Stabilization of Cooked Meat Flavor with Maillard Reaction Products

M.E. BAILEY, A.D. CLARKE, H.B. HEDRICK, S.Y. SHIN-LEE and G.K. CHOATE

University of Missouri, Food Science and Nutrition Department, Columbia, Missouri 65211

SUMMARY: Ground pork loin and beef clod roasts were treated with various levels of Maillard reaction products (MRP) prepared from histidine, cysteine and glucose and roasted to an internal temperature of 70°C. Sensory and chemical analyses were used to quantitate changes in warmed-over flavor (WOF) during storage at 4°C. MRP incorporated in these meat samples at a level of 0.15% or above significantly reduced WOF during storage. Sodium tripolyphosphate (STP) (0.38%) also helped to lower WOF when used with MRP. Sensory scores for warmed-over aroma, warmed-over flavor, meaty flavor and oxidation, along with TBA values and various volatiles (particularly aldehydes), were good indices of WOF development.

INTRODUCTION: Cooked, uncured meat refrigerated for a short time develops WOF, first observed and described by TIMS and WATTS (1958). This undesirable flavor of cooked meat and related products has increased in importance recently due to the rapid increase in the utilization of "fast foods" and the growing importance of rapid food preparation in consumer home cookery. This general subject has been reviewed extensively by LOVE and PEARSON (1971) and by ST. ANGELO and BAILEY (1987), as well as others, but practical inhibition procedures useful for commercial processing of cooked meat for subsequent storage have not been forthcoming even though SATO et al. (1973) suggested some possible approaches for improving flavor of these products. A likely candidate for preserving or improving cooked meat flavor during refrigerated storage is processing with MRP prepared from natural precursors (BAILEY, 1988). The effectiveness of MRP for preserving desirable meat flavors of uncured cooked meat is described in this paper.

MATERIALS and METHODS: *Meat Sample Preparation.* Both beef and pork were studied in these experiments. Meat samples were cooked after processing with antioxidants synthesized by reacting sugars, amino acids and phosphate buffer to form MRP.

Preparation of MRP. This was done by refluxing 0.2 M histidine and 0.2 M glucose with and without 0.4 mM cysteine at pH 7.0 (0.1 N phosphate buffer) in a 130°C heating mantle for 2.0 hours.

Meat Processing and Cookery. Ground pork was baked in a gas convection oven at 175°C for 14 min. to an internal temperature of 70°C. Experimental samples were treated with MRP prepared without cysteine at 10% (w/w) prior to baking and compared to non-treated controls. Fat-free shoulder clod roasts (6.95 kg) were pumped to 8% (w/w) with MRP to 0.14% (w/w % solute) or 0.27% (w/w % solute) with and without 0.4% salt and 0.2% STP. The roasts were tumbled with 200 ml of pump solution for 1 hour at 10 revolutions/minute prior to cooking. The beef roasts were cooked in an Alkar-Rasmussen thermal processing unit (Alkar Engineering Corp., Lodi, WI) at a dry bulb temp. of 80°C for 2 hours followed by a temp. of 91°C for another 2 hours to an internal endpoint of 68.3°C.

Storage of Processed and Cooked Meat. The cooked ground pork was stored at 4°C in beakers covered with watch glasses and evaluated after 0, 1, 2 and 3 days. The beef roasts were wrapped in moisture-proof freezer paper and stored at 4°C for 0, 7, 14 and 21 days.

Sensory Evaluation. The pork samples were re-heated in a 175°C oven for 14 minutes and kept warm (70°C) in a sand bath preheated to 110°C. They were then evaluated by 6 trained judges for warmed-over aroma, fresh meat flavor, porky, rancid/cardboardy/oxidized and metallic flavors. Evaluation of the various flavors was done by recording on a 10 cm non-structured scale weighted on one end with the term "weak" and on the opposite end by "strong".

The beef was evaluated by 10 sensory panelists who were served 1.27 cm^2 crust-free samples that had been warmed in a 70°C oven and served in a pre-heated (70°C) sand bath. The beef samples were evaluated for "browned" flavor, warmed-over aroma and warmed-over flavor by using a 10 cm unstructured scale anchored by the term "intense flavor" on one end and "none" on the other end. The descriptive analyses method of STONE et al. (1980) was used to quantitate results from these studies.

