Development of Rancidity During Short-Time Storage of Cooked Poultry Meat

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Cooked chicken and turkey meats were tested for flavor and for content of TBA-reactive substances when newly cooked and after storage 1 to 4 days, refrigerated or frozen. Chicken meat showed small flavor losses in both light and dark meats after short-term frozen storage, but pronounced flavor changes were observed after refrigerated storage. For light chicken meat, TBA numbers increased as flavor progressively deteriorated; the test, however, did not indicate significant differences in TBA number for dark chicken meat under the storage treatments. With cooked light and dark turkey meat, TBA numbers correlated significantly with flavor change (r = −0.77), indicating that oxidative changes occur as flavor deteriorates during refrigeration. The taste panel evaluation and chemical determinations were done on the same samples to permit calculation of relationship between the two measurements. Addition of propyl gallate prevented the changes measured by the TBA test but MSG did not. The study shows that the chemical test gives useful evidence of flavor change. The change was temperature-dependent and occurred rapidly during short-term refrigerated storage.

The characteristic flavor of cooked poultry meat is rapidly lost during short holding periods if meat is not frozen. Meatiness of aroma and taste of chicken and turkey become noticeably stale after a few hr of refrigerated storage. In meats and fish, flavor deterioration has been attributed to oxidative changes. Watts (1961) explained the change as an oxidation of the unsaturated lipids which are metabolically active within cellular structures of lean muscle tissues. In work with cooked mullet, Zipser and Watts (1961) found the degree of change in odor dependent upon the character of lipids and quantity of heme pigments in the tissue. These workers also observed that freezer temperatures inhibited the change. Tripolyphosphate and ascorbate antioxidants, as well as exclusion of oxygen, also had protective effects. Workers in the same laboratory (Ramsey and Watts, 1963) reported that treating the meat with extracts of vegetables lowered TBA numbers and increased odor scores for refrigerated beef slices. In this study polyphosphate was effective with both beef slices and ground beef.

Keskinel *et al.* (1964) determined oxidative changes during storage of raw and cooked beef, lamb, pork, and turkey meats by the 2-thiobarbituric acid (TBA) test. Both raw turkey light meat and dark meat showed rapid increase in TBA-reactive substances after periods of refrigerated storage at 2° C, reaching the equivalent of 7 to 8 mg of malonaldehyde per 1000 g of sample in 2 days. Ground cooked light and dark turkey meat had TBA numbers of 15 and 18 after a single day. No organoleptic supporting data were reported in the Keskinel study.

Investigations of the development of off-flavor and increased peroxide values in poultry meat products stored at several freezing temperatures have been reported by Hanson *et al.* (1960). In that study monosodium glutamate had no measurable effect on the oxidative changes over periods of 4 to 9 months storage. Lineweaver *et al.* (1952) made studies of the effects of mixtures of antioxidants, as well as limited tests of nordihydroguaiaretic acid, propyl gallate, and butylated hydroxyanisole, on the development of rancidity in frozen creamed turkey. The effects of propyl gallate on peroxide values in those experiments varied.

No published reports have been found in which the off-flavor development in poultry meat during short-term storage at refrigeration temperatures has been tested by parallel sensory and chemical measurements. It seemed useful also to test MSG and propyl gallate with the separated light and dark meats without other food ingredients.

The study reported here explored further the development of rancidity in cooked chicken and turkey meats during short periods of either refrigerated or frozen storage. TBA numbers and panel evaluations of flavor were obtained for meat under the same treatment. Effects of the addition of propyl gallate and of monosodium glutamate were observed.

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MATERIALS AND METHODS

Preliminary Study with Chicken Meat. Cooked Meat for Tests. Cooked chicken meat was prepared for sensory and chemical tests. Female Hubbard-White Mountain chickens were slaughtered at 9 to 11 weeks of age, processed, packaged in polyethylene bags, and frozen in whole form at −29° C. They were stored at −29° C prior to use. In each series, four chickens were thawed in the bags under refrigeration (2° C). Before cooking, each was rinsed, drained, blotted dry, trussed, and placed on a rack on an open pan. Roasting was at 163° C to an internal temperature of 88° C. When cool enough to handle, the meat was removed from bones and skin. Samples of light and dark muscles were wrapped separately in aluminum foil. Samples from one chicken were tested immediately after cooking; light and dark meats from the other three chickens were frozen or refrigerated for taste panel evaluation or chemical determination on the 3 following days. Tests performed each day were on meat from a different chicken and, although the treatments were held constant, sensory tests and chemical determinations were made at different times and on other chickens from the same lot. Each light- or dark-meat sample was cut into 1-cm cubes and mixed.

