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Development of Radiation-Sterilized Chicken

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SUMMARY

Research has led to a process for producing a "first generation" irradiation sterilized chicken product that is acceptable and reproducible, and one that is expected to play an important part in military rations in the future. Acceptability tests have been closely coordinated with process procedures in the development of the product. Certain improvements in the sensory characteristics of the product are still needed, and research to find methods for making them are underway.

Most important of the recognized deficiencies in the "first generation" product are those associated with radiation induced off-color, texture deterioration and irradiation flavor. Results of experiments on improvements in methods of enzyme inactivation, improvements in packaging techniques, irradiation at low temperatures, and reduction in dose requirements to attain sterility is yielding information that is being used to correct these deficiencies and to improve the acceptability of the product.

INTRODUCTION

Results of evaluations, including technical panel, preference and acceptability testing, indicate that radiation-sterilized chicken is a satisfactory product and is suitable for use in Army garrison mess hall feeding systems. This paper (1) summarizes the results of investigations conducted in this area and (2) describes recent work conducted at the U. S. Army Natick Laboratories leading to the development of a standard process that assures a uniform, acceptable product.

During the development of a process for producing irradiated chicken, variations in final product have been closely correlated with acceptability and preference tests, which are subjective tests, and the only quantitative measures available to determine whether a product has or has not been improved. Numerous process variables are involved in the development of any process; in radiation processing these include such factors as type and quality of the raw material (e.g., light vs. dark meat, broiler vs. fowl) enzyme-inactivation techniques, effects of package environment including vacuum and in-package odor scavengers, and temperature during irradiation. Many of these variables have been studied, and the results of these subjective tests have given quantitative data on which to base decisions.

The importance of chicken to the military is indicated by the studies of Peryam *et al.* (1960) and by the frequency of its use in mess halls (Joint Army-Air Force Menu Board, 1966). As shown in Table 1, chicken is second to beef in preference and frequency of use as a major meat item. Since chicken, as a result of advances in poultry husbandry, is produced at as low if not lower cost per pound than other meats, its use as a component in military rations has distinct economical advantages.

LITERATURE REVIEW

Many of the early investigations on food irradiation included chicken as experimental material. The results of the studies on cooked (enzyme inactivated) chicken were encouraging. Kirn *et al.* (1956) reported that the flavor of irradiated roast chicken was scored as "very poor" one day after irradiation; but the same product was scored as acceptable for flavor, appearance, and aroma after 10 and 1800 days' storage. Proctor *et al.* (1956), working with cooked chicken, found little difference in flavor between the irradiated samples and controls.

Lineweaver (1958), using panels of trained judges, found that irradiation odor and flavor developed in raw chicken meat at doses ranging from 0.1 to 5.0 Mrads from both gamma and electron irradiation. The intensity of irradiation flavor and odor resulting from the gamma irradiation was found to be roughly proportional to the dosage. Experiments on enzyme inactivated chicken meat subjected in the frozen state to electron irradiation also showed the develoment of irradiation odor and flavor at doses of 0.2 and 2.0 Mrads. In contrast to these evaluations by trained judges, when a consumer type panel of 26 untrained persons were given a single sample, the majority of the panelists found chicken irradiated at a dosage of 2.0 Mrads to be highly acceptable and chicken irradiated at a dosage of 5.0 Mrads fairly acceptable.

Hanson *et al.* (1964) demonstrated significant benefits by the use of low temperatures during irradiation. They observed a marked reduction in irradiation flavor and odor intensity by irradiating heat-enzyme-inactivated chicken at −20°C or −70°C. They also reported a significant reduction in these same sensory factors through the use of in-package packets of activated charcoal. This later observation is in contrast to the observation of Gernon *et al.* (1961) and Stadelman (1961) who report only a "slight benefit" and "no benefit," respectively, on the use of charcoal packets.

Wierbicki (1963) reported that three thermal methods—steam, microwave oven, and deep fat frying—prior to irradiation can be satisfactorily used for enzyme inactivation. Hanson *et al.* (1963) recommend enzyme inactivation to an internal temperature of about 80°C to reduce redness which develops during storage. Stadelman (1961) concluded from his studies in which he used a variety of methods to enzyme inactivate the meat that deep fat frying resulted in the least change in flavor and odor in the irradiated product; however, on the basis of tenderness, short heat treatments in a microwave oven was most desirable.

Coleby (1959) demonstrated that cooking by deep fat frying methods yielded a product with less off-odors and off-flavors than by roasting. This observation has been confirmed by Hannan and Sheppard (1959), Coleby *et al.* (1960) and Hanson *et al.* (1964).

