THE RELATION OF FLAVOR TO CHEMICAL CHANGES IN COOKED TURKEY RESULTING FROM REFRIGERATED STORAGE AND REHEATING

by

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INTRODUCTION

Flavor of cooked turkey is affected adversely by refrigerated storage and reheating. Certain chemical and physical changes may occur during cooking, refrigerated storage, and reheating and therefore affect the final acceptability of the meat. The influence of those changes on flavor of turkey is of major concern since acceptance of food is determined in part by flavor.

Characteristic meat flavor arises from a complex blend of compounds. Cramer (1963) listed compounds which may contribute directly to meat taste: fatty acids, amino acids, peptides, carbohydrates, nucleic acids, glycolytic intermediates, and inorganic salts. Meat aroma included lipid oxidation products, nitrogenous- and sulfur-containing compounds. Progress has been made in linking flavor of poultry with some of those components.

Recently, investigators have indicated the importance of the contribution of free amino acids to meat flavor. Furthermore, measured changes in free amines, which occurred during aging of meat, have accompanied flavor changes (McCain *et al*., 1968).

Oxidation of intramuscular lipids may result in development of rancid and stale off-flavors in cooked meat. Results of studies have shown that oxidative deterioration may be influenced by storage temperature and increased with storage time. The effect of heat on lipids with respect to flavor changes remains unclear.

Little information is available on flavor stability after refrigerated storage and reheating of cooked turkey. In a study of flavor stability, descriptive terms for flavor and aroma components in the meat must be selected and standardized. Reports of such descriptive terms, especially in relation to flavor changes, are limited.

The purpose of this study was to identify, describe, and compare flavor characteristics in freshly cooked and in reheated turkey. Lipid oxidation and quantitative changes in free amines which resulted from storage and reheating of turkey were measured and related to flavor changes.

REVIEW OF LITERATURE

Definition of Flavor

Flavor as defined by Kazeniac (1961) is a combination of sensations and may be divided into the following four categories: taste, aroma, body, and mouth satisfaction. Taste includes the four basic tastes of sweetness, sourness, saltiness, and bitterness. Aroma describes sensations perceptible by the olfactory receptors in the nose. The term body is reserved for texture. It is apparent in the mouth, though no contribution is made to taste or aroma. Mouth satisfaction encompasses sensations characterized by increased salivation, pleasant effect, and general smooth blending with very little actual taste. Such factors as juiciness and tenderness contribute to body and mouth satisfaction.

Thus described, flavor is an interaction of those four basic sensations. Most flavor research has been directed to the more tangible components of flavor, taste and aroma.

Basic Meat Flavor Components

Meat flavor research has centered on location and identification of precursor systems in raw meat, and identification of both volatile and non-volatile flavor compounds in cooked meat (Hornstein, 1967). Investigators have found flavor precursors to be low molecular weight, water-soluble compounds within the lean muscle tissue of red meats. Those extractable substances yielded a characteristic meaty aroma when heated (Batzer et al., 1960 and 1962; Hornstein and Crowe, 1960; Macy et al., 1964a and 1964b; Wasserman and Gray, 1965; Wood and Bender, 1957; Wood, 1961). The flavor development has been attributed to the Maillard reaction between amino acids and reducing sugars (Hornstein and Crowe, 1960; Wood, 1961). Similar results were obtained by Pippen et al. (1954) and Peterson (1957) in their studies on chicken flavor.

Flavor precursors in the lyophilized diffusates from the water extracts included amino acids, non-amino nitrogen compounds, carbohydrates, and phosphoric acid esters (Macy et al., 1964a). Those investigators reported that the low molecular weight organic constituents were qualitatively similar in beef, pork, and lamb. Differences among the species included the presence of glutathione in lamb but not in beef. Those workers (Macy et al., 1964b) also reported that the amino nitrogen compounds were qualitatively and quantitatively similar in all three species.

Flavor Constituents of Poultry Meat

Volatile Sulfur Compounds. Crocker's (1948) distillation of muscle tissue from chicken, pork, and beef marked the beginning of research regarding the chemistry of chicken flavor. He concluded that all meats possessed similar flavor compounds which were located within the cooked meat fibers. Bouthilet (1951) reaffirmed that conclusion. He postulated that glutathione was the major muscle precursor of chicken flavor.

Investigators have reported the importance of volatile sulfur compounds in chicken flavor. Hydrogen sulfide has been identified in chicken volatiles (Bouthilet, 1951; Mecchi et al., 1964; Pippen and Eyring, 1957; Pippen, 1967). It was observed that upon standing, desulfuration of broth continued as long as true chicken flavor existed (Pippen and Eyring, 1957).

The transient nature of hydrogen sulfide was demonstrated when its content was reduced to below threshold level by freezing, thawing, and reheating of meat (Pippen, 1967). Indirect involvement of hydrogen sulfide in chicken aroma formation through interaction with carbonyl compounds was reported (Pippen et al., 1965). Hydrogen sulfide dissolved with acetaldehyde in chicken fat formed sulfur compounds with sauerkraut type aroma.

Kazeniac (1961) suggested that sulfides were in the form of ammonium sulfide since there was a large excess of ammonia in chicken volatiles. Minor et al. (1965) suggested that sulfur compounds were responsible for the "meaty" aroma in poultry meat.