Sensory Tests of Chicken Meat. Flavor was rated by a nine-member panel using a numerical scale of 10 to 0. Two samples of cubed light meat and two of dark meat were placed in 50-ml beakers which were coded, covered with foil, and served in white pans containing hot water.

TBA Determinations on Chicken. The 2-thiobarbituric acid (TBA) test without acid-heat treatment (Tarladgis *et al.*, 1964) was applied to water extractions of 8 g of meat. An average K value derived from a series of determinations on 1,1,3,3-tetraethoxypropane standards (range, 1×10^{-8} to 7×10^{-8} moles per 5 ml) was used in calculation. Absorbance readings were made (B & L 600 spectrophotometer) at 530

Table I. Average Sensory Ratings[a] and TBA Values[b] for Cooked Light and Dark Chicken Meat Stored Frozen or Refrigerated for 1, 2, or 3 Days[c]

	Newly cooked	Frozen			Refrigerated		
		1 day	2 days	3 days	1 day	2 days	3 days
Flavor Ratings							
Light meat	8.6^{α}	$8.0^{\alpha,\beta}$	7.7^{β}	7.7^{β}	7.5^{β}	6.0^{γ}	5.4^{γ}
Dark meat	8.5^{α}	7.7^{β}	7.5^{β}	7.4^{β}	5.9^{γ}	4.8^{Δ}	4.1^{π}
TBA Values							
Light meat	0.80^{α}	$0.89^{\alpha,\beta}$	$0.94^{\beta,\gamma}$	$.88^{\alpha,\beta}$	1.04^{γ}	1.24^{Δ}	1.48^{π}
Dark meat	1.83^{α}	2.10^{β}	2.03^{β}	1.83^{α}	2.08^{β}	$2.01^{\alpha,\beta}$	2.15^{β}

[a] Overall flavor was rated from 10 to 0, with 10 representing best chicken flavor; each number is a mean of 27 judgments, except fresh, which had 54 judgments. [b] TBA determination as mg malonaldehyde per 1000 g meat by Tarladgis modified method; each value a mean of five tests made in duplicate on separate samples. [c] Means with the same Greek letter superscript are not significantly different at $P < 0.05$.

mμ against a sample blank to which water was added, instead of TBA Reagent I as recommended by Tarladgis *et al.* (1964). Calculations were expressed as mg of malonaldehyde per 1000 g of meat.

Study with Turkey Meat. Cooked Meat for Tests. Cooked turkey meat was prepared for sensory and chemical tests. Mature hen turkeys from the university flock were slaughtered, dressed and chilled, then sawed in half longitudinally. Each half was sealed in a polyethylene bag, labelled, and frozen at −29° C.

The turkey halves were thawed in the bags at room temperature for 16 hr then rinsed, drained, and blotted dry, after which they were roasted cavity-side down at 163° C to an internal temperature of 88° C. Halves of the same turkey were roasted for each replication.

Muscles of the breast (light meat) and of leg-thigh (dark meat) were separated from skin, bone, blood vessels, and tendons, then cut into 1-cm cubes and mixed to provide samples for both sensory and chemical tests. For the sensory panel, samples were apportioned into 50-ml beakers, covered with foil, and stored under refrigeration (4° C) or in the freezer (−20° C) for tasting after 2 or 4 days. For chemical determinations, 10 g of the cubed meat was weighed into 50-ml beakers and solutions of additives were pipeted over the meat. Beakers were sealed with foil and stored for 2 or 4 days frozen or under refrigeration.

