flavor, and aroma fraction of roasted peanuts or perhaps to the presence of one or more pyrazines as suggested by Mason *et al.* (1966).

ACKNOWLEDGMENT

The authors are indebted to Eugene Alix for technical services and to D. P. Schwartz for the gift of several 2,4-DNP-hydrazone derivatives of 2-alkenals and 2,4-alkadienals. The authors are also indebted to Frank McGill, Agricultural Extension Service, Tifton, Ga., for assistance in obtaining peanuts of known history and to J. L. Butler and R. S. Hutchison for curing, shelling, and grading.

LITERATURE CITED

Badings, H. T., "Cold-Storage Defects in Butter and Their Relation to the Autoxidation of Unsaturated Fatty Acids," Veenman and Zonen N. V., Wageningen, the Netherlands, 1970.
Ballschmieter, H. M., Germishuizen, P. J., *Fette Seifen Anstrichm.* **70,** 571 (1968).
Dupuy, H. P., Southern Marketing and Nutrition Research Division, ARS, USDA, New Orleans, Louisiana, unpublished data, 1970.
Ellis, R., Gaddis, A. M., Currie, G. T., *J. Food Sci.* **26,** 131 (1961).
Guadagni, D. G., Buttery, R. G., Okano, S., *J. Sci. Food Agr.* **14,** 761 (1963).
Henick, A. S., Benca, M. F., Mitchell, J. H., Jr., *J. Amer. Oil Chem. Soc.* **31,** 88 (1954).
Hodge, J. E., "Chemistry and Physiology in Flavors," Schultz, H. W., Day, E. A., Libby, L. M., Eds., AVI Publishing Co., Westport, Conn., 1967, pp 465–491.
Kinsella, J. E., *Chem. Ind. (London)* 36 (1969).
Kleipool, R. J. C., Heins, J. T., *Nature (London)* **203,** 1280 (1964).
Johnson, Bobby R., Ph.D. Dissertation, Oklahoma State University, Stillwater, Okla, 1970.
Mason, M. E., Johnson, B. R., Hamming, M. C., J. AGR. FOOD CHEM. **14,** 454 (1966).
Mason, M. E., Johnson, B. R., Hamming, M. C., J. AGR. FOOD CHEM. **15,** 66 (1967).
Mason, M. E., Newell, J. A., Johnson, B. R., Koehler, P. E., Waller, G. R., J. AGR. FOOD CHEM. **17,** 728 (1969).
Mookherjee, B. D., Chang, S. S., *J. Amer. Oil Chem. Soc.* **40,** 232 (1963).
Mookherjee, B. D., Deck, R. E., Chang, S. S., J. AGR. FOOD CHEM. **13,** 131 (1965).
Pattee, H. E., Beasley, E. O., Singleton, J. A., *J. Food Sci.* **30,** 388 (1965).
Pattee, H. E., Singleton, J. A., Cobb, W. Y., *J. Food Sci.* **34,** 625 (1969).
Pattee, H. E., Singleton, J. A., Johns, E. B., Mullin, B. C., J. AGR. FOOD CHEM. **18,** 353 (1970).
Schwartz, D. P., Eastern Marketing and Nutrition Research Div., ARS, USDA, Washington, D. C., private communication, 1971.
Schwartz, D. P., Haller, H. S., Keeney, M., *Anal. Chem.* **35,** 2191 (1963).
Schwartz, D. P., Parks, O. W., *Anal. Chem.* **33,** 1396 (1961).
Schwartz, D. P., Shamey, J., Brewington, C. R., Parks, O. W., *Microchem. J.* **13,** 407 (1968).
Schwartz, D. P., Virtanen, A. I., *Acta Chem. Scand.* **22,** 1717 (1968).
Senn, V. J., Southern Marketing and Nutrition Research Division, ARS, USDA, New Orleans, La., unpublished data, 1970.
Shriner, R. L., Fuson, R. C., Curtin, D. Y., "The Systematic Identification of Organic Compounds," Wiley, New York, N.Y., 1956, p 219.
van Praag, M., Stein, H. S., Tibbetts, M. S., J. AGR. FOOD CHEM. **16,** 1005 (1968).
Walradt, J. P., Pittet, A. O., Kinlin, T. E., Sanderson, A., Abstracts 160th National Meeting of the American Chemical Society, Chicago, Ill., Sept. 1970, No. AGFD 70.
Young, C. T., Holley, K. T., *Ga. Expt. Sta. Tech. Bull. N. S.* **41,** 1965.

Received for review October 18, 1971. Accepted January 10, 1972. Presented at the 161st Meeting, ACS, Los Angeles, California, March 28–April 2, 1971. One of us, D. F. B., was a National Research Council Postdoctoral Associate for 1969–1971. Mention of commercial products does not imply their endorsement by the Department over similar products not mentioned.

