, the temperature conditions in the cabinet (warmer and highly fluctuating) caused greater instability of the oxymyoglobin than a constant temperature of -24°C. The temperature abuse resulted in discoloration on the surface of samples from three of the plants. For samples from one of the remaining plants the temperature abuse resulted in a more acceptable surface colour.

INTRODUCTION

Denmark has a considerable production of frozen minced beef (often extended with soy protein). Colour problems have often been experienced for these products, the surface becoming brownish during storage due to oxidation of the reddish oxymyoglobin to the brownish metmyoglobin. As the appearance of meat is very important to the consumer it is necessary for the manufactures to know which factors determine the colour stability of the product.

Temperature, light and packaging film are some of the main external factors of significance. Previous studies in this field have been concerned with the effect of temperatures (Hustrulid et al., 1949; Winter et al., 1952; Sandberg, 1970; Santamaria, 1970; Lentz, 1979; Hunt et al., 1975; Moleeratanond et al., 1981), fluorescent light (Santamaria, 1970; Lentz, 1971; Lentz, 1979; Bertelsen and Boegh-Soerensen, 1984) and packaging film (Sandberg, 1970; Lentz, 1971; Lundquist, 1972; Hunt et al., 1975; Lentz, 1979).

However, most of these studies have dealt with frozen steaks. The present study was undertaken to evaluate the effect of light and temperature on the colour stability of frozen minced beef.

MATERIALS & METHODS

Samples

Minced beef was produced at six different commercial processing plants. The meat (often thawed frozen meat) was coarsely ground then mixed with about 20% hydrated soy protein (1 part soy protein to 3 parts water). Then the mixture was ground again. The fat content of the final product was approximately 25%.

The minced beef was packed in retail-sized (1 lb.) polyethylene (PE) chubs, and was then placed in cartons (about 25 in each). At one plant (No. 2) the chubs were frozen before being placed in the cartons. At the other plants the chubs were frozen in the cartons. At all plants the freezing process was blast freezing (air temperature about -30°C).

A few days after production, the samples were transported to the laboratory.

Packaging materials

All plants used approximately the same type of PE chubs.

The oxygen-permeability of the PE chubs was approximately 3000 cc/m^2/24 hr./atm., measured at 25°C. The material transmitted about 70% of the light of wavelengths greater than 260 nm.

Storage conditions

In order to simulate the storage conditions these products are normally exposed to, the samples (20 from each processing plant) were initially stored for 4-4½ months in the dark in a freezer storage room at -24°C. Then six samples from each plant were displayed for a period of four weeks in the top layer of a freezer cabinet which was fitted with commonly used lighting sources. During this period, the remaining samples were kept in the freezer storage room.

To simulate a temperature abuse during transport three of the six samples were stored two days in a refrigerator (+2°C) before display.

To prevent the effect of light in the display cabinet half of the surface of each sample was covered with heavy black paper (light impermeable). Once a day, five days a week, the samples in the display cabinet were moved around, to ensure uniform light and temperature exposure.

Display temperature. The samples were stored in an open top frozen food display cabinet, which was defrosted automatically once a day. The surface temperature during that period increased to max. -7°C. In the daytime - with no night cover - the surface temperature varied from -10°C to -16°C. During the night the temperature was from -17°C to -19°C.

Display lighting. The illumination was fluorescent tubes (Philips TL 18W/36), installed approximately 1 m above the product. The intensity was measured by a light meter to 520 lux (at the surface of the meat). The product was exposed to light approximately 7 hours a day, five days a week.

Colour evaluation

The surface colour of the frozen samples was evaluated during frozen storage and during display by two or tree trained panellists. During frozen storage, prior to storage in the display cabinet the evaluation was carried out in a room normally used for sensory evaluation of meat products, where the lighting was a combination of White Deluxe and Warm White Deluxe.

During display the unopened samples were scored by the same panellists in the display cabinet two or tree times a week. The samples were scored using a 0-10 scale: 10 = very fine, 8 = normal and satisfactory, 6 = defects, 4 = substantial defects, 2 = distinct defects and 0 = great defects.

A score below 6 was considered non acceptable for the consumer.

In addition, both the surface colour of the exposed and the protected part of each sample was measured objectively with a Hunter Colour Difference Meter. The measurements were carried out on wrapped samples and the results were expressed as lightness, hue and saturation.

RESULTS AND DISCUSSION

Influence of storage

Freezer storage. On arrival to the laboratory the samples were scored 6 or 7 . Samples scored 6 had a greasy appearance and at the surface of some of the samples discolorations had appeared. After storage at -24°C for 4-4½ months, the samples were scored 5, 6 or 6.5, indicating rather small changes during freezer storage.

Freezer cabinet. The changes in visual score during the display period are shown in table 1 for samples transferred directly from freezer store (I) and for samples stored two days at +2°C before display (II). The table shows the initial visual score compared to the score after 4 weeks in the display cabinet for both the exposed part (520 lux) and the part of the samples which was covered with heavy black paper (0 lux).

In addition the table shows the changes in visual score for samples stored in the same period in a freezer storage room at -24°C.