Treatments with Additives. To each 10-g sample of light or dark turkey meat was added 2 ml of distilled water or solution of an additive. The 2-ml treatment contained 0.007 g of propyl gallate (PG), or 0.03 g of monosodium glutamate (MSG), or 0.007 g of PG plus 0.03 g of MSG. The antioxidant propyl gallate was applied at a relatively high level of 0.07%, or 700 ppm, the level given for an antioxidant salt (NAS/NRC, 1965). The treatment solution approximated the maximum solubility of propyl gallate in water. In preliminary tests, lower concentrations of PG were tried and found noticeably effective at 0.007% and slightly effective at 0.0007% of sample weight. The commonly used flavor enhancer MSG was applied at 3000 ppm of sample (0.3%) which represents the upper limit usually used with meats (NAS/NRC, 1965). Four identically treated samples of light or dark meat were stored as follows: refrigerated 2 or 4 days or frozen 2 or 4 days.

Sensory Tests of Turkey Meat. Flavor was evaluated by a 12-member panel using three types of tests (numerical rating, paired comparisons, and descriptive analysis). Tests were made on freshly cooked light and dark meats, and on the same lot of meat after 2 or 4 days of frozen or refrigerated storage. The effects of type and length of storage on flavor were measured.

TBA Determinations on Turkey. The method of Tarladgis *et al.* (1964) was followed except for three modifications. Each 10-g meat sample, plus 50 ml of distilled water, was blended on low speed for 30 sec only; the shorter blending period allowed more rapid filtration and the filtrates had greater clarity. Tubes containing filtrate plus TBA Reagent I, as well as standards and blanks, were stored at 22° C for 16 hr in the dark. Absorbance at 530 mμ was read in the spectrophotometer using a self-blank (filtrate plus water instead of reagent) to nullify cloudiness. Standards were run with each determination.

RESULTS AND DISCUSSION

Changes in Chicken Flavor and TBA Numbers. The characteristic flavor of cooked light and dark chicken meat was rated somewhat lower after 1 to 3 days of frozen storage, but the differences within this short interval were not significant. Under refrigeration, however, flavor deteriorated rapidly (Table I). Three days of refrigeration caused flavor ratings to drop from 8.6 for freshly cooked light meat to 5.4; the change for dark meat was from 8.5 to 4.1. The stale off-flavors which developed during this period caused the dark meat to become obviously rancid.

TBA determinations on samples treated by the same procedure, but not from identical meat, showed increases in TBA-reactive constituents in refrigerated samples of light meat, and a similar trend in dark meat (Table I). These parallel changes with storage suggested that the relationship of flavor and TBA number should be tested more critically. This was done in the subsequent study on turkey meat.

Changes in Turkey Flavor and TBA Numbers. The initial flavor of both light and dark cooked turkey meat was not lost during 2 or 4 days of frozen storage. When the cooked meats were refrigerated, however, flavor ratings for light meat fell from 7.5 to 6.1 in 2 days and to 5.1 after 4 days of storage (Table II). Refrigerated dark meat was rated 7.0 before storage, but 5.3 after 2 days and 3.6 after 4 days.

Determinations on samples of the same turkey meats which were tasted showed higher TBA numbers in light or dark meat after 2 or 4 days of frozen storage (Table II). During refrigeration there was a marked increase in TBA-reactive substances in the two types of meat. The light meat, which contained 0.95 mg of malonaldehyde per 1000 g initially, had an average of 1.55 mg after 2 days and 1.90 mg after 4 days of refrigeration. Refrigerated dark meat had high TBA numbers of 3.07 and 2.85.