Tappel (1957) conducted an investigation on the pink discoloration in irradiated meats and included chicken in

Table 1. Meat preference of men in the United States Armed Forces. Hedonic Scale Ratings (1–9).[a]

Meat item	Grilled or fried	Roasted or baked	Frequency of serving as a major meat item for 1966[b]
Beef	8.31	8.02	102
Chicken	8.24	7.99	72
Pork	7.83	7.72	61
Ham	7.60	7.68	55
Veal	7.60	7.34	48
Lamb	6.71	6.13	6

[a] From Peryam *et al.* (1960)
[b] From U.S. Army-Air Force Annual Food Plan, 1966.

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his study. He concluded that irradiation converts the normal brown denatured globin hemochrome pigments into red pigments which are best characterized as denatured globin hemochrome.

The necessity for enzyme inactivation of irradiated chicken for use in military rations is clear. Many studies have shown that raw meats can not be stored at non-refrigerated temperatures for any reasonable period of time without deterioration because of the activity of the autolytic enzymes (Groninger *et al.,* 1956; Lineweaver, 1958; Gernon and Seaton, 1962). These investigators also showed the necessity for keeping irradiation doses to the minimum permitted. Based on limited observation made in this laboratory, using trained technical panel, no differences in preference could be noted between electron and gamma irradiated chicken.

Storage tests at five different temperatures were conducted by Liccardello *et al.* (1959) on both white and dark chicken meat packed in sardine cans under vacuum (25 in. Hg) and irradiated with a 2 MeV electron beam (2.8 Mrad). At 20°C storage both the white and dark meat were acceptable for 8 months, but at 37°C neither was acceptable at the end of one month's storage. Gernon and Seaton (1962) reported on irradiated (4.5 Mrad) chicken thighs, stored at 22°C, which were served to a consumer type panel that rated them on a 9-point hedonic scale (Peryam and Pilgrim, 1957). This panel rated the product 7.1, 6.7, 6.8, and 6.9 after 1, 4, 9, and 16 month's storage, respectively. Heiligman (1965) obtained similar results; panelists scored the irradiated chicken as acceptable and stable after storage for 21 months at 21°C and 18 months at 38°C.

Product development. Previous investigations have given a good basis for the development of a process for producing an acceptable irradiation sterilized chicken product. This product may be termed a "first generation" product because it is the first chicken product produced by a well defined process procedure. New and improved procedures will be incorporated into the current process as they are developed.

Substantial efforts have been devoted to the development of improved chicken (Wierbicki, 1963; Wierbicki and Heiligman, 1964; Wierbicki *et al.,* 1965) at the U. S. Army Natick Laboratories. Development proceeded by two paths; (1) by the development of new procedures, and (2) by the development of a standardized process. There is an overlap of the two approaches since the results of the first approach are utilized in shaping a standard process. The standard process developed is:

Raw material—
Fresh boneless breast and bone-in thighs received 24–48 hours after slaughter, from 3–3½ lb. chickens. The breasts are cut in two. The breast pieces and thighs weigh about 4 oz. each.

Enzyme inactivation—
Blanch in 105°C steam for 18–20 minutes to an internal temperature of about 85°C.

Packaging—
In No. 3 (404×700) cans holding 9–10 thighs and/or breast pieces, net weight approximately 2 lb. 4 oz., closed under vacuum (20 in. Hg. minimum)—cool to 3–5°C.

Irradiation—
Within 24 hours after closure, gamma irradiate at ambient temperature with a treatment of 4.5–5.6 Mrad.

In the course of this work, attempts were made to apply previous findings to the development of a reproducible process. Careful attention was paid to raw material, and the times and temperatures used in each processing step. There were no dramatic breakthroughs as a result of this work, but rather an accumulation of small improvements. A product is now available which is consistently good, but there is still room for improvement.

TROOP ACCEPTANCE TESTS

Irradiation sterilized chicken has undergone acceptance testing by troops. In the first series of tests conducted in 1958–1959 to determine the acceptability of irradiated food, it received a relatively high score (Hembree and Burt, 1965).

Sample preparation and scoring. In the acceptance tests, each participant was asked to rate several components of a meal of which one was an irradiated or control chicken product. Preferences were reported on the 9-point Hedonic Scale. A score of 5 was considered to indicate threshold acceptability and a score of 7 to indicate an acceptable product (Wierbicki *et al.,* 1965).

The products were produced by the standard process and were stored for approximately three months at room temperature prior to evaluation.

The data in Table 2 summarize the results of troop acceptance studies on irradiation sterilized chicken. Without exception, the test items scored sufficiently high to be considered acceptable as components of standard meals.