PLANT	FREEZER CABINET						FREEZER STORE	
	I			II				after
	Initial	after 4 weeks		Initial	after 4 weeks		Initial	4 weeks
		0 lux	520 lux		0 lux	520 lux		
1	7.0	6.0	4.5	7.0	6.0	4.5	7.0	7.0
2	7.0	5.5	4.5	5.2	3.5	3.5	7.0	7.0
3	6.5	6.5	6.0	6.0	6.5	6.0	6.5	6.5
4	5.0	5.5	5.0	5.0	5.0	4.5	5.0	5.5
5	6.5	6.0	5.5	7.0	6.5	5.5	6.5	6.0
6	6.0	5.0	4.0	5.3	4.0	3.0	6.0	5.0

TABLE 1. Visual score (average of 3 samples) during storage in a freezer cabinet or in a freezer storage room (-24°C in the dark). I. Transferred directly from freezer store. II. Stored 2 days at +2°C before display. The evaluation of all samples was carried out under the display lighting (Philips TL 18W/36).

From the table it is evident that the fluorescent light affects the visual appearance of all samples negatively. The visual score of the exposed part of the samples from Plant 1 for instance decreased from 7 to 4.5, while the protected part decreased only to 6.0.

Brown discolorations appeared on the illuminated parts of the samples, presumably because of the light catalyzing the oxidation of oxymyoglobin to metmyoglobin. It is essential to note that the temperature of the illuminated parts and the parts protected from light was practically the same, indicating a photo-chemical effect of the light.

The colour deterioration was reflected in the Hunterlab values. Concurrently with the decrease in oxymyoglobin the saturation index (SI) decreased (Table 2) while the hue increased. No systematic changes could be detected in the lightness during storage.

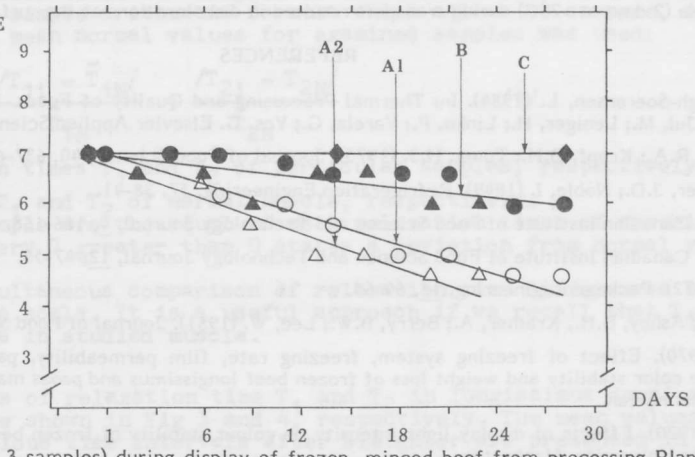
PLANT	FREEZER CABINET						FREEZER STORE	
	I			II				after
	Initial	after 4 weeks		Initial	after 4 weeks		Initial	4 weeks
		0 lux	520 lux		0 lux	520 lux		
1	16.8	15.1	12.9	17.2	15.3	12.8	16.8	17.6
2	19.7	17.9	15.9	16.9	14.5	13.1	19.7	20.3
3	16.2	16.8	15.2	17.6	17.3	15.9	16.2	17.6
4	16.7	17.0	15.0	17.2	16.5	16.1	15.7	17.5
5	12.8	14.6	13.0	16.6	15.5	14.2	12.8	12.9
6	22.1	19.1	13.4	18.6	17.4	13.9	22.1	22.5

TABLE 2. Hunterlab saturation, SI (average of 3 samples) during storage in a freezer cabinet or in a freezer storage room (-24°C in the dark). I. Transferred directly from freezer store. II. Stored 2 days at +2°C before display.

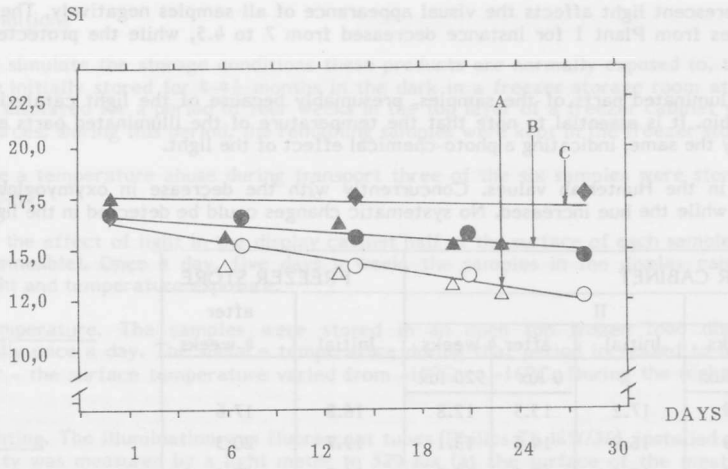
From table 1 it appears, that samples stored at a constant temperature (-24°C) had a slightly better colour stability compared to samples stored in the display cabinet at warmer and highly fluctuating temperatures. The colour of the samples in the display cabinet was less reddish than the colour of the samples in the freezer store. One reason might be that the surface temperature of samples in the display cabinet during daytime reached the temperature range (about -12°C) where the oxymyoglobin instability has a maximum (Satterlee and Zachariah, 1972).