Correlation of Flavor Ratings and TBA Numbers for Turkey Meat. When average panel ratings for each sample of turkey meat at each storage period, frozen or refrigerated, were compared statistically with chemical determinations of TBA-

Table II. Average Panel Ratings[a] and TBA Values[b] for Cooked Light and Dark Turkey Meat Stored Frozen or Refrigerated for 2 or 4 Days[c]

	Newly cooked	Frozen 2 days	Frozen 4 days	Refrigerated 2 days	Refrigerated 4 days
(Light Meat)					
Flavor ratings	7.5^{α}	7.7^{α}	7.7^{α}	$6.1^{\beta,\gamma}$	$5.1^{\gamma,\Delta}$
TBA numbers					
Untreated meat	0.75^{α}	1.08^{β}	1.23^{γ}	1.55^{Δ}	1.90^{π}
With MSG[d]	...	1.14	1.19	1.66	1.84
With PG[e]	...	0.82	0.89	1.00	1.01
With PG and MSG[f]	...	0.96	0.94	0.98	1.00
(Dark Meat)					
Flavor ratings	7.0^{α}	7.4^{α}	7.5^{α}	5.3^{β}	3.6^{γ}
TBA numbers					
Untreated meat	1.25^{α}	1.81^{γ}	1.67^{β}	3.07^{π}	2.85^{Δ}
With MSG	...	1.89	1.56	3.08	2.98
With PG	...	0.63	0.69	0.90	0.62
With PG + MSG	...	0.76	0.68	0.94	0.86

[a] Overall flavor was rated from 10 to 0, with 10 representing best turkey flavor, each number a mean of 36 judgments. [b] TBA determination as mg of malonaldehyde per 1000 g meat by modified Tarladgis method; each value is mean for 3 replications, each determination made in duplicate. [c] Means with the same Greek letter superscript are not significantly different at $P < 0.05$. [d] Monosodium glutamate (0.03 g) added to 10 g of meat. [e] Propyl gallate (0.007 g) to 10 g of meat. [f] Propyl gallate (0.007 g) plus 0.03 g monosodium glutamate to 10 g of meat.

Table III. Selections of Better Turkey Flavor between Frozen and Refrigerated Light Meat Samples and Between Dark Meat Samples after Two Storage Periods[a,b]

	Light Meat Frozen	Light Meat Refrigerated	Dark Meat Frozen	Dark Meat Refrigerated
2-day storage	32	4	29	7
4-day storage	31	5	36	0

[a] Number of times samples having the treatment were chosen by 12 tasters in three replications. [b] Difference between totals in each comparison was highly significant.

reactive content of the same meats, the correlation coefficient (r) was −0.77. Hence, an increase of TBA number was accompanied by a decrease in flavor rating. This relationship was observed consistently except for dark meat refrigerated for 4 days.

Paired Comparisons and Descriptive Analysis of Turkey Meat Flavor. When panelists were asked to select the better flavor between frozen and refrigerated light meat or dark meat, at 2 or 4 days of storage, frozen samples were selected over refrigerated samples. The superiority of the flavor of frozen samples was highly significant in each case, both for light and dark pairs and for each period of storage (Table III). It is evident that freezing retards flavor deterioration, as Watts (1961) reported. The effect is so conspicuous that it is strongly recommended that cooked poultry meat be frozen as soon as possible.

The characteristics of the flavor of the meat as noted by the sensory panel reveal the effects of the changes during storage (Table IV). The sweetness of fresh or frozen samples decreases in refrigerated meat. Mustiness, staleness, or rancidity of flavor were noted in refrigerated samples after storage for 2 or 4 days.

Effects of Additives on TBA Numbers. The average TBA numbers for turkey meat when untreated and stored, and for the same meat when treated with MSG and stored, are so nearly the same that MSG at the level used (0.3%) clearly does not affect the development of compounds associated with rancidity (Table II). Statistical analysis of individual values also shows that any numerical differences have no significance. This flavor-enhancing additive, as previously indicated for more complex foods (Hanson *et al.*, 1960), did not affect development of oxidative rancidity during short-time storage of cooked turkey meat. Neither did it alter the effects of the antioxidant when used in combination with propyl gallate.

Propyl gallate (at 0.07%) had an observable effect on the TBA numbers of frozen or refrigerated turkey meat (Table II). With white meat the values for the stored samples increased only from 0.75 mg per 1000 g to 1.01; untreated meat showed values as high as 1.90. Even more pronounced was the actual lowering of TBA numbers observed for stored dark meat treated with propyl gallate. An unexplained reduction must have occurred in such treated meat, for an average value for newly-cooked dark meat (1.25) was reduced to 0.62 for refrigerated samples stored 4 days.

Meats to which additives had been added were not tasted, so it is not known if the flavor itself was affected. Because of demands of simultaneous chemical and sensory tests, panel evaluations had to be curtailed. It was previously noted in preliminary tests that 0.007%, even 0.0007%, had a limited effect on TBA numbers.

TBA numbers of the dark-pigmented muscles of chicken and turkey were initially greater and increased rapidly to higher levels than those of the light-colored muscles. Webb and Goodwin (1970) reported similarly that the thigh-drum portion developed higher TBA numbers than breast meat in stored frozen cooked chicken. This is in accord with Zipser and Watts' (1961) explanation that the rate of development of off-odors was dependent on the quantity of heme pigments in

Table IV. Summary of Descriptive Characteristics of Flavor in Turkey Meats when Newly Cooked or Stored

Characteristics of Flavor	Light Newly cooked	Light Frozen 2 days	Light Frozen 4 days	Light Refrigerated 2 days	Light Refrigerated 4 days	Dark Newly cooked	Dark Frozen 2 days	Dark Frozen 4 days	Dark Refrigerated 2 days	Dark Refrigerated 4 days
Bland	14[a]	15	9	13	7	3	4	2	3	1
Sweet	12	8	14	2	5	13	14	12	6	1
Rich	7	10	9	7	5	23	24	24	18	11
Meaty	24	25	33	20	14	29	28	33	23	15
Sulfury	14	14	10	14	14	7	6	7	10	11
Gizzard-like	0	0	0	1	1	11	11	12	11	10
Musty	1	1	0	8	7	2	0	1	9	13
Stale, "old"	7	5	6	17	22	7	4	1	19	26
Rancid	2	0	1	14	19	3	3	0	16	27

[a] Number indicates how many times the characteristic was noted by 12 tasters in three replications.

the tissue. Tasters accepted dark poultry meat with higher TBA values than light meat; the writers speculate that the rich, gizzard-like, meaty flavor of the dark muscles masks or complements initial development of oxidative flavor changes.

The TBA numbers recorded here for cooked cubed turkey meat after refrigeration are considerably lower than the 7 to 8 mg per 1000 g reported by Keskinel *et al.* (1964) for raw turkey and 15 to 18 mg per 1000 g in ground cooked turkey. It is probable that the acid-heat method used by Keskinel yielded data which, though proportional, may be high owing to conditions of the procedure.

These studies indicate a high correlation between the TBA-reactive substances and sensory ratings, as well as comparisons and descriptions of the staleness of poultry meat flavor. This staleness of flavor is recognized as incipient rancidity. Refrigeration of cooked poultry meat, though effective in assuring microbiological safety, is ineffective in maintaining the characteristic cooked flavor. Freezing checks the oxidative process, and should be accomplished at the earliest opportunity when meat is to be held over for short periods. Propyl gallate proved to be effective in preventing the oxidative changes.

LITERATURE CITED

Hanson, H. L., Brushway, M. J., Lineweaver, H., *Food Technol.* **14,** 328 (1960).

Keskinel, A., Ayres, J. C., Snyder, H. E., *Food Technol.* **18,** 223 (1964).

Lineweaver, H., Anderson, J. D., Hanson, H. L., *Food Technol.* **6,** 1 (1952).

National Academy of Sciences, National Research Council Publication 1270, "Chemicals Used in Food Processing," 1965.

Ramsey, M. B., Watts, B. M., *Food Technol.* **17,** 1056 (1963).

Tarladgis, B. G., Pearson, A. M., Dugan, L. R., *J. Sci. Food Agr.* **15,** 602 (1964).

Watts, B. M., Proc. Flavor Chem. Symposium, Campbell Soup Co., pp. 83–96, Camden, N.J. (1961).

Webb, J. E., Goodwin, T. L., *Brit. Poult. Sci.* **11,** 171 (1970).

Zipser, M. W., Watts, B. M., *Food Technol.* **15,** 318 (1961).

Received for review May 18, 1970. Accepted August 17, 1970. Scientific paper No. 3469, Washington Agricultural Research Center, College of Agriculture, Pullman, Wash., Project 1515.