Volatile Carbonyls. Carbonyl compounds represent some of the end products of chemical reactions which occur during cooking of meat (Lineweaver and Pippen, 1961). Pippen et al. (1958 and 1960) separated and identified 18 carbonyl compounds in the volatile fraction of cooked chicken. Those same investigators (1960) also reported that normal concentrations of acetoin and diacetyl in chicken broth could not be detected organoleptically. However, if a substantial amount of acetoin was oxidized to diacetyl, its presence could be easily detected as a buttery-oily type aroma. That aroma was characteristic of freshly cooked chicken and was transient in nature. When levels of acetoin/diacetyl were too high, sour notes made chicken flavor undesirable. Minor et al. (1965) concluded that in poultry meat, carbonyls were responsible for the "chickeny" aroma and that they functioned at sub-threshold concentrations by exerting synergistic flavor effects.

Pippen and Nonaka (1963) compared volatile carbonyl compounds from fresh and rancid chicken meat. The quantity of carbonyls from the rancid meat was larger than that from the fresh. Those workers stated that below a certain level, carbonyl compounds such as n-hexanal, n-2,4 deca-dienal contributed to desirable flavor; above that level those compounds gave rise to rancid or off-flavor in the meat. Nonaka and Pippen (1966) isolated volatiles from fried chicken undergoing flavor deterioration. Results revealed that the increase of n-hexanal was proportional to the storage time and was associated with off-flavor development.

Amino Acids. Studies concerning the influence of specific amino acids and of peptides on poultry flavor have been limited. Kazeniac (1961) reported that amino acids had been isolated in chicken broth. None had any taste resembling chicken except cysteine with its sulfury characteristic. Addition of glutamic and aspartic acids, arginine, lysine, and α-alanine improved broth flavor. Mecchi *et al*. (1964) reported that the presence of hydrogen sulfide in heated chicken muscle was caused by protein decomposition and could be related directly to the cysteine and cystine content of the muscle. Ammonia, identified in cooked chicken volatiles, is a breakdown product of dicarboxylic amino acids (Hornstein, 1967). McCain *et al*. (1968) investigated possible relationships between flavor changes and increases in free amino acids during aging of ham.

Lipids. The role of fat in meat flavor has been of interest because of the large amounts of fat present in meat and the tendency of fat to undergo chemical changes. From the studies reported, it has been demonstrated that primary constituents of meat flavor are water soluble. Fat has a role in general meat flavor through its ability to dissolve and retain aromatic compounds formed during cooking (Hornstein and Crowe, 1964; Kazeniac, 1961).

A major change that occurs in stored cooked meat is oxidative rancidity (Katz et al., 1966). Oxidation of unsaturated fatty acids results in carbonyl formation which may contribute to rancid and stale off-flavors if present in high concentration (Watts, 1962). The 2-thiobarbituric acid (TBA) test is an objective measurement of lipid oxidation (Tarladgis et al., 1960). The TBA values (mg malonaldehyde per 1,000 g tissue) have been related to flavor deterioration in meat products. The TBA values within a range of 0.5-1.0 have been reported for detection of off-odors in pork (Tarladgis et al., 1960; Tims and Watts, 1958; Turner et al., 1954; Younathan and Watts, 1960). Mahon (1962) stated that TBA values greater than 2 indicated rancid chicken. While threshold values for detection of off-flavors and off-odors and rancidity in cooked meats have been reported, TBA values denoting threshold of unacceptability have not been established.

The pH of meat may influence TBA test values. Keskinel et al. (1964) reported an inverse relationship of pH to TBA values in ground beef. Another factor which may influence TBA test values is total fat content. Jewel (1963) found that total fat content of chicken was negatively correlated with TBA values. However, Marion and Forsythe (1964) reported a positive correlation between total lipids and autoxidation rate in turkey.

Results of studies in which oxidative changes in cooked turkey, beef, lamb, and pork were compared showed greater changes in turkey than in the other meats (Keskinel *et al*., 1964). Rapid autoxidation of turkey muscle was attributed in part to the high percentage of unsaturated fatty acids. Scott (1958) reported that turkey fat contained 30 percent saturated and 70 percent unsaturated fatty acids. In addition, a low level of tocopherol, a natural antioxidant, in turkey muscle may make it more susceptible to oxidation than other meats (Mecchi *et al*., 1956).

Flavor Evaluation

Information on descriptive terms for flavor and aroma components of cooked turkey is limited. Vail and Conrad (1948) reported that only the terms "mild" and "bitter" had meaning for all judges in the sensory evaluation of poultry meat. Peterson (1957) described aroma components of poultry as bready, meaty-brothy, burnt, ammonia, and sulfide sulfur. He classified poultry flavor components as sour, sweet, salty, sulfury, oily, monosodium glutamate, bready, meaty, and burnt.

Hall (1964) conducted sensory studies to select terms to describe characteristic flavor of turkey and chicken. His panel of trained judges selected terms such as meaty-brothy (monosodium glutamate), fatty (oily), acid (sour), browned (burnt), ammonia, visceral, sulfurous, sweet, salty, and bitter.

Reports of evaluation of flavor changes in cooked poultry indicate that the terms "off-flavor", "stale", "rancid" and "warmed over" have been associated with tissue autoxidation (Watts, 1962). Off-flavor in frozen turkey roasts stored for 11 months was described as stale rather than rancid in a study by Cash and Carlin (1968). However, the meaning of those terms with respect to flavor components has not been standardized.

Various organoleptic methods for the evaluation of flavor differences in foods have been reviewed by Dawson et al. (1963) and Amerine et al. (1965). A discriminative response method (the difference test) may be used in an analysis of flavor. That test measures specific effects by simple discrimination. Trained panelists indicate whether samples are similar or different and do not indicate preference. The paired comparison test is used to indicate which one of a pair of samples has the greater or lesser degree of intensity of a specified character (Gridgeman, 1955). Advantages of that test are that small differences between samples can be determined and direct comparison of samples made without reference to a standard.