The simulated temperature abuse influenced the appearance of samples from some plants. On the surface of samples from Plants 2, 3 and 6 brown discolorations appeared sporadically after two days at +2°C. However for samples from Plant 5 the temperature abuse resulted in a more attractive (more red) surface colour (Table 1 and 2). Originally these samples were very dark caused by a slow freezing at the processing plant. During storage at +2°C the metmyoglobin at the surface probably was reduced to oxymyoglobin which was maintained during the freezing in the display cabinet. (As previously mentioned these samples were frozen in cartons at the plant; in the cabinet they were frozen individually resulting in a faster freezing in spite of lower air velocity and warmer air temperature).

The changes in colour characteristics of the samples from processing Plant 1 in the display period are shown in fig. 1 (visual score) and fig. 2 (SI-value). Regression lines of visual score and saturation on time are presented together with the means at each determination. For light protected samples no significant differences could be detected in visual score between samples transferred directly from freezer store and samples stored 2 days at +2°C before display. Regarding saturation no differences could be detected between these two groups for either the exposed or the protected parts of the samples. Consequently they are presented by a common regression line. The figures show that both light and temperature affect the appearance of frozen, minced beef.



FIGUR 1. Visual score (average of 3 samples) during display of frozen, minced beef from processing Plant 1. A1 and A2. Displayed in the top layer of a freezer cabinet with fluorescent tubes (Philips TL 18W/36, intensity = 520 lux). Transferred directly from freezer store (A1). Stored 2 days at +2°C before display (A2). B. As A1 and A2, protected from light. C. Stored at -24°C in the dark. The evaluation of all samples was carried out under Philips TL 18W/36. ○ ● : Directly from freezer store, △ ▲ : Stored two days at 2°C before display.



FIGUR 2. Hunter saturation, SI (average of 3 samples) during storage of frozen, minced beef from processing Plant 1. A. Displayed in the top layer of a freezer cabinet with fluorescent tubes (Philips TL 18W/36, intensity = 520 lux). B. As A, protected from light. C. Stored at -24°C in the dark.
△▲and ○ ● : As fig. 1.

Correlation between visual score and Hunterlab values

Correlation coefficients were calculated between the visual score and the Hunterlab values. A fairly high correlation (0.80 - 0.90) was found between the score and the saturation (or the hue) for samples produced at processing Plants 1, 2 and 6, whereas the corresponding values were low for the other samples. The low correlation for some of the samples may be due to:

1. The panellists considered other factors than colour. For instance some samples got a rather low score because they had a greasy appearance.
2. Some samples were unevenly discoloured. The panellists gave an average score, while the Hunterlab measured a limited area of the meat surface.
3. The surface of the frozen minced beef is uneven which leads to difficulties in measuring the colour.

CONCLUSION

The main discolorations on the surface of frozen minced beef occur in the retail cabinet, while the changes in colour during storage at -24°C in the dark for 4-5 months are quite small. Discolorations are primarily caused by the cabinet lighting which catalyzes oxidation of oxymyoglobin to metmyoglobin. In addition the warmer and highly fluctuating temperatures in display cabinet caused greater instability of the oxymyoglobin than the constant temperature in the freezer store.

A temperature abuse (2 days at +2°C) during transport resulted in discolorations at the surface of some samples.

REFERENCES

Bertelsen, G.; Boegh-Soerensen, L. (1984). In: Thermal Processing and Quality of Foods. Edited by Zeuthen, P.; Cheftel, J.C.; Eriksson, C.; Jul, M.; Leniger, H.; Linko, P.; Varela, G.; Vos, G. Elsevier Applied Science Publishers, p. 711-715.

Hunt, M.C.; Smith, R.A.; Kropf, D.H.; Tuma, H.J. (1975). Journal of Food Science, 40, 637-640.

Hustrulid, A.; Winter, J.D.; Noble, I. (1949). Refrigeration Engineering, 57, 38-41.

Lentz, C.P. (1971). Canadian Institute of Food Science and Technology Journal, 4, 166-168.

Lentz, C.P. (1979). Canadian Institute of Food Science and Technology Journal, 12, 47-50.

Lundquist, B.R. (1972). Package Engineering, 17, 60-63.

Moleeratanond, W.; Ashby, B.H., Kramer, A.; Berry, B.W.; Lee, W. (1981). Journal of Food Science, 46, 829-833.

Sandberg, M.L. (1970). Effect of freezing system, freezing rate, film permeability, packaging time and display case temperature on the color stability and weight loss of frozen beef longissimus and psoas major muscles. M.S. Thesis, Kansas State University, Manhattan.

Santamaria, J.A. (1970). Effects of display light intensity on colour stability of frozen beef cuts in transparent film. M.S. Thesis, Kansas State University, Manhattan.

Satterlee, L.D.; Zachariah, N.Y. (1972). Journal of Food Science, 37, 909-912.

Winter, J.D.; Hustrulid, A.; Noble, I. (1952). Food Technology, 6, 311-318.