Eating Quality, Sulfhydryl Content, and TBA Values of Turkey Breast Muscle

Jane A. Bowers

Selected flavor and aroma components, juiciness, sulfhydryl groups, and TBA values were determined for freshly cooked and for precooked, frozen, reheated (in gas and in microwave ovens) turkey muscle. In general, freshly cooked muscle had the lowest rancid and stale and highest meaty–brothy flavor and aroma scores; microwave-reheated meat had intermediate scores; and conventionally reheated had the highest rancid and stale and lowest meaty–brothy flavor and aroma scores. Differences in TBA values and sulfhydryl groups were noted between cooked and raw muscle tissue, but not among muscle tissues subjected to the three heating treatments.

Flavor of cooked turkey deteriorates during storage and reheating. Oxidation of muscle lipids has been related to flavor deterioration in cooked meats (Tims and Watts, 1958; Turner *et al.*, 1954) and the thiobarbituric acid (TBA) test has been used to determine extent of oxidation. TBA values increased as off-flavor and odor developed with storage time and storage temperature for precooked meat (Cash and Carlin, 1968; Chang *et al.*, 1961; Keskinel *et al.*, 1964; Jacobson and Koehler, 1970).

Sulfur aroma components have been noted in poultry meat volatiles. An interaction between hydrogen sulfide and carbonyl compounds was suggested by Pippen *et al.* (1965) and may promote off-flavor in reheated meat. Minor *et al.* (1965) suggested that the "meaty" aroma of chicken was due to sulfur compounds. Heating affects protein functional groups of muscle. Hamm and Hofmann (1965) observed a decrease in the number of sulfhydryl groups in beef myofibrils heated to 120°C. They suggested that the decrease was caused by oxidation of the sulfhydryl groups to disulfide groups and to formation of H_2S from myofibrils (which began at about 80°C).

Flavor of microwave-reheated turkey muscle recently has been shown to be more meaty–brothy and less stale than that of conventionally reheated turkey muscle (Cipra *et al.*, 1971); chemical changes that may help explain such a dif-

Department of Foods and Nutrition, Kansas Agricultural Experiment Station, Manhattan, Kansas 66502.

ference in the flavor and aroma of microwave and conventionally reheated turkey muscle have not been studied.

This study evaluated selected flavor and aroma components and juiciness and measured fat oxidation and sulfhydryl group of freshly cooked and precooked, frozen, reheated (in gas and in microwave ovens) turkey muscle.

EXPERIMENTAL PROCEDURE

Fourteen paired frozen breasts from seven tom turkeys (U.S. Grade A) similar in age, weight (22–24 lb), management, and processing procedures were obtained from a local plant. Four weeks before being evaluated, turkey breasts were thawed at 4°C for 24 hr and at 26°C for 1 hr. Each paired breast was cut equally to anterior and posterior portions. Treatments, assigned randomly to the four breast portions from each turkey, were: raw; freshly cooked; precooked, frozen, microwave-reheated; and precooked, frozen, conventionally reheated. The average weight of the 28 roasts was 660 g.

Muscle portions for freshly cooked, microwave-reheated, and conventionally reheated treatments were fashioned into roasts with skin and wrapped in oven-proof film (3M). For precooking, roasts were placed in pyrex dishes (5 × 9 in.) in a rotary hearth gas oven maintained at 177°C, heated to an internal temperature of 76°C, cooled in ice 1 hr, and then frozen (−17°C). Roasts to be freshly cooked and samples for raw analysis were frozen immediately. Roasts were stored 4 weeks (−17°C) before being evaluated.

At each evaluation period, the four roasts (one of each treatment) from one turkey were thawed 23–24 hr at 4°C. For the freshly cooked sample, an uncooked roast (in ovenproof film) was placed in a pyrex dish (5 × 9 in.) in rotary hearth oven maintained at 177°C and cooked to an internal temperature of 85°C. For reheating, precooked breasts (in ovenproof film) were placed in pyrex dishes and heated in a rotary hearth gas oven (177°C) or a microwave oven (Amana Rada-range, Model RR-2, 2450 MHz). Those roasts were reheated to an internal temperature of 55°C. Cooking time and total cooking loss were calculated.

Sensory evaluation of samples was by six panel members in individual booths. Warm samples ($^1/_4$-in. slices from the center of each roast) were presented randomly to six trained panelists for flavor and juiciness evaluation. Samples were placed in coded sniffers and kept warm for aroma evaluation. Before evaluation periods, training sessions were conducted to help panelists identify the selected flavors and aromas. Intensities of the flavor and aroma components in the three cooked treatments were scored (0, imperceptible to 5, very pronounced). Juiciness also was scored (1, very dry to 5, very juicy).