In some instances, a comparison of average hedonic scores show a statistically significant preference for the non-irradiated control items which were prepared from fresh (or fresh frozen) chicken parts (or canned boned chicken a la king). In about an equal number of cases, there is no significant difference in preference between the irradiated test chicken and the fresh non-irradiated control.

The results of a series of tests to determine the effect of repetitive consumption of irradiated chicken on acceptance are shown in Table 3. For these tests, the irradiated chicken was processed with the standard procedure and fresh non-irradiated chicken was used for the controls. The procedures used in conducting the test and method of sample presentation are described by Hembree and Burt (1965). While all samples were found in the accept-

Table 2. Acceptance tests—Irradiated chicken products.[a]

Food item	Year tested	No. of subjects Irrad.	Fresh	Average hedonic rating Irrad.	Fresh
Chicken					
Fried	1963	215	292	6.8	7.2
Fried	1963	236	260	6.7	7.2*
Fried	1963	—	—	5.7	6.5*
Oven fried	1963	—	—	5.6	6.7*
Barbecued	1963	—	—	5.6	6.4*
Fried breasts	1965	312	324	6.3	6.4
Fried thighs	1965	280	279	5.9	6.1
A la king	1965	313	272	5.7	5.7

[a] Irradiated 4.5–5.6 Mrad and stored for 3 months at room temperature prior to evaluation.
* Difference between mean rating is significant at the .05 probability level.

Table 3. Acceptance tests—repeated servings of irradiated chicken products.[a]

Food item	Week of test	No. of subjects Irrad.	Fresh	Average hedonic rating Irrad.	Fresh
Chicken					
Southern fried	1	224	325	6.0	7.0*
Oven fried,	2	255	344	5.9	6.6
and	3	225	339	5.3	6.4*
Barbecued	4	184	272	5.5	6.6*
Chicken	5	197	258	5.6	6.3*

[a] Irradiated 4.5–5.6 Mrad and stored for 3 months at room temperature prior to evaluation.
* Difference between mean ratings is significant at the .05 probability level.

Table 4. Acceptance tests—Irradiated chicken breasts.[a]

Unit		No. of subjects Irrad.	— Fresh		Average hedonic ratings Irrad.		— Fresh
1		65	53		6.1		6.5
2		47	40		6.2		6.2
3		48	35		5.7		6.6*
4		33	31		6.4		6.9
5		46	69		6.8		6.5
6		74	69		6.0		6.5
	Total	313	297	Ave.	6.1	Ave.	6.5

[a] Irradiated at 4.5–5.6 and stored for 3 months at room temperature prior to evaluation.
* Difference between mean rating is significant at the .05 probability level.

Table 5. Acceptance tests—Irradiated chicken thighs.[a]

Unit		No. of subjects Irrad.	— Fresh		Average hedonic ratings Irrad.		— Fresh
1		51	50		6.0		6.1
2		40	38		5.2		5.3
3		41	23		6.0		6.2
4		35	27		6.2		7.2*
5		44	64		6.4		6.2
6		59	49		6.1		6.5
	Total	270	251	Ave.	6.0	Ave.	6.2

[a] Irradiated 4.5–5:6 Mrad and stored for 3 months prior to evaluation.
* Difference between mean rating is significant at the .05 probability level.

able range, the controls, except in one instance, were preferred to the test item. An analysis of variance indicates that the effects of weekly repetitive feeding on acceptance were the same for the irradiated and the non-irradiated chicken.

In the beginning of the development of irradiation sterilized chicken, boneless breasts and bone-in-thighs were combined in the same package in natural proportions. Recently this procedure was changed and the results of troop acceptance tests in which they were packed in separate packages are shown in Tables 4 and 5. For these tests, non-irradiated fresh frozen parts were used for the controls and the products were served as fried chicken. All products were scored in the acceptable range with no significant difference in average scores of irradiated and control items. Only one unit of the six used in testing either the breast or thighs showed a significantly higher preference for the control item.

DISCUSSION

In the course of the foregoing tests, irradiated chicken was served in over 3,000 meals to soldiers. The results show that the "first generation" product is acceptable. The results, and those obtained through the use of technical panels, also show that further improvements are needed before a product which is consistently comparable with the fresh control is achieved. Also, there are more steps to be taken before commercialization can be realized.

Packaging and production possibilities. Components of certain types of rations require packaging in flexible materials. Developmental work in this area is in progress and results indicate that certain materials of the polyolifin, polyamide, and polyvinyl-chloride classes may be satisfactory.

The subject of a pilot plant meat irradiator to conduct investigