Effects of Low-Pungency Ground Mustard Seed on Oxidative Stability, Cooking Yield, and Color Characteristics of Comminuted Pork

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Comminuted pork samples were mixed with 0–2% low-pungency ground mustard seed (LPGMS) or its extracts. The 2-thiobarbituric acid (TBA) values indicated a strong, concentration-dependent antioxidant activity for LPGMS, equivalent to that of nitrite and common phenolic antioxidants such as TBHQ. The antioxidant effect of an 85% methanolic extract of LPGMS was superior to that of its extracts in absolute methanol or in water. This observation parallels the total content of phenolics in these extracts. The cooking loss of meats treated with 0–2% LPGMS was markedly decreased. Use of LPGMS had no adverse effect on the color of both cured and uncured products, as measured by Hunter *L*, *a*, *b* values, and did not influence their color fading during accelerated light exposure.

INTRODUCTION

Autoxidation is a primary cause of flavor and quality deterioration of muscle foods. In addition, oxidation of unsaturated fatty acids brings about the loss of other nutrients such as vitamins and is responsible for adverse effects on the color and texture of meats. Testing natural antioxidants for use in muscle foods is appropriate due to increasing sensitivity of consumers to synthetic additives. Thus, study of the antioxidant properties of natural ingredients such as rosemary and other spices as well as naturally occurring substances has received considerable attention in recent years (Barbut et al., 1985; Al-Jalay et al., 1987; Shahidi, 1988; Mendiolea et al., 1990; Stoick et al., 1991). Furthermore, some natural binders, such as soy protein products, have been found to improve the cooking yield and keeping quality of comminuted meat products (Pratt, 1972; Hammerschmidt and Pratt, 1978; Pruthin, 1980; Pratt et al., 1981; Rhee et al., 1981; Ziprin et al., 1981).

Low-pungency ground mustard seed (LPGMS) is a meat additive which may be used as a spice for flavor and technological quality improvements, at levels of 1–2% (w/w), in sausage products such as wieners and bologna. The pungency of mustard is reduced by an enzyme deactivation method. The product so obtained has GRAS status and may be used in all standardized foods that contain spices. The pungency of mustard arises from production of isothiocyanates from glucosinolates by the action of the myrosinase enzyme (Shahidi and Naczk, 1990). However, the above product lacks the pungency associated with ground mustard due to inhibition of isothiocyanate production by myrosinase deactivation.

The objectives of this study were to examine the effects of application of LPGMS, or its extracts, on the cooking yield and keeping quality of cooked cured and uncured meats. The effects of LPGMS on cooking yield and color characteristics of treated meats were investigated as well.

MATERIALS AND METHODS

Materials. Fresh, 24-h postslaughter pork loin samples were obtained from the Newfoundland Farm Products Corp. (St. John's, NF). LPGMS was obtained from UFL Foods Inc. (Mississauga, ON). Sodium nitrite and antioxidants used were commercial products purchased from Sigma Chemical Co. (St. Louis, MO), and sodium ascorbate was obtained from Hoffman-La Roche Ltd. (Etobicoke, ON).

Extracts of LPGMS were obtained by (1) aqueous extraction, (2) methanol extraction, and (3) 85% methanol–water extraction of 6 g of sample with 100 mL of solvent at 80 °C for 20 min. The total phenolics in LPGMS extracts were determined using Folin–Dennis reagent, as described by Rhee et al. (1979, 1981). In all cases the extraction solvent was removed by freeze-drying prior to the use of extracts in meat systems.

Sample Preparation and Analyses. In each case, 80 g of comminuted meat prepared by using an Oster meat grinder (Model KBZ3, Braun AG, Frankfurt, Germany) equipped with 0.79- and 0.48-cm plates, less the amount of LPGMS (0–2%) or other additives, was mixed with 20 g of H_2O. Additives were dissolved or dispersed in water and added to the meat. Mixtures were homogenized manually, using a glass rod, and then cooked in open jars which were placed in a water bath at 85 °C for 40 min. After homogenization in a blender for 30 s, samples were evaluated after up to 20 days of storage at 4 ± 1 °C using the 2-thiobarbituric acid (TBA) test of Tarladgis et al. (1960), as modified by Shahidi et al. (1987). Experiments were carried out in triplicate on the same batch of meat and were also carried out with meat from different days. In the latter case, although absolute values were different, trends were always similar (results not shown). Water holding capacity (WHC) of each sample, expressed as percent cook yield, was determined as outlined below. The fat content of the meats in all cases was 10–12%.