TBA Numbers. TBA analyses were performed by the procedure developed by TARLADGIS et al. (1960). It was calculated by multiplying the sample absorbance by a constant (K) which was pre-determined to be 25.6.

Analysis of Volatile Compounds. Volatiles were analyzed by the method of SUZUKI and BAILEY (1985), except a different headspace pre-sampling procedure was used. It consisted of trapping of volatiles on Tenax GC (80-100 mesh) supported by volatile-free silanized glass wool in a pyrex tube (9 x 90mm) mounted on a condenser supported by a 250 ml flask containing 5 g of sample, 25 ml of distilled water and 1.64 μg of internal standard (2-methyl-4-octanone in pentane). Volatiles were evolved by heating 30 minutes at 140°C (mantle temp.) under a stream of nitrogen (190 ml/min). The Tenax GC-trapped volatiles were dried by back-flushing with nitrogen gas at 190 ml/min. for 5 min. The volatiles were then quantitated by the direct sampling method of SUZUKI and BAILEY (1985).

RESULTS and DISCUSSION: *Sensory Analysis of WOF of Cooked Pork.* Sensory analysis was performed on freshly cooked pork and pork stored for 1 and 2 days at 4°C. Five characteristics, warmed-over flavor, fresh meaty flavor, porky flavor, rancid/cardboardy/oxidized flavor and metallic flavor, were chosen from terms identified by the panel during training sessions. Results obtained from Duncan's multiple range tests of analysis of variance data concerning the changes in flavor of cooked pork samples stored at 4°C are presented in Table 1.

Table 1. Mean WOF scores[a,b] for cooked ground pork during storage at 4°C

Attribute	Days of storage			LSD[f]
	0	1	2	
Warmed-over aroma	0.97[c] ±0.35	5.92[d] ±0.74	8.19[e] ±0.57	0.56
Fresh-meaty	8.40[c] ±0.51	3.67[d] ±0.71	1.69[e] ±0.59	0.64
Porky	4.44[c] ±1.10	3.66[d] ±0.55	4.28[e] ±1.64	1.14
Rancid/cardboardy/oxidized	0.91[c] ±0.34	5.78[d] ±0.56	8.11[e] ±0.68	0.54
Metallic	0.89[c] ±0.39	3.61[d] ±0.76	5.23[e] ±1.02	0.65

[a]N=70.
[b]Range for scores 0 to 10; 0 = no flavor and 10 = very intense flavor.
[c,d,e]Means followed by different letters differ significantly ($P<0.001$).
[f]LSD values used to establish differences by Duncan's multiple range test.

There were highly significantly ($P < 0.001$) changes in flavor attributes during storage at 4°C, but no significant differences among replications for any attribute. All indices of flavor change, except fresh-meaty flavor and porky flavor, increased. The intensity of fresh-meaty flavor decreased as storage increased and this seems to be an important attribute of WOF. There was no trend in the change of porky flavor indicating that it was not related to WOF.

Increase in Volatile Compounds During Storage of Pork at 4°C for 3 Days. Fifty-two compounds were quantitated in pork during storage at 4°C for 3 days. Twenty of the most important are listed in Table 2, along with their concentrations found during storage. These changes are all significant at the 0.05 level and reveal progressive increases in concentration during refrigeration.

Table 2. Concentration (PPM[a,b]) of volatile compounds from cooked pork during storage at 4°C