The 2-thiobarbituric acid (TBA) test described by Tarladgis *et al.* (1960) was used to study oxidative changes in tissue lipids. Slurries were prepared from sample sizes of approximately 7 g. Optical density readings (Beckman DU) were converted to milligrams of malonaldehyde per 1000 g of meat.

Two methods were used to measure sulfhydryl groups. The colorimetric procedure for free tissue sulfhydryl groups as described by Ellman (1959) was used for duplicate 0.3–0.4 g samples. Also, an amperometric titration procedure for measuring total content of sulfhydryl groups was performed using the sample preparation and a similar procedure of Gawronski *et al.* (1967). Titration solutions of Benesch *et al.* (1955) and rotating platinum electrode and galvanometer as described by Kolthoff and Harris (1946) were used.

Data were subjected to analysis of variance which removed turkey and panel member variations from the desired comparisons and provided ample degrees of freedom for estimation of the error variance.

RESULTS AND DISCUSSION

The average time for precooking the turkey breast roasts to 76°C was 78 min and for cooking roasts to 85°C was 95 min.

Table I. Mean Value of Seven Replications for Flavor, Aroma, and Juiciness, Sulfhydryl Content, and TBA Values of Turkey Breast Muscle[a]

Factors	Raw	Freshly cooked	Microwave-reheated	Conventionally reheated	Significance of F values[b] Treatment	Turkey
Flavor scores[c]						
Rancid		1.7	2.3	2.9	**	ns
Stale		1.9	2.4	2.6	**	*
Sulfur		1.9	1.8	2.1	ns	ns
Meaty–brothy		2.9	2.8	2.3	**	ns
Bitter		1.3	1.3	1.4	ns	ns
Sweet		1.6	1.4	1.4	ns	ns
Acid		1.9	2.5	2.4	**	ns
Aroma scores[c]						
Rancid		2.1	2.1	2.6	*	ns
Stale		2.0	2.4	2.5	*	ns
Sulfur		2.0	1.8	1.8	ns	ns
Meaty–brothy		2.9	3.1	2.5	**	ns
Ammonia		2.0	1.7	1.7	ns	ns
Juiciness scores[d]		3.0	2.5	2.6	*	ns
Sulfhydryl groups						
Ellman method, mmol/g of muscle	0.491	0.594	0.626	0.702	ns	**
Amperometric method, mmol × 10^{-4}/g of muscle	2.73	1.16	1.05	0.90	*	ns
TBA Value, mg/1000 g of muscle	0.33	1.60	1.54	1.71	**	*

[a] Means underlined by the same line do not differ significantly. [b] ns = not significant; * = $p < 0.05$; ** = $p < 0.01$. [c] Scoring range, 0 = imperceptible; 5 = very pronounced. [d] Scoring range, 0 = very dry; 5 = very juicy.

Average time for microwave reheating of roasts was 11 min and for conventional reheating was 59 min. Total cooking loss for the freshly cooked roasts was 28.3% and for reheated roasts was 37.4 and 32.1% for microwave and conventional, respectively. Even though reheating time was reduced greatly with the use of microwaves, the total percentage cooking loss was increased.

Rancid, stale, meaty–brothy, and acid flavor components were affected significantly by treatment (Table I). Flavor of freshly cooked samples were least ($p < 0.01$) rancid and stale while flavor of conventionally reheated samples was the most rancid and stale and was significantly different from the freshly cooked samples. Flavor scores for microwave reheated samples were intermediate. The meaty–brothy flavor of freshly cooked and microwave-reheated turkey was similar and higher than that of conventionally-reheated turkey. Reheated samples had higher acid flavor scores than freshly cooked samples. Sulfur, bitter, and sweet flavor components of turkey muscle were not affected by treatments used in this study.

Treatment differences were noted for rancid, stale, and meaty–brothy aroma. Aroma evaluations followed a pattern similar to those for flavor. Freshly cooked samples and microwave-reheated samples had similar and lower ($p < 0.01$) rancid scores than did conventionally reheated samples. Freshly cooked samples had lower stale aroma scores than reheated (both microwave and conventional) samples. Freshly cooked and microwave-reheated samples had similar meaty–brothy aroma scores and were higher than those of conventionally reheated samples. Scores for sulfur and ammonia aroma components were not affected by treatment.

In general, freshly cooked meat had the lowest rancid and stale scores and highest meaty–brothy flavor and aroma scores, while microwave-reheated samples had intermediate scores and conventionally reheated samples had the highest rancid and stale scores and lowest meaty–brothy flavor and aroma scores.