Quadruplicate 5-g samples of the cooked homogenized meat containing all other ingredients were weighed into preweighed centrifuge tubes. The tubes were capped and placed in a boiling water bath for 20 min. The tubes were allowed to cool for 15 min, the mixture was centrifuged (2000*g*), and the juice released was drained off. Each cooked meat sample was then put on a Whatman No. 1 filter paper, blotted, and placed back into the tube which was then reweighed to determine the cook yield. The percent cook yield was calculated as the ratio of the weight after cooking and removal of exudates by draining and blotting to that of the raw meat multiplied by 100, as a measure of WHC. This method is, in principle, the same as those reported by Honikel et al. (1981) and Bernthal et al. (1991).

Hunter *L*, *a*, *b* color values of the cooked cured and uncured meats containing 0–2% of LPGMS were evaluated using a Colormet colorimeter (Instrumar Engineering Ltd., St John's, NF). The unit was standardized with a B-143 white calibration tile with a Hunter *L* value of 94.5 ± 0.2, *a* value of −1.0 ± 0.1, and *b* value of 0.0 ± 0.2. For color-fading experiments, samples, 1 cm thick, were packed in polyethylene pouches and placed 25 cm below a set of two 30-W Daylite fluorescent lights (375 lx) at 4 °C.

Statistical Analysis. Analysis of variance and Tuckey's Studentized range test (Snedecor and Cochran, 1980) were used to determine differences in mean values based on data collected

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Table I. TBA Values (Milligrams of Malonaldehyde Equivalents/1000 g of Sample) of Cooked Ground Pork Treated with 0–2% LPGMS during a 20-Day Storage at 4 °C[a]

additive	storage period, days				
	0	3	7	10	20
none	6.16 ± 0.32^{az}	9.45 ± 0.12^{ax}	8.61 ± 0.11^{ay}	9.20 ± 0.20^{ax}	10.28 ± 0.18^{aw}
LPGMS, 0.5%	3.35 ± 0.21^{bz}	6.01 ± 0.09^{by}	6.59 ± 0.10^{bx}	6.90 ± 0.28^{bx}	6.82 ± 0.15^{bx}
LPGMS, 1.0%	1.14 ± 0.18^{dz}	1.91 ± 0.10^{dy}	2.73 ± 0.08^{dx}	2.76 ± 0.15^{dx}	2.54 ± 0.12^{dx}
LPGMS, 1.5%	0.64 ± 0.09^{ez}	0.67 ± 0.08^{efz}	0.70 ± 0.12^{ez}	0.76 ± 0.10^{efz}	0.66 ± 0.08^{fz}
LPGMS, 2.0%	0.31 ± 0.05^{efz}	0.43 ± 0.03^{fgy}	0.28 ± 0.08^{fz}	0.35 ± 0.05^{gyz}	0.37 ± 0.03^{gyz}
BHT, 30 ppm	1.60 ± 0.10^{ez}	3.12 ± 0.18^{cy}	5.02 ± 0.14^{cw}	4.73 ± 0.12^{cw}	4.33 ± 0.12^{cx}
BHT, 200 ppm	0.50 ± 0.05^{efz}	0.76 ± 0.05^{ey}	0.91 ± 0.08^{exy}	0.98 ± 0.06^{ex}	0.95 ± 0.05^{ex}
TBHQ, 30 ppm	0.13 ± 0.02^{fz}	0.30 ± 0.02^{gy}	0.34 ± 0.02^{fy}	0.50 ± 0.01^{fgw}	0.44 ± 0.01^{fgx}
TBHQ, 200 ppm	0.13 ± 0.02^{fz}	0.18 ± 0.01^{gy}	0.26 ± 0.02^{fx}	0.38 ± 0.02^{fgw}	0.45 ± 0.02^{fgw}
$NaNO_2$, 156 ppm[b]	0.32 ± 0.08^{efz}	0.33 ± 0.05^{gz}	0.37 ± 0.05^{fz}	0.36 ± 0.07^{gz}	0.43 ± 0.05^{fgy}

[a] Results are mean values of three determinations ± standard deviation. Means in the same column (a–g) or in the same row (v–z) with the same superscripts are not different ($P > 0.05$). [b] Sample contained 550 ppm of sodium ascorbate.