Effects of Storage on Cooked Meat

Investigators have reported the effects of length and temperature of storage on lipid oxidation in cooked meat. Oxidized products accumulated rapidly in cooked meat stored at refrigerated temperatures, $5 \pm 1^{\circ}C$, as compared with frozen storage, $-18^{\circ}C$ (Keskinel et al., 1964).

The TBA values increased with time and were accompanied by decreased odor desirability scores in precooked beef preserved by refrigeration (Chang et al., 1961). Similar results were obtained by Tims and Watts (1958) in a study of cooked beef, pork, lamb, and chicken held at refrigerator temperatures for nine days. Jewel (1963) also reported an increase in TBA values in broiler-fryers held at refrigerated temperatures after cooking. The TBA values increased and off-odor developed with storage time in precooked, frozen turkey (Brodine, 1966; Cash and Carlin, 1968; Velicer, 1966).

EXPERIMENTAL PROCEDURE

Breasts from 12 Broad Breasted Bronze toms (25-30 lb dressed weight, U. S. Grade A) from the same flock and processed under the same conditions were obtained from the Kansas State University Poultry Department. Each breast was divided into halves, coded, and labeled right and left as viewed from dorsal to anterior of the bird. Halves were wrapped in aluminum foil and stored at -13°C in a household type freezer. Each half was thawed at refrigerator temperature (6°C) for 24 hrs to an internal temperature of 0 ± 2°C and the pectoralis major (PM) muscle removed before use in the experiment.

Treatments

Paired PM muscles which had been subjected to two treatments were evaluated at each cooking period. The PM muscle from one side of the breast was used for chemical measurements and organoleptic flavor evaluation immediately after cooking. The

PM muscle from the corresponding side of the same bird was used for similar measurements after cooking, storage, and reheating. Left and right halves were randomly selected for a given treatment at each of 12 evaluation periods (Table 1).

Table 1. Random selection of treatments for halves of paired turkey breast muscles.

Evaluation Period	Bird Number	Treatments	
		Braised	Braised Reheated
1	7	Left	Right
2	10	Left	Right
3	2	Left	Right
4	12	Right	Left
5	1	Right	Left
6	9	Left	Right
7	4	Left	Right
8	3	Left	Right
9	6	Left	Right
10	11	Right	Left
11	8	Right	Left
12	5	Right	Left

On the day prior to evaluation, turkey halves to be held for reheating were braised, with skin removed, on racks in covered, aluminum pans in a rotary gas oven maintained at $350^{o}F$. Muscles were cooked to an internal end point temperature of $85^{o}C$

(185°F). Meat was cooled at room temperature (25°C) to an internal temperature of 50°C, wrapped in plastic bags, and held at 6°C for 24 hrs. On the day of evaluation meat was wrapped in aluminum foil and reheated to an internal temperature of 60°C (140°F) in a rotary gas oven maintained at 400°F. The corresponding turkey halves were braised according to the same procedure and evaluated immediately after cooking. Measurements were made on the two treatments on the same day.

Organoleptic evaluation and chemical measurements, except ether extract, were made the day of cooking and reheating. Cooked ground meat samples were frozen until ether extract analyses were made. The sampling plan is illustrated in Fig. 1.

Organoleptic Evaluation

The center portion of each PM muscle was cut into ¼-in. slices which were presented randomly to a trained panel of seven graduate students and faculty members. In preliminary work, training sessions were conducted and descriptive terms for flavor and aroma components in turkey meat were selected. Flavor and aroma differences between the two treatments as well as intensity of the selected components were scored (Form I, Appendix p. 31).

Chemical Measurements

Duplicate measurements were made on cooked, ground meat samples as follows:

