EFFECTS OF COOKING IN AIR OR IN NITROGEN ON THE DEVELOPMENT OF FISHY FLAVOR IN THE BREAST MEAT OF TURKEYS FED TUNA OIL WITH AND WITHOUT α-TOCOPHEROL SUPPLEMENT OR INJECTION

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ABSTRACT

The breast meat of turkeys which had been fed fish oil with and without α-tocopherol supplement or injection were cooked in air or under nitrogen with a slight vacuum. Cooking under nitrogen prevented the development of fishy flavor nearly as well as dietary α-tocopherol acetate supplementation. Some evidence is given which shows that fishy fiavor develops postmortem (during cooking) and not in vivo.

Crawford et al. (1974) explored the effects of feeding fish oil with and without α-tocopherol acetate on the flavor of turkeys. This paper and other work by Crawford et al. (1975) showed that dietary α-tocopherol can be very effective in preventing the development of fishy flavor. Similarly, α-tocopherol acetate had a profound effect on the "elimination" of fishy flavor when it and beef fat were substituted for fish oil in the rations of turkeys that had been fed diets containing fish oil for several weeks. Injection of α-tocopherol (a few days before slaughter) into the thighs of turkeys fed diets containing fish oil showed a positive effect on the reduction of fishy flavor.

Consideration of these results and the finding that poultry carcass stability is related to the degree of lipid unsaturation and the tocopherol content (Mecchi, Pool, Behman, Hamachi, and Klose 1956; Mecchi, Pool, Nonaka, Klose, Marsden, and Lillie 1956; Webb, Brunson, and Yates 1972, 1973; Webb, Marion, and Hayse 1972) led us to the reasoning that fishy flavor in poultry may result from in vivo and/or postmortem oxidation of lipids containing long chain ω-3 fatty acids. Crawford et al. (1975) entertained the possibility that such oxidation and subsequent fishy flavor development occur mostly in vivo. At first glance, the effects of dietary α-tocopherol acetate on prevention of fishy flavor seem to support this hypothesis. However, the effectiveness of injecting α-tocopherol only a few days before slaughter casts some doubt on this reasoning since in vivo oxidation prior to injection should have had ample time to occur. Whereas this doubt does not call for total apostasy, it does suggest that postmortem oxidation and subsequent development of fishy flavor is indeed a possibility and deserves consideration.

The exact nature and origin of fishy flavor in turkeys is not known, but it is known that the development of such flavor requires the uptake of ω-3 fatty acids from dietary oils rich in these fatty acids. Most fish oils are rich sources of long chained ω-3 fatty acids which are readily taken up into the carcass of turkeys when included in their diet. Linseed oil contains more than 50% linolenic acid and when incorporated into turkey diets, the linolenic acid is taken up and elongated to the longer chained homologues thereby causing fishy flavor to develop (Klose et al. 1951; Miller et al. 1967a, b; Crawford et al. 1974).

If postmortem oxidation plays a major role in the development of fishy flavor, it is likely that the development would occur largely during cooking. Pippen and Nonaka (1963) found that the amount of volatiles from raw chicken was small and the aroma rather insipid when compared to the relatively large amount of highly odoriferous volatiles from cooked chicken. They also reported that chicken boiled in air yielded a more complex and larger volatile fraction than chicken boiled in nitrogen. Crawford (1972) reported that replacement of air in the headspace with nitrogen gave some protection against scorch during the retorting of 4-pound cans of tuna. This suggests that less carbonyls (volatiles) were formed under nitrogen since volatile carbonyls, sugars, and

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amino compounds (Fujimoto et al. 1968) have been implicated in such nonenzymatic browning (Tarr 1954; Jones 1962).

It is clear that the development of the normal aroma of poultry is time-temperature dependent and that air or nitrogen cooking atmospheres have profound effects on the development of this aroma. Therefore, it is likely that control of the cooking atmosphere may affect the development of fishy flavor in poultry meat if this flavor requires air and/or heat for its development.

This paper explores the effects of cooking in different atmospheres on the flavor of breast meat from turkeys fed diets containing tuna oil with and without dietary α-tocopherol acetate or α-tocopherol injection. Diced breast meat was cooked in air as well as under nitrogen with a slight vacuum.

EXPERIMENTAL

Turkey Diets and Feeding

The turkeys used in this experiment were taken from groups of turkeys raised experimentally for other work. Their diets and feeding are described in some detail by Crawford et al. (1975). Briefly, there were 50 White Broad Breast poults in experiment C that were divided into five groups of 10 each and they were fed as follows: chick starter (6.75% fish meal) was fed to 3 wk of age, then a 50:50 mixture of chick starter and a 50% soybean meal basal diet for a few days, followed by the 50% soybean meal diet supplemented with 2% soybean oil and 2% beef fat to 8 wk of age. At 8 wk of age, the following fat and oil supplements replaced the previous ones and they were fed from 8 to 14 wk of age:

Group	*Oil Supplement to Basal Diet*[1]
1 C	4% BF
2 C	2% BF + 2% TO
3 C	2% BF + 2% TO
4 C	2% BF + 2% TO
5 C	2% BF + 2% TO

[1]BF = Beef fat; TO = Tuna fish oil.