Table II. TBA Values (Milligrams of Malonaldehyde Equivalents/1000 g of Sample) of Cooked Ground Pork Treated with Extracts from LPGMS Stored for up to 20 Days at 4 °C[a]

extraction solution[b]	LPGMS equivalent, %	phenolics, ppm	storage period, days				
			0	3	7	10	20
control	none	none	6.15 ± 0.32^{az}	9.45 ± 0.12^{ax}	8.61 ± 0.11^{ay}	9.20 ± 0.20^{ax}	10.28 ± 0.18^{aw}
water	0.6	65	5.21 ± 0.18^{bz}	7.18 ± 0.20^{by}	6.99 ± 0.22^{by}	7.32 ± 0.14^{by}	9.83 ± 0.28^{ax}
	1.2	130	5.09 ± 0.11^{byz}	5.49 ± 0.15^{cy}	5.32 ± 0.18^{cyz}	4.95 ± 0.20^{dz}	5.40 ± 0.12^{bcy}
	1.5	162	4.42 ± 0.10^{cz}	4.77 ± 0.12^{dy}	4.80 ± 0.10^{dy}	5.16 ± 0.11^{cdx}	5.54 ± 0.14^{bcw}
methanol	0.6	85	4.63 ± 0.12^{cz}	5.74 ± 0.11^{cxy}	5.26 ± 0.12^{cy}	5.54 ± 0.20^{cxy}	5.81 ± 0.20^{bx}
	1.2	170	$3.28 \pm 0.10^{e}{}_{z}$	5.50 ± 0.21^{cx}	3.81 ± 0.13^{ey}	3.53 ± 0.18^{eyz}	3.39 ± 0.08^{dz}
	1.5	212	2.23 ± 0.08^{fy}	2.36 ± 0.08^{fy}	1.72 ± 0.10^{gz}	2.32 ± 0.18^{gy}	2.10 ± 0.12^{ey}
85% methanol	0.6	93	3.64 ± 0.10^{dy}	3.03 ± 0.12^{ez}	5.01 ± 0.14^{cdx}	5.42 ± 0.20^{cdx}	5.20 ± 0.31^{cx}
	1.2	185	2.87 ± 0.08^{ey}	2.80 ± 0.10^{ey}	2.18 ± 0.18^{fz}	2.92 ± 0.10^{fy}	2.21 ± 0.12^{ez}
	1.5	232	1.60 ± 0.18^{gy}	1.06 ± 0.12^{gz}	0.98 ± 0.08^{hz}	1.28 ± 0.10^{hyz}	1.43 ± 0.12^{fy}

[a] Results are mean values of three determinations ± standard deviation. Means in the same column (a–h) or in the same row (w–z) with the same superscripts are not different ($P > 0.05$). [b] Each mL of extract was equivalent to 0.6 g of meal with a total phenolic content equal to 65–93 ppm addition level to meats. Phenolics in each extract in mg/100 g of meal were 1078.95 ± 4.45 for water, 1416.03 ± 6.80 for methanol, and 1557.33 ± 1.00 for 85% methanol extracts.

from replicate runs of each treatment. Significance was determined at the 95% level of probability.

RESULTS AND DISCUSSION

Table I summarizes the mean 2-thiobarbituric acid (TBA) values of ground pork cooked with 0–2% (w/w) of low-pungency ground mustard seed. While the TBA values of the control pork sample increased to 9.20 and 10.28 mg of malonaldehyde equivalents/1000 g after 10 and 20 days of storage, respectively, treated samples had much lower TBA values. The percent inhibition of production of TBA reactive substances (TBARS) defined as

$$\% \text{ inhibition of TBARS} = \left(1 - \frac{\text{TBARS of treated sample}}{\text{TBARS of control}}\right) \times 100$$

was 34% for 0.5%, 75% for 1.0%, 94% for 1.5%, and 96% for 2.0% LPGMS addition after a 20-day storage period at refrigerated temperatures. Thus, LPGMS had a pronounced antioxidant activity which was concentration dependent. On the basis of these results, between 1.5 and 2% LPGMS addition to meats effectively retards their flavor deterioration in the uncured state.