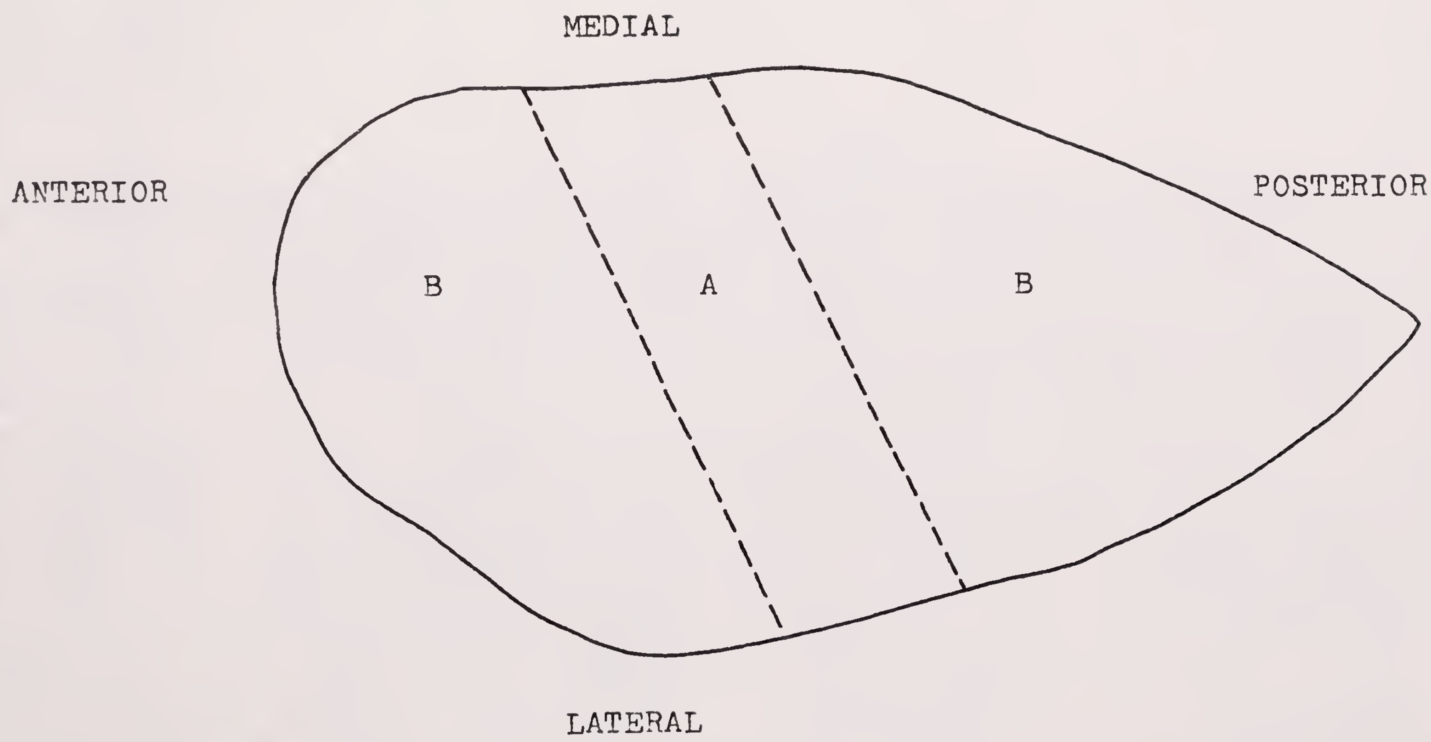

Fig. 1. Sampling plan for pectoralis major muscle.

A = Organoleptic evaluation ($\frac{1}{4}$-in. slices)

B = Ground meat; used for determining free amines, TBA, ether extract, and pH values

Total Free Amines. Two gram samples were deproteinized with 1 percent picric acid solution (Tallon *et al.*, 1954). Total free amines in the protein-free filtrates were determined by a colorimetric method based on the reaction with ninhydrin as described by Yemm and Cocking (1955). Free amines (μ moles per g) were calculated from a standard curve prepared from glycine.

Malonaldehyde. The 2-thiobarbituric acid (TBA) test as described by Tarladgis *et al.* (1960) was used with slight modification to study oxidative changes in tissue lipids. Slurries were prepared with samples of approximately 6 g. Optical density readings were multiplied by the factor 7.8 to convert to mg of malonaldehyde per 1,000 g meat (Tarladgis *et al.*, 1960).

pH. Five gram samples and 20 ml distilled water (25°C) were mixed thoroughly with a stirring rod and allowed to set for 20 min. Readings were made on a Fisher expanded scale pH meter (model 310). Prior to use, the instrument was standardized with a buffer solution of pH 7.00.

Ether Extract. The A.O.A.C. method No. 23.005 (1965) was followed with slight modification in determining percentage ether extract. Two gram samples were dried on ether-extracted cotton at 110°C in a vacuum oven. Dried samples were extracted for 20 hrs on a Goldfisch extraction apparatus, the ether evaporated, the extract dried to constant weight in a vacuum oven at 110°C, and the percentage ether extract calculated on the wet weight basis.[1]

Analysis of Data

A paired comparison design with 12 replications of each treatment was used. Data from the two treatments were analyzed by Student's t-test to determine if differences were significant. Correlation coefficients were calculated to study the relationship of flavor constituents to chemical measurements.

RESULTS AND DISCUSSION

Flavor evaluation of braised and braised-reheated turkey breast was based on selected chemical and organoleptic measurements. Effects of refrigerated storage and reheating upon flavor are discussed. Means and significance of t values for each measurement (Tables 3 and 5) and correlation coefficients indicating relationships among selected flavor and aroma constituents and to chemical measurements (Table 4) are given. Data of all measurements for 12 replications are presented in Tables 6 to 10, Appendix.

Organoleptic Evaluation

Flavor and aroma of the freshly braised turkey muscle were rated superior to the braised-reheated muscle by the panel in all evaluation periods (Table 2). Panel members noted

[1]KSU Chemical Services Laboratory

differences between treatments for specific flavor and aroma components. Significance of those differences was determined by the *t* test (Table 3).

Table 2. Mean scores[a] for flavor and aroma difference[b] between braised and braised-reheated turkey.

Evaluation Period	Difference Score
1	+2.9
2	+0.9
3	+1.7
4	+1.7
5	+2.4
6	+1.3
7	+1.2
8	+2.0
9	+0.8
10	+2.9
11	+2.8
12	+1.6
Mean	+1.8

[a]Average of 7 panelists

[b]Scores: +5.0, large difference (Braised superior to braised-reheated)
0.0, no difference
-5.0, large difference (Braised-reheated superior to braised)

Table 3. Means and significance of t values for aroma and flavor intensity scores for braised and braised-reheated turkey.

Factors	Braised	Braised-Reheated	Significance of t values[a]
Aroma components			
Meaty-brothy	1.7	1.0	**
Acid	0.4	0.5	*
Ammonia	0.2	0.4	**
Sulfur	0.4	0.6	*
Rancid	0.3	1.1	**
Stale	0.4	1.4	**
Flavor components			
Meaty-brothy	1.9	1.5	**
Acid	0.4	0.7	**
Sulfur	0.4	0.5	ns
Sweet	0.6	0.5	ns
Salty	0.5	0.6	**
Bitter	0.2	0.4	**
Rancid	0.3	0.6	ns
Stale	0.3	1.0	**

[a] * $P < 0.05$
** $P < 0.01$
ns not significant

There were greater aroma than flavor differences between freshly braised and braised-reheated muscles. Significant differences ($P < 0.01$ or $P < 0.05$) between treatments were observed for all aroma components identified. Intensities of rancid, stale, ammonia, acid, and sulfur aroma constituents were greater in reheated than freshly braised meat, whereas intensity of meaty-brothy aroma was greater in freshly braised meat.

Differences in flavor components between freshly braised and reheated meat showed trends similar to those for aroma. Storage and reheating increased ($P < 0.01$) intensities of stale, acid, bitter, and salty flavor components. Significant aroma, but not flavor, differences between treatments were observed for rancid and sulfur components. Freshly braised meat had a more intense ($P < 0.01$) meaty-brothy flavor and aroma than reheated meat. An unpleasant after-taste in reheated meat was reported by over 50 percent of the panelists. That sensation may be explained in part by the greater intensity of bitter and acid components in reheated than freshly cooked meat. Kazeniac (1961) stated that carbonyls contributed a bitter off-flavor to chicken. He also suggested that diacetyl, when in high concentration, imparted a sour effect to chicken.

A majority of panelists described freshly braised meat as having more intense "characteristic turkey" flavor than reheated meat. This may be explained in part by the greater ($P < 0.01$) intensity of meaty-brothy, monosodium glutamate-like, component in freshly braised meat. Meaty-brothy flavor and aroma were related negatively to all other flavor and aroma components identified with the exception of sweet flavor (Table 4).

Staleness in reheated meat was described by panelists as aldehyde-like, whereas rancidity was characterized as being

Table 4. Simple, linear correlation coefficients (r-values) for selected flavor and aroma scores and chemical measurements for combined braised and braised-reheated turkey.

Factors Correlated	Combined Treatments	
D.F. = 22	Aroma	Flavor
Meaty-brothy flavor vs		
rancid	-0.377	-0.408*
stale	-0.565**	-0.579**
sulfur	-0.031	-0.015
ammonia	-0.462*	
acid	-0.304	-0.331
sweet		0.225
salty		-0.021
Meaty-brothy aroma vs		
rancid	-0.529**	-0.442*
stale	-0.771**	-0.597**
sulfur	-0.186	-0.086
ammonia	-0.353	
acid	-0.331	-0.535**
sweet		0.426*
Rancid flavor vs		
sulfur	0.410*	0.341
ammonia	0.533**	
acid	0.319	0.338
bitter		0.519**
Rancid aroma vs		
sulfur	0.400	0.455*
ammonia	0.572**	
acid	0.524**	0.522**
bitter		0.612**
Stale flavor vs		
sulfur	0.489*	0.462*
ammonia	0.733**	
acid	0.468*	0.551**
bitter		0.587**
Stale aroma vs		
sulfur	0.446*	0.386
ammonia	0.669**	
acid	0.557**	0.736**
bitter		0.640**

Table 4. (concl.)

Factors Correlated	Combined Treatments	
D.F. = 22	Aroma	Flavor
Free amines vs		
sulfur	0.408*	0.452*
stale	0.138	0.219
rancid	0.304	0.105
ammonia	0.151	
TBA number vs		
rancid	0.148	0.117
stale	-0.033	0.154

* $P < 0.05$
** $P < 0.01$

similar to old oil and fat. Correlation coefficients ($P < 0.01$) showed that as ammonia aroma increased, staleness and rancidity increased (Table 4). Sulfur aroma was related positively ($P < 0.05$) to stale flavor and aroma and to rancid flavor (Table 4). Acid flavor and aroma and bitter flavor were correlated positively ($P < 0.01$ or $P < 0.05$) with staleness and rancidity (Table 4).

Panelists noted development of ammonia and sulfur compounds in reheated meat and those may have contributed to increased intensities of off-flavor and aroma in that treatment. Other investigators have reported nitrogen-, sulfur-, and carbonyl-containing aroma components in cooked chicken volatiles (Bouthilet, 1951; Mecchi et al., 1964; Minor et al., 1965; Pippen and Eyring, 1957; Pippen et al., 1958). Stale and rancid flavor developed in cooked poultry as the quantity of carbonyls increased (Nonaka and Pippen, 1966). Therefore, an increase in staleness and rancidity as a result of storage and reheating would be expected. In addition, an interaction between hydrogen sulfide and carbonyl compounds suggested by Pippen *et al*. (1965) may have promoted off-flavor development in reheated meat.

Chemical Measurements

Mean values for TBA numbers, percentage ether extract, total free amines, and pH are shown in Table 5. No significant differences between treatments were observed for those measurements. However, there was a trend for higher TBA numbers in reheated than freshly cooked meat (Table 6, Appendix). The slight increase in TBA number in reheated meat may be attributed to lipid oxidation during storage and/or reheating. A greater increase in TBA number could be expected with a longer storage

Table 5. Means and *t* values for TBA numbers, ether extract, free amines, and pH for braised and braised-reheated turkey.

Factors	Braised	Braised-Reheated	Significance of *t* values[a]
TBA number (mg malonaldehyde/ 1,000 g meat)	1.08	1.11	ns
Ether extract (%)	1.18	1.25	ns
Free amines (μ moles glycine/ g meat)	2235.73	2196.57	ns
pH	6.05	6.00	ns

[a]ns not significant

period, since oxidation of fats tends to increase with time. Significant increases in TBA numbers associated with development of off-flavor and/or rancidity were reported in other studies which involved longer periods of refrigerated or frozen storage of cooked poultry (Brodine, 1966; Cash and Carlin, 1968; Jewel, 1963; Tims and Watts, 1958; Velicer, 1966). Since stale and rancid components in the reheated meat were detected by panelists, it appeared that sensory evaluation was more sensitive than TBA numbers for indicating degree of staleness and rancidity in cooked turkey stored for a short period of time.