At 14 wk of age, the above groups of turkeys were fed a 30% soymeal basal diet plus the following oil supplement to 16 wk of age:

Group	*Oil Supplement to Basal Diet*[1]
1 C	Keep on 4% BF
2 C	Change to 4% BF
3 C	Change to 4% BF + 100 mg Vit. E/kg
4 C	Change to 4% BF + 200 mg Vit E/kg
5 C	Keep on 2% BF + 2% TO

[1]BF = Beef fat; Vit. E = *dl* α-tocopherol acetate; TO = Tuna fish oil

In experiment B, 50 poults were obtained and handled as above. On day 3, they were fed a basal diet plus 4% beef fat to 14 wk of age. From 14 to 16 wk of age, they were fed as follows:

Group	*Oil Supplement to Basal Diet*
1 B	4% BF
2 B	2% BF + 2% TO
3 B	2% BF + 2% TO (+ injection of 170 mg α-tocopherol into thigh at 72, 48, 24 h before sacrifice)
4 B	2% BF + 2% TO + 100 mg Vit. E/kg
5 B	2% BF + 2% TO + 500 mg Vit. E/kg

Sampling, Canning, and Analysis

All turkeys were sacrificed at 16 wk of age then handled and stored at -30°C as described by Crawford et al. (1974). Two turkeys from each group were randomly selected and thawed overnight in a 2°C cold room. The breasts were excised and diced in the cold after the skin had been removed. Breast meat from turkeys of the same group were mixed together and appropriately identified. The diced breast meat was canned immediately as follows: breast meat from each group was hand packed into 307 × 113 cans (eight cans per group) leaving a headspace of about ½ inch. All cans from each group were alternately evacuated and flushed with nitrogen several times. On the final nitrogen flush, the lids were sealed when the vacuum dropped to 5 inches. Four of the cans from each group were frozen at -30°C until used and the other four cans were cooked immediately at 116°C (15 psi) for 80 min to an internal temperature of ca. 112°-115°C, cooled, and stored at 2°C until used. The four uncooked cans from each group were removed from -30°C storage, thawed to about 2°C, opened, and the contents cooked in aluminum trays (with loose covers) at about 117°C for 30 min (internal temperature ca. 70°C) before serving. Those cans that were cooked at 116°C were warmed in boiling water for 10 min before opening and serving. Organoleptic analysis was performed by a panel of eight judges using a balanced incomplete block design ($t = 5, r = 4$). Only one panel per day was

convened and the air and nitrogen packs were randomly offered from day to day. Duncan's multiple range test (α = 0.05) was used to compare the adjusted mean of the taste panel scores. The scoring was: 1 = no fishy flavor, 5 = very fishy flavor.

RESULTS AND DISCUSSION

The results reported in Table 2 are to be interpreted with some caution because of the low level of fishiness in the meat from turkeys fed 2% fish oil for only 2 wk. Therefore, only trends are indicated for the results in Table 2 where statistical significance could not be achieved.

Tables 1 and 2 report Duncan's multiple range test of the mean taste panel scores of breast meat cooked in air or nitrogen from turkeys fed various diets containing tuna oil and/or beef fat with and without dietary α-tocopherol acetate or α-tocopherol injection. All meats that contained α-tocopherol gave taste panel scores that were comparable to the scores for the control for all methods of cooking. When breast meat is cooked under nitrogen with a slight vacuum no appreciable difference in flavor is caused by any of the diets. However, the breast meat from turkeys fed diets containing 2% tuna oil (treatments 5C and 2B) did have slightly higher scores, although not statistically different from the control (treatments 1C or 1B, 4% beef fat). The breast meat cooked in air from turkeys fed diets containing 2% tuna oil (treatments 5C and 2B) showed more off flavor than those cooked in nitrogen when each is compared to its control (treatments 1C or 1B, 4% beef fat). Furthermore, the order and rank of the scores for the air-cooked meat were very similar to those of breast meat from whole roasted turkeys previously reported by Crawford et al. (1975). These turkeys were randomly selected from the same groups of turkeys used in this experiment and were roasted at 177°C to center breast temperature of about 70°C.

From the results of this experiment, it may be concluded that cooking breast meat of potentially fishy flavored turkeys under nitrogen is nearly as effective in preventing fishy flavor development as feeding α-tocopherol acetate (in the diets with the tuna oil) and roasting in the normal manner. This implies that fishy flavor develops postmortem and requires air for its development. Alternately, it could be concluded that cooking under nitrogen per se had practically no effect in preventing this development but that fishy flavor had already developed in vivo and the heat of cooking at 116°C for 80 min destroyed the components which cause this flavor. Some observations and recent work (Crawford unpubl. data) tend to support the first conclusion.

