Encapsulation of the Cooked Cured-Meat Pigment and Irradiation of Nitrite-Free Cured Products

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SUMMARY: As part of a program to develop nitrite-free meat curing systems, we have stabilized the preformed cooked cured-meat pigment (CCMP) by its encapsulation in food-grade wall materials. The powdered cooked cured-meat pigment (PCCMP) so produced was stable for ≥18 months at refrigerated temperatures. Upon its dissolution in water or in pickle solutions, it acted as a potent colourant in nitrite-free curing systems. Meat emulsion systems which included CCMP were sterilized by a radiation process (0-10 kGy). The products so obtained had colour and flavour stability characteristics equivalent to their nitrite-cured counterparts. Thus, CCMP together with radiation sterilization may serve as a viable alternative to nitrite in the curing of meat products.

INTRODUCTION: Colour and flavour are important sensory aspects of muscle foods. Attractive colour of nitrite-cured meats is known to play an overwhelming effect in consumer acceptability of such products (Fox, 1966; MacDougall et al., 1975; Shahidi, 1989a,b). In addition, nitrite is responsible for the characteristic delicate flavour and extended shelf-life and microbial stability of cured meats (Piotrowski et al., 1970; Price and Greene, 1978; Sofos et al., 1979; Pierson and Smoot, 1982; Gray and Pearson, 1984). Nitrite is also known to be responsible for formation of certain N-nitrosamines in some cured products under specific conditions (Sen et al., 1973; Gray, 1976; Gray and Randall, 1979). Thus, formulation of nitrite-free ingredients in the curing of meat products is desirable (Sweet, 1975).

We have previously reported several nitrite-free mixtures for the curing of comminuted and solid cuts of meat from different species ranging from cod to red meat and poultry, including myoglobin-rich seal meat (Shahidi and Pegg, 1990; Shahidi et al. 1990; Shahidi and Pegg, 1991a). An essential ingredient of all of these non-nitrite curing mixtures was the preformed cooked cured-meat pigment (CCMP) (Shahidi, 1989a; Shahidi et al., 1990). It was formed either directly from bovine red blood cells or indirectly via a hemin intermediate (Shahidi et al., 1984, 1985; Shahidi and Pegg, 1988, 1991c). The pre-formed CCMP successfully duplicated the colouring effects of nitrite in meats.

The objectives of present study were to a) protect the CCMP from light and oxygen by its encapsulation and b) to examine the effects of irradiation on the colour and flavour stability of CCMP-treated meat samples.

MATERIALS AND METHODS: Materials - All chemicals used in this study were reagent-or food grade and were used without further purification. The CCMP was prepared as described previously (Shahidi et al., 1985; Shahidi and Pegg, 1988, 1991c). β-cyclodextrin was provided by Toyomenka (America, Inc., New York). N-LOK was acquired from National Starch and Chemical Corporation (Bridgewater, New Jersey) and Maltrin M-250 was supplied by the Grain Processing Corporation (Muscatine, Iowa).

Post-rigour pork loins were obtained from Newfoundland Farm Products Corporation (St. John's, Newfoundland). They were comminuted using a Braun Meat Mincer after removal of their subcutaneous fat. Meat emulsion systems were prepared by addition of 20% by weight of water and other ingredients to samples. Meats were cooked in Mason jars for 40 min to reach an internal temperature of 75 ± 2°C. After cooling, samples were homogenized and packaged in polyethylene pouches (Eastern Paper Company, St. John's, NF).

Preparation of the Powdered Cooked Cured-Meat Pigment (PCCMP) - An emulsion of the CCMP and encapsulating agents were formulated prior to spray drying. Encapsulating agents were generally employed at a 1.5% (w/w) level. The emulsion generally contained 3.5 to 10.0% (w/w) solids. Emulsions were spray dried using a Büchi Mini Spray Dryer, Model 190, (Büchi Laboratory - Techniques Limited, Flawil, Switzerland). Its inlet temperature was ≥150°C, outlet temperature 98°C and feed flow 5.5 $ml \cdot min^{-1}$ using a nitrogen pressure of 375 kPa(g).

Radiation Treatments - Pigment and nitrite-treated samples were placed in 2 L beakers containing ice and were irradiated in a Gammacell 220 (AECL) at a dose rate of 0.180 $kGy \cdot min^{-1}$ for 28 or 55.5 min to obtain 5 and 10 kGy doses, respectively. All samples were then analyzed for their colour and oxidative states.

Colour Evaluation - The colour of meat samples, before and after irradiation, was determined using a colorimeter (Model XL-20 Tristimulus Colorimeter, Gardner Laboratory, Inc., Bethesda, MD). Hunter L (lightness/darkness), **a** (+/-, red/green) and **b** (+/-, yellow/blue) values were measured. The colorimeter was standardized as described elsewhere (Shahidi and Pegg, 1988, 1991b). The Hunter **L**, **a**, **b** values were measured at 5 different locations on the meat surface.