Those results in general confirm those for precooked stored muscle. Jacobson and Koehler (1970) reported a loss of flavor for chicken and turkey after 2–4 day's refrigeration. Cipra and Bowers (1970) reported an increase in stale and rancid and a decrease in meaty–brothy flavor and aroma components of turkey muscle with reheating after 24 hr refrigeration. Cash and Carlin (1968) reported a flavor decrease with precooking and frozen storage (3, 7, 9, and 11 months) of turkey roasts. In comparison of microwave and conventional precooking and reheating of turkey roasts, Cipra *et al.* (1971) reported less stale and more intense turkey flavor for microwave heating of muscle.

Flavor of cooked meat usually deteriorates during storage and reheating. Perhaps longer exposure to heat while reheating with gas than with microwaves permits chemical changes that deteriorate flavor more in conventionally reheated samples.

Freshly cooked muscle was juicier ($p < 0.05$) than reheated muscle. Cooking losses were higher for reheated muscle than for freshly cooked muscle, which may partly explain the difference in juiciness. Juiciness was the same for samples reheated by microwave or conventional methods.

Sulfhydryl groups were analyzed by two methods. No differences in amount of sulfhydryl groups were found among the three cooked samples. Likewise, sensory scores for sulfur aroma and flavor were similar for the cooked samples. The Ellman method indicated an increase in free sulfhydryl groups upon heating of the turkey muscle tissue. However, the difference was significant only between raw samples and precooked conventionally reheated samples. Randall and Bratzler (1970), using the Ellman method on unheated and heated pork muscle, found that free sulfhydryl groups increased significantly with heating. Hamm and Hofmann (1965) suggested that heat denaturation causes an unfolding of peptide chains and releases reactive SH groups which may explain the difference in free sulfhydryl groups.

A reverse trend was noted for the amount of total sulfhydryl groups determined by an amperometric method. Raw muscle tissue had more sulfhydryl groups than heated muscle tissue did. Hamm and Hofmann (1965) using a method similar to the amperometric method for reacting SH groups with $AgNO_3$ found that the amount of sulfhydryl was not affected greatly with heating up to 70°C, but was decreased with further heating to 120°C. Samples in this study were all heated to temperatures higher than 70°C and therefore results of this study are in agreement with those of Hamm and Hofmann (1965). They suggested that the loss of sulfhydryl groups may be due to oxidation of SH to SS groups and to the formation of H_2S.

TBA values for all samples were fairly low and did not differ statistically for the three heated samples but were higher for the heated than for the raw muscle tissue. In other studies TBA values have been related to sensory scores, but generally there is a greater range for TBA values than those reported here. Chemical differences were noted between raw and heated samples but not among the various heated treatments; thus they do not explain the differences noted in flavor and aroma of the heated samples.

LITERATURE CITED

Benesch, R. E., Lardy, H. A., Benesch, R., *J. Biol. Chem.* **216,** 663 (1955).
Cash, D. B., Carlin, A. F., *Food Technol.* **22,** 1477 (1968).
Chang, P. Y., Younathan, M. T., Watts, B. M., *Food Technol.* **15,** 168 (1961).
Cipra, J. S., Bowers, J. A., *Food Technol.* **24,** 85 (1970).
Cipra, J. S., Bowers, J. A., Hooper, A. S., *J. Amer. Dietet. Ass.* **58,** 38 (1971).
Ellman, G. L., *Arch. Biochem. Biophys.* **83,** 70 (1959).
Gawronski, T. H., Spencer, J. V., Pubols, M. H., J. AGR. FOOD CHEM. **15,** 781 (1967).
Jacobson, M., Koehler, H. H., J. AGR. FOOD CHEM. **18,** 1069 (1970).
Hamm, R., Hofmann, K., *Nature (London)* **207,** 1269 (1965).
Keskinel, A., Ayres, J. C., Snyder, H. E., *Food Technol.* **18,** 223 (1964).
Kolthoff, I. M., Harris, W. E., *Ind. Eng. Chem. Anal. Ed.* **18,** 161 (1946).
Minor, L. J., Pearson, A. M., Dawson, L. E., Schweigert, B. S., J. AGR. FOOD CHEM. **13,** 298 (1965).
Pippen, E. L., de Fremery, D., Lineweaver, H., Hanson, H. L., *Poultry Sci.* **44,** 816 (1965).
Randall, C. J., Bratzler, L. J., *J. Food Sci.* **35,** 248 (1970).
Tarladgis, B. G., Watts, B. M., Younathan, M. T., Dugan, L. R., *J. Amer. Oil Chem. Soc.* **30,** 44 (1960).
Tims, M., Watts, B. M., *Food Technol.* **12,** 240 (1958).
Turner, E. W., Paynter, W. D., Montie, E. M., Bessert, M. W., Struck, G. M., Olson, F. C., *Food Technol.* **8,** 326 (1954).

Received for review November 15, 1971. Accepted January 3, 1972. Contribution No. 273, Department of Foods and Nutrition, Kansas Agricultural Experiment Station.