Extracts of LPGMS also showed good antioxidant effects (Table II). However, the antioxidant activity of these extracts depended on the nature of the solvent extraction system employed for their isolation and again on the amount of extract used in each treatment. The 85% methanolic extracts, after solvent removal, exhibited the best antioxidant properties as compared to extracts from absolute methanol or water. The antioxidant properties of the extracts might be due, in part, to the level of the phenolic compounds extracted (Zadernowski et al., 1991). The content of phenolic compounds in the extracts and their antioxidant activities followed a similar trend:

85% methanol (1557.4 ± 1.0) > methanol (1416.3 ± 6.8) > H_2O (1079.0 ± 4.5)

Values in parentheses denote the total content of phenolics present in the extracts, expressed as milligrams per 100 g of original meal. The specific phenolic antioxidants present in LPGMS are currently under investigation in our laboratory.

Table III. Effect of Added LPGMS and Sodium Tripolyphosphate (STPP) on Cook Yield of Ground Pork[a]

additive	concn, %	cook yield, %
none	0	59.88 ± 0.20^{f}
LPGMS	0.5	64.11 ± 0.08^{d}
LPGMS	1.0	66.46 ± 0.13^{c}
LPGMS	1.5	68.74 ± 0.25^{b}
LPGMS	2.0	69.92 ± 0.14^{a}
STPP	0.15	61.84 ± 0.29^{e}
STPP	0.30	62.07 ± 0.25^{e}
STPP	0.50	63.47 ± 0.83^{d}

[a] Results are mean values of four determinations ± standard deviation. Values with the same superscript are not different ($P > 0.05$).

In addition to its antioxidant properties, LPGMS was quite effective in enhancing cook yield. At the 2% level LPGMS increased cook yield by about 10% (Table III). In comparison with sodium tripolyphosphate (STPP), the LPGMS at 0.5% was comparable to STPP at 0.3–0.5%. However, at 1.5–2%, it was better than STPP.

Table IV. Effect of LPGMS on Hunter *L*, *a*, *b* Color Values of Cooked Ground Pork[a]

additive	uncured meat			cured meat[b]		
	L	*a*	*b*	*L*	*a*	*b*
none	64.5 ± 0.3[b]	3.9 ± 0.1[a]	12.7 ± 0.1[cd]	62.7 ± 0.6[b]	11.5 ± 0.1[a]	9.9 ± 0.1[c]
LPGMS (0.5%)	65.5 ± 0.4[a]	3.9 ± 0.1[a]	12.6 ± 0.1[d]	63.6 ± 0.4[ab]	11.0 ± 0.1[b]	10.3 ± 0.1[d]
LPGMS (1.0%)	65.7 ± 0.2[a]	3.7 ± 0.1[ab]	12.9 ± 0.1[bc]	63.9 ± 0.3[a]	10.6 ± 0.1[c]	10.6 ± 0.1[c]
LPGMS (1.5%)	65.9 ± 0.2[a]	3.7 ± 0.1[ab]	13.1 ± 0.1[b]	64.4 ± 0.3[a]	10.4 ± 0.1[c]	10.9 ± 0.1[b]
LPGSM (2.0%)	65.8 ± 0.3[a]	3.5 ± 0.1[b]	13.4 ± 0.1[a]	64.3 ± 0.3[a]	10.0 ± 0.2[d]	11.2 ± 0.1[a]

[a] Results are mean values of eight determinations ± standard deviation. Values in each column with the same superscript are not different ($P > 0.05$). [b] Samples contained 156 ppm of sodium nitrite and 550 ppm of sodium ascorbate.

Finally, LPGMS had no detrimental effect on the color quality of treated meat samples whether nitrite-cured or uncured. While Hunter *L* (lightness) values varied irregularly, Hunter *a* (+, red) and *b* (+, yellow) values showed a definite but slight decrease and increase, respectively, whose magnitude depended on the amount of LPGMS (Table IV). The slight yellow tint in the products, however, did not have any adverse effect on the color quality of the model emulsion systems prepared as judged by the experimenters. Furthermore, color fading of the cured samples containing LPGMS under intense fluorescent lighting was similar to that of the control devoid of LPGMS. Thus, addition of LPGMS had no protective effect on color stability.

In conclusion, LPGMS was a natural antioxidant capable of extending the shelf life of meat products and enhancing their cook yields. The effect of LPGMS on the color of cooked cured and uncured meat products was minimal.

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