Compound	Days of storage		
	0	1	3
Aldehydes, saturated			
Pentanal	0.019	0.306	0.745
Hexanal	0.067	3.525	8.714
Heptanal	0.020	0.108	0.222
Octanal	0.017	0.115	0.234
Nonanal	0.126	0.322	0.740
Aldehydes, unsaturated			
2-Hexenal	0.004	0.017	0.029
2-Heptenal	0.028	0.084	0.254
2-Octenal	0.004	0.121	0.382
2-Nonenal	0.006	0.047	0.152
2-Decenal	0.006	0.065	0.110
2,4-Nonadienal	n.d.[c]	0.016	0.061
2,4-Decadienal	0.005	0.107	0.249
Alcohols			
1-Pentanol	0.017	0.233	0.530
1-Hexanol	0.004	0.021	0.075
1-Heptanol	n.d.	0.011	0.025
1-Heptene-3-ol	n.d.	0.091	0.354
Ketones			
2-Heptanone	0.008	0.032	0.065
2,3-Octanedione	n.d.	0.203	0.721
2-Decanone	0.006	0.043	0.080
Others			
2-Pentyl furan	0.007	0.068	0.142

[a]N = 10.
[b]Concentration during storage are all significantly ($P < 0.05$) different.
[c]None detected.

TBA values were used to determine the most ideal conditions for preparing MRP antioxidants with histidine and glucose for maximum protection of pork desirable flavor during refrigerated storage. Acidity of pH 7.0 was chosen as a compromise between pH 9.0, which gave MRP with maximum antioxidant activity, and pH 5.6, which gave maximal meaty flavor of pork during storage. MRP prepared with 0.2 M glucose and 0.2 M histidine and added to ground pork at 10% prevented WOF during storage at 4°C for 3 days. A two hour heating time at 130°C was sufficient to produce MRP from 0.2 M histidine and 0.2 M glucose with near maximal antioxidant properties during the period studied. There were highly significant ($P<0.001$) correlations between TBA numbers and WOF attributes, between TBA numbers and volatile organic compounds, and between volatile organic compounds and WOF attributes.

Sensory and Chemical Analyses of WOF of Cooked Beef. Analyses of variance of sensory and chemical measurements of cooked beef roasts during storage at 4°C for 21 days revealed significant changes in warmed-over aroma, warmed-over flavor, browned flavor, overall acceptability and TBA values during storage at 4°C for 21 days. There were also significant changes due to treatment. Table 3 contains results of treatment on the mean sensory and TBA scores for pre-cooked roasts during storage for 21 days.

Table 3. Mean sensory scores[a,b] and TBA values for pre-cooked roasts treated with MRP during storage for 21 days at 4°C

Treatment	Sensory attribute				TBA values (mg/kg meat)
	Warmed-over aroma	Warmed-over flavor	Browned flavor	OA[d]	
100% water	3.07[e]	3.37[e]	1.36[e]	3.08[e]	3.28[e]
0.14% MRP	2.60[ef]	2.75[f]	1.86[f]	4.72[f]	2.45[f]
0.14% MRP +0.75% NaCl +0.38% STP[c]	2.18[fg]	2.01[g]	3.10[g]	-	1.76[g]
0.28% MRP	2.12[fg]	2.13[g]	1.90[f]	4.90[g]	2.16[g]
0.28% MRP +0.75% NaCl +0.38% STP[c]	1.96[g]	1.74[h]	3.53[g]	-	1.33[g]

[a]N=40.
[b]0=none; 10=intense.
[c]STP = sodium tripolyphosphate.
[d]OA = overall acceptability.
[e-h]Means bearing different superscripts in the same column are significantly different ($P<0.05$).

All MRP treatments significantly ($P<0.05$) reduced sensory attributes of WOF, except browned flavor, during 21 day storage. The meaty-browned flavor was rated higher in samples treated with 0.14% or 0.28% MRP which contained 0.75% salt and 0.38% STP. TBA values were also lower in samples treated with MRP, salt and STP compared to untreated samples or those containing only MRP. The desirable browned flavor was better protected by MRP containing 0.38% STP than without STP, but the MRP at either 0.14 or 0.28% offered some protection against WOF during storage of beef roasts at 4°C for 21 days.

CONCLUSIONS: Ground pork and roast beef develop warmed-over flavor during storage at 4°C, which can be protected by processing with Maillard reaction products with and without sodium tripolyphosphate. A major change in flavor is reduction of desirable meaty browned flavor during storage. A variety of sensory attributes along with TBA values and the concentration of oxidation volatiles from fatty acids can be used to quantitate warmed-over flavor of pork and beef during refrigerated storage.

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