Free amines and pH were not affected significantly by storage and reheating. Increases in free amines during storage of meat have been associated with naturally-occurring and/or microbial enzymatic degradation of protein (McCain _et al_., 1968). However, meat in such studies was not cooked. Therefore, the present data indicate that flavor changes in cooked turkey held for a short time at refrigerated temperatures may not be the result of increases in total free amines. As intensities of sulfur flavor and aroma components increased ($P < 0.05$), concentration of free amines increased (Table 4).

SUMMARY

Flavor evaluation of braised and braised-reheated turkey breast muscle was based on selected chemical and organoleptic measurements. Effects of refrigerated storage (24 hr) and reheating upon flavor were investigated. Significance of

differences between freshly cooked and reheated treatments was measured by the t test; correlation coefficients indicated relationships of selected flavor components to one another and to selected chemical measurements. A paired comparison design with 12 replications of each treatment was used.

Freshly braised meat was rated superior to braised-reheated meat by trained panelists in all flavor evaluation periods. The t test indicated differences ($P < 0.01$ or $P < 0.05$) between freshly cooked and reheated meat for rancid, stale, ammonia, meaty-brothy, acid and sulfur aroma components. There were greater aroma than flavor differences between freshly braised and braised-reheated muscles. Differences in flavor components between treatments showed trends similar to those for aroma. Stale, acid, bitter, and salty flavor components were more intense ($P < 0.01$) in reheated meat while meaty-brothy flavor was more intense ($P < 0.01$) in freshly cooked meat. Storage and reheating had no significant effect on TBA number, percentage ether extract, total free amines, or pH. However, a slight increase in TBA number in the reheated treatment was noted.

Correlation coefficients between paired flavor and aroma components in cooked turkey indicated a positive relationship ($P < 0.05$) between meaty-brothy aroma and sweet flavor. As intensity of meaty-brothy aroma increased, intensities of rancid and stale components decreased ($P < 0.01$ or $P < 0.05$). Meaty-brothy flavor was correlated negatively ($P < 0.01$ or $P < 0.05$) with rancid flavor and stale flavor and aroma. Rancidity and staleness were correlated positively ($P < 0.01$) with ammonia and bitter components. Acid flavor and aroma were related positively ($P < 0.01$ or $P < 0.05$) to rancid aroma and stale flavor and aroma. Correlation coefficients showed that sulfur flavor was related positively ($P < 0.05$) to rancid aroma and stale flavor; sulfur aroma was related positively ($P < 0.05$) to rancid flavor and stale flavor and aroma. As sulfur constituents increased ($P < 0.05$) concentration of free amines increased.

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APPENDIX

Form I

SCORE CARD FOR TURKEY MEAT

Name ____________________ Date __________ Period ____________

1. Please compare Sample A and Sample B for flavor and odor differences according to the following scale:

   0 = No difference
   1 = Very slight difference
   2 = Slight difference
   3 = Moderate difference
   4 = Large difference
   5 = Very large difference

Difference Score	Comments		Quality of Sample B as compared to Sample A (Check one):		
	Flavor	Odor	Superior	Inferior	Equal

II. Please rate intensity for each flavor and odor component according to the following scale:

   0 = Absent   2 = Medium
   1 = Slight   3 = Strong

Components	Aroma		Flavor	
	A	B	A	B
Meaty brothy (monosodium glutamate)				
Acid (sour)				
Ammonia			------	------
Sulfurous				
Sweet	----	------		
Salty	-----	------		
Bitter	-----	------		
Rancid				
Stale (cold-storage)				
Other				

Table 6. Percentage ether extract, free amines, pH, and TBA numbers of braised (B) and braised-reheated (B-R) turkey.

Evaluation Periods	Ether Extract[a]		Free Amines[b]		pH		TBA[c]	
	B	B-R	B	B-R	B	B-R	B	B-R
1	0.95	1.28	1960.90	2800.30	6.02	6.04	1.52	1.45
2	1.66	1.73	2051.92	2042.68	6.04	5.94	1.01	1.07
3	1.50	1.34	1877.52	2064.97	5.90	5.94	1.11	1.11
4	1.09	1.34	2165.71	2173.19	6.10	6.12	1.11	1.06
5	2.00	2.16	2125.43	1940.48	5.99	5.96	1.09	1.18
6	1.10	1.18	1540.14	1524.26	6.00	5.96	1.07	1.27
7	0.86	1.22	2141.36	2020.95	6.15	6.19	1.11	1.05
8	0.85	1.04	2247.97	2598.55	6.00	6.00	1.08	1.10
9	1.27	0.87	3644.16	3235.77	6.08	6.04	1.03	1.06
10	0.82	1.14	2285.88	2019.99	6.22	6.15	0.96	1.02
11	1.13	1.04	1816.30	1918.45	5.98	5.92	1.00	0.99
12	0.93	0.66	2471.48	2029.28	6.10	6.15	0.84	0.94
Mean	1.18	1.25	2235.73	2196.57	6.05	6.00	1.08	1.11
t values[d]	0.971		1.398		0.517		1.188	

[a]Expressed as percent fat, calculated on wet weight basis.

[b]Expressed as μ moles/g meat.

[c]Expressed as mg malonaldehyde/1,000 g meat.

[d]$t_{.05} = 2.201$

$t_{.01} = 3.106$

Table 7. Scores for flavor difference[a] between braised and braised-reheated turkey.

Evaluation Period	Judges							Mean
	1	2	3	4	5	6	7	
1	+1.5	----	+2.0	+2.0	+3.0	+4.0	+4.0	+2.9
2	-1.0	----	+1.0	+2.0	-3.5	+3.0	+3.0	+0.9
3	+1.0	+2.0	+3.0	+2.0	+3.0	-2.0	+3.0	+1.7
4	-1.0	----	----	+2.0	+3.5	+2.0	+2.0	+1.7
5	+1.0	+3.0	----	+2.0	+3.5	+2.0	+3.0	+2.4
6	+1.5	+1.0	-2.0	0.0	+3.0	+4.0	----	+1.3
7	+1.5	-1.0	+1.0	+2.0	+2.5	+1.0	----	+1.2
8	+1.0	+1.0	----	+3.0	+4.0	0.0	+3.0	+2.0
9	+1.5	----	+1.0	+1.0	-4.0	+2.0	+3.0	+0.8
10	+2.0	+2.0	+3.0	+3.0	+4.0	+2.0	+4.0	+2.9
11	-1.0	+4.0	+2.0	----	+4.0	+4.0	+4.0	+2.8
12	+2.0	+3.0	+1.0	+2.0	+4.0	+1.0	-2.0	+1.6
Mean								+1.8

[a]Scores: +5, large difference (braised superior to braised-reheated).

0, no difference

-5, large difference (braised-reheated superior to braised).

Table 8. Flavor intensity scores[a]: meaty-brothy, acid, sulfur, sweet, salty, bitter, rancid, and stale for braised (B) and braised-reheated (B-R) turkey.

Evaluation Period	Meaty-brothy		Acid		Sulfur		Sweet		Salty		Bitter		Rancid		Stale	
	B	B-R	B	B-R	B	B-R	B	B-R	B	B-R	B	B-R	B	B-R	B	B-R
1	1.8	1.7	0.3	0.7	0.2	0.5	0.8	0.3	0.3	0.7	0.0	0.2	0.0	1.0	0.2	1.3
2	2.1	1.9	0.6	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.0	0.0	0.3	0.3	0.2	0.5
3	1.6	1.1	0.3	0.7	0.3	0.6	0.4	0.6	0.4	0.4	0.0	0.3	0.3	0.7	0.6	1.3
4	2.2	1.6	0.4	0.6	0.6	1.0	0.4	0.6	0.8	0.8	0.2	0.6	0.4	0.6	0.2	1.0
5	2.5	1.7	0.3	0.8	0.3	0.8	0.7	0.5	0.7	0.7	0.2	0.7	0.3	0.5	0.2	0.8
6	1.2	1.2	0.4	0.4	0.2	0.2	0.4	0.6	0.4	0.6	0.2	0.4	0.0	1.0	0.0	0.8
7	1.7	1.2	0.5	0.5	0.5	0.2	0.7	0.7	0.3	0.5	0.3	0.2	0.2	0.2	0.2	0.8
8	2.3	1.5	0.5	0.8	0.3	0.7	0.7	0.3	0.7	0.8	0.2	0.7	0.2	0.5	0.2	1.2
9	1.8	1.9	0.5	0.8	0.7	0.7	0.3	0.7	0.5	0.7	0.3	0.2	0.5	0.5	0.8	0.8
10	2.4	1.1	0.4	0.9	0.1	0.3	0.6	0.3	0.4	0.7	0.1	0.7	0.1	0.7	0.1	1.3
11	1.8	1.2	0.8	1.2	0.3	0.3	0.8	0.2	0.5	0.7	0.2	0.7	0.3	0.5	0.3	0.8
12	1.5	1.4	0.3	0.6	0.4	0.3	0.7	0.4	0.6	0.7	0.3	0.6	0.5	0.8	0.3	0.8
Mean	1.9	1.5	0.4	0.7	0.4	0.5	0.6	0.5	0.5	0.6	0.2	0.4	0.3	0.6	0.3	1.0
_t_ values[b]	3.817		6.019		2.017		1.169		3.737		3.936		0.345		6.893	

[a]Highest possible score, 3 points.

[b]$\underline{t}_{.05} = 2.201$.

$\underline{t}_{.01} = 3.106$.

Table 9. Aroma intensity scores[a]: meaty-brothy, acid, ammonia, sulfur, rancid, and stale for braised (B) and braised-reheated (B-R) turkey.

Evaluation Period	Meaty-brothy		Acid		Ammonia		Sulfur		Rancid		Stale	
	B	B-R	B	B-R	B	B-R	B	B-R	B	B-R	B	B-R
1	1.7	1.0	0.3	0.5	0.2	0.2	0.3	0.5	0.5	1.5	0.3	1.2
2	1.6	0.9	0.3	0.1	0.2	0.1	0.4	0.6	0.4	0.4	0.7	1.0
3	1.4	1.0	0.3	0.6	0.0	0.7	0.3	0.4	0.3	0.6	0.4	1.1
4	2.0	1.2	0.4	0.6	0.2	0.4	0.4	0.6	0.4	1.2	0.2	1.4
5	2.2	1.0	0.2	0.5	0.2	0.5	0.5	0.8	0.3	1.2	0.2	1.5
6	1.0	0.8	0.4	0.2	0.0	0.4	0.2	0.6	0.2	0.8	0.4	1.2
7	1.3	0.8	0.2	0.2	0.2	0.3	0.3	0.5	0.0	0.8	0.5	1.3
8	2.3	1.3	0.3	0.5	0.2	0.7	0.5	0.7	0.2	1.2	0.0	1.2
9	1.3	1.2	0.5	0.8	0.3	0.5	0.8	0.5	0.8	1.5	1.2	1.7
10	1.7	1.1	0.4	0.6	0.1	0.6	0.4	0.6	0.1	1.1	0.3	1.7
11	1.7	0.5	0.5	1.0	0.3	0.5	0.3	0.5	0.3	1.0	0.8	1.6
12	1.6	1.0	0.4	0.4	0.3	0.3	0.6	0.3	0.3	1.7	0.2	1.5
Mean	1.7	1.0	0.4	0.5	0.2	0.4	0.4	0.6	0.3	1.1	0.4	1.4
$\underline{t}$ values[b]	6.592		2.458		3.614		2.419		7.366		9.299	

[a]Highest score possible, 3 points.

[b]$\underline{t}_{.05} = 2.201$.

$\underline{t}_{.01} = 3.316$.

Table 10. Simple, linear correlation coefficients (r-values) for selected flavor and aroma scores and chemical measurements for braised and braised-reheated turkey.

Factors Correlated	Braised D.F. = 10		Braised-Reheated D.F. = 10		Combined Treatments D.F. = 22	
	Aroma	Flavor	Aroma	Flavor	Aroma	Flavor
Meaty-brothy flavor vs						
rancid	-0.036	0.075	0.261	-0.204	-0.377	-0.408*
stale	-0.269	-0.156	-0.073	-0.372	-0.565**	-0.579**
sulfur	0.265	-0.073	0.288	0.465	-0.031	-0.015
ammonia	0.205		-0.442		-0.462*	
acid	-0.265	0.040	-0.083	0.054	-0.304	-0.331
sweet		0.136		-0.001		0.225
salty		0.428		0.052		-0.021
Meaty-brothy aroma vs						
rancid	-0.047	0.136	0.399	0.071	-0.529**	-0.442*
stale	-0.546	-0.203	0.042	0.428	-0.771**	-0.597**
sulfur	0.218	-0.083	0.223	0.664*	-0.186	-0.086
ammonia	0.325		0.306		-0.353	
acid	-0.263	-0.040	-0.000	-0.210	-0.331	-0.535**
sweet		0.410		0.192		0.426*
Rancid flavor vs						
sulfur	0.721**	0.736**	-0.238	-0.055	0.410*	0.341
ammonia	0.588*		0.033		0.533**	
acid	0.298	0.111	0.058	-0.274	0.319	0.338
bitter		0.438		0.154		0.519**
Rancid aroma vs						
sulfur	0.589*	0.489	-0.179	0.311	0.400	0.455*
ammonia	0.404		0.034		0.572**	
acid	0.446	0.005	0.396	0.031	0.524**	0.522**
bitter		-0.402		0.379		0.612**

Table 10. (concl.)

Factors Correlated	Braised D.F. = 10		Braised-Reheated D.F. = 10		Combined Treatments D.F. = 22	
	Aroma	Flavor	Aroma	Flavor	Aroma	Flavor
Stale flavor vs						
sulfur	0.597*	0.590*	-0.052	0.266	0.489*	0.462*
ammonia	0.263		0.550*		0.733**	
acid	0.313	0.035	0.322	0.050	0.468*	0.551**
bitter		0.108		0.277		0.587**
Stale aroma vs						
sulfur	0.292	0.432	-0.030	0.098	0.446*	0.386
ammonia	0.314		0.296		0.669**	
acid	0.498	0.558	0.651*	0.420	0.557**	0.736**
bitter		0.128		0.529*		0.640**
Free amines vs						
sulfur	0.861**	0.593*	-0.079	0.446	0.408*	0.452*
stale	0.456	0.660*	0.178	0.262	0.138	0.219
rancid	0.699*	0.484	0.525	-0.052	0.304	0.105
ammonia	0.560					
TBA vs						
rancid	0.208	-0.554	0.046	0.545	0.148	0.117
stale	0.144	-0.090	-0.435	0.309	-0.033	0.154

*$P < 0.05$.

**$P < 0.01$.

THE RELATION OF FLAVOR TO CHEMICAL CHANGES IN COOKED TURKEY RESULTING FROM REFRIGERATED STORAGE AND REHEATING

by

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Flavor constituents of braised turkey breast muscle and flavor stability after refrigerated storage and reheating were studied. Evaluation was based on selected chemical and organoleptic measurements in 12 replications. Trained panelists identified and described specific flavor and aroma components as well as differences between freshly braised and braised-reheated turkey. Total free amines, TBA number, percentage ether extract, and pH were determined. Significance of differences between treatments was evaluated by the *t* test. Correlation coefficients indicated relationships among selected flavor and aroma constituents and chemical measurements.

Freshly braised meat was rated superior to reheated meat by panelists in all evaluation periods. Significant differences ($P < 0.01$ or $P < 0.05$) between freshly cooked and reheated meat for rancid, stale, ammonia, meaty-brothy, acid, and sulfur aroma components were indicated by *t* values. There were greater aroma than flavor differences between treatments; however, differences in flavor components between treatments showed trends similar to those for aroma. Stale, acid, bitter, and salty flavor components were more intense ($P < 0.01$) in reheated meat while meaty-brothy flavor was more intense ($P < 0.01$) in freshly cooked meat. Storage and reheating had no significant effect on TBA number, percentage ether extract, total free amines, or pH. A slight increase in TBA number in the reheated treatment was noted. It appeared that sensory evaluation was more sensitive than TBA numbers for indicating degree of staleness and/or rancidity in cooked turkey stored for a short period of time.

Correlation coefficients between paired flavor and aroma constituents in braised turkey indicated a positive relationship ($P < 0.05$) between meaty-brothy aroma and sweet flavor and negative relationships ($P < 0.01$ or $P < 0.05$) between meaty-brothy aroma and the components of rancidity and staleness. In general, as rancidity and staleness increased ($P < 0.01$ or $P < 0.05$) intensity of ammonia, bitter, acid, and sulfur components increased. Sulfur flavor and aroma were related positively ($P < 0.05$) to concentration of free amines.