Oxidative Stability - Oxidative state of treated meats were monitored by determining their 2-thiobarbituric acid (TBA) values as described previously (Shahidi et al. 1987). For nitrite-cured meats, if necessary, sulfanilamide was added to the mixtures as described elsewhere (Shahidi, 1989a; Shahidi et al., 1991). The TBA numbers, mg malonaldehyde equivalents per 1000 g sample, were calculated by multiplying the measured TBA absorbance units at 532 nm by 8.1 (Shahidi et al. 1987).

RESULTS AND DISCUSSION: Only typical results of the Hunter **a** values (redness) of meats treated with encapsulated CCMP in individual wall materials, namely N-LOK, β-cyclodextrin (CD), and Maltrin M-250 are given in Table 1. Storage of the PCCMP samples for up to 20 months at refrigeration temperatures had little effect on their colour-imparting potency as reflected in Hunter **a** values of the treated meat samples. Furthermore, protection of CCMP by the above-mentioned wall materials was nearly similar. In comparison with their nitrite-cured counterparts, CCMP- and PCCMP-treated meats showed a red colour effect which was similar to that of meat treated with 156 ppm sodium nitrite (Shahidi and Pegg, 1990).

Absorption characteristics of PCCMP in the visible region were similar to that of freshly-prepared CCMP and that of pigment extracted from a nitrite-cured (Hornsey, 1956) or a CCMP-treated meat sample. Thus, it might be deduced that encapsulation of CCMP did not cause any changes in its chemical integrity.

Table 2 summarizes the Hunter **a** values of meat samples cooked with CCMP and irradiated at 5 or 10 kGy, as a function of storage time at refrigeration temperature and as compared with those of nonirradicted meats. All samples became less pinkish upon storage as Hunter **a** values decreased after a 3-week storage period. However, in comparison with nitrite-cured meats, CCMP-treated samples showed a slightly higher **a** value after 3-week storage. Furthermore, the decrease in Hunter **a** values in nitrite-cured meats averaged 1.5±0.1 units while it was 1.0±0.2 units for CCMP-treated samples. Thus, it might be concluded that the residual nitrite present in traditionally cured meats has no influence on their colour fixation during radiation processing.

Flavour stability and oxidative state of irradiated samples, as determined by their TBA values is shown in Table 3. Generally, meat samples had a smaller TBA value after their irradiation at either 5 or 10 kGy dose. Furthermore, the TBA of CCMP-treated samples after irradiation was increased to a lesser extent than those of their untreated counterparts. Thus, in addition to colouring effects of CCMP, its weak antioxidant effect coupled with beneficial effects of irradiation, and possible use of C and E vitamins might provide another method for preservation of cooked nitrite-free meat products.

ACKNOWLEDGEMENTS: Financial support from the National Sciences and Engineering Research Council of Canada is gratefully acknowledged.

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Table 1. Effect of encapsulation on the Hunter a values of treated meats during 20-month storage.[a]

Additive (ppm)/Wall Material	Storage Period, Months	Hunter a Value
None/None	0	4.7 ± 0.1
$NaNO_2$(156)/None	0	11.8 ± 0.2
CCMP(12)/None	0	11.7 ± 0.2
CCMP(50)/None	0	12.9 ± 0.1
CCMP(50)/N-LOK	0	11.9 ± 0.2
	9	10.9 ± 0.2
	18	10.4 ± 0.2
CCMP(50)/CD	0	11.7 ± 0.1
	11	11.2 ± 0.2
	20	10.9 ± 0.3
CCMP(50)/M-250	0	11.6 ± 0.1
	9	10.3 ± 0.2

[a] CCMP, cooked cured-meat pigment; CD, β-cyclodextrine and M-250, Maltrin M-250.

Table 2. Effect of irradiation on Hunter a value of meats during a 3-week storage.

Additive (ppm)	Storage Period, Weeks	Hunter a Value		
		0 kGy	5 kGy	10 kGy
None	0	3.8 ± 0.1	4.8 ± 0.1	4.7 ± 0.2
	3	5.6 ± 0.2	3.8 ± 0.1	2.2 ± 0.5
$NaNO_2$(156)	0	11.7 ± 0.2	11.3 ± 0.2	11.3 ± 0.2
	3	10.1 ± 0.1	9.7 ± 0.1	9.9 ± 0.1
CCMP (12)	0	11.8 ± 0.2	11.7 ± 0.2	11.7 ± 0.2
	3	10.8 ± 0.2	10.9 ± 0.1	10.5 ± 0.1

Table 3. Effect of irradiation on the 2-thiobarbituric acid (TBA) values of cooked meats during a 3-week storage.

Additive (ppm)	Storage, period Weeks	TBA Value		
		0 kGy	5 kGy	10 kGy
None	0	4.55 ± 0.05	0.89 ± 0.07	1.39 ± 0.08
	3	8.41 ± 0.12	6.59 ± 0.06	6.62 ± 0.05
$NaNO_2$ (156)	0	0.21 ± 0.03	0.18 ± 0.03	0.17 ± 0.02
	3	0.74 ± 0.02	0.43 ± 0.05	0.45 ± 0.04
CCMP (12)	0	0.11 ± 0.03	0.13 ± 0.03	0.23 ± 0.02
	3	4.23 ± 0.02	2.12 ± 0.03	2.30 ± 0.08