We have observed that the odor of fresh raw turkey was insipid regardless of the type of dietary oil. However, after comminuting and storing in the refrigerator overnight, the flesh from turkeys fed tuna oil smelled fishy while the odor of beef fat-fed turkeys remained rather insipid.

TABLE 1.—Duncan's multiple range test of mean[1] taste panel scores[2] for breast meat cooked in air or nitrogen from turkeys fed various diets containing tuna oil and/or beef with and without α-tocopherol acetate.

Cooked in nitrogen		Cooked in air		Roasted normally[4]	
Treatment[3]	Scores	Treatment[3]	Scores	Treatment[3]	Scores
5C 2% TO	2.05	5C 2% TO	3.23	5C 2% TO	3.14
4C 4% BF + 200 E	1.80	3C 4% BF + 100 E	1.66	2C 4% BF	2.43
3C 4% BF + 100 E	1.77	2C 4% BF_1	1.63	3C 4% BF + 100 E	1.31
2C 4% BF_1	1.71	1C 4% BF	1.24	1C 4% BF	1.29
1C 4% BF	1.65	4C 4% BF + 200 E	1.08	4C 4% BF + 200 E	0.99

[1]Mean taste panel scores connected by a common line are not significantly different at the 0.05 probability level.

[2]Taste panel scoring: 1 = no fishy flavor, 5 = very fishy flavor. Abbreviations: TO = tuna oil; E = mg *dl* α-tocopherol acetate per kilogram of diet; BF = beef fat; BF_1 = beef fat substituted for 2% TO + 2% BF.

[3]All groups (except group 1C, the control which was maintained on diet with 4% BF for all 16 wk) were fed a basal diet with 2% TO plus 2% BF from 8 to 14 wk of age and from 14 to 16 wk of age, they were fed a basal diet with: group 1C = 4% BF, group 2C = change to 4% BF, group 3C = change to 4% BF + 100 mg/kg α-tocopherol acetate, group 4C = change to 4% BF + 200 mg α-tocopherol acetate, group 5C = kept on 2% TO + 2% BF.

[4]These results for the breast meat of normally roasted whole turkeys were previously reported by Crawford et al. (1975).

TABLE 2.—Duncan's multiple range test of mean[1] taste panel scores[2] for breast meat cooked in air or nitrogen from turkeys fed various diets containing tuna oil and/or beef fat with and without α-tocopherol acetate supplement or injection.

Cooked in nitrogen		Cooked in air		Roasted normally[4]	
Treatment[3]	Scores	Treatment[3]	Scores	Treatment[3]	Scores
2B 2% TO	1.82	2B 2% TO	2.16	2B 2% TO	2.23
4B 2% TO + 100 E	1.71	5B 2% TO + 500 E	1.74	5B 2% TO + 500 E	2.18
5B 2% TO + 500 E	1.61	4B 2% TO + 100 E	1.41	4B 2% TO + 100 E	1.86
3B 2% TO + In	1.59	3B 2% TO + In	1.35	3B 2% TO + In	1.32
1B 4% BF	1.43	1B 4% BF	1.22	1B 4% BF	1.19

[1]Mean taste panel scores connected by a common line are not significantly different at the 0.05 probability level.

[2]Taste panel scoring: 1 = no fishy flavor, 5 = very fishy flavor. Abbreviations: TO = tuna oil; E = milligrams *dl* α-tocopherol acetate per kilogram of diet; In = inject α-tocopherol; BF = beef fat.

[3]All groups were fed a basal diet + 4% BF to 14 wk of age and from 14 to 16 wk of age, they were fed a basal diet with: group 1B = 4% BF, group 2B = 2% BF + 2% TO, group 3B = 2% BF + 2% TO (+ inject 170 mg of α-tocopherol into thigh 72, 48, and 24 h before sacrifice), group 4B = 2% BF + 2% TO + 100 mg α-tocopherol acetate per kilogram, group 5B = 2% BF + 2% TO + 500 mg α-tocopherol acetate per kilogram.

[4]These results for the breast meat of normally roasted whole turkeys were previously reported by Crawford et al. (1975).

Fresh tuna fish also has very little odor but will develop a characteristic odor during refrigerated storage or cooking. These observations tend to support the supposition that fishy flavor develops during postmortem oxidation.

Additionally, volatiles were steam distilled from the same tuna oil that was fed to the turkeys in this experiment. These volatiles appeared to have the same fishy aroma as turkeys judged to have fishy flavor by the taste panel. The volatiles were added to water (ca. 2 μl/125 ml) in cans with a nitrogen or air headspace plus a slight vacuum and cooked at 116°C in the same fashion as the breast meat. An odor panel revealed little, if any, loss in character or intensity for the odor of the volatiles cooked under nitrogen or in air. Although this experiment with the volatiles offers only deductive reasoning, it nonetheless lends support to the argument that a heat-stable fishy flavor develops during cooking in air and that cooking under nitrogen prevents the development of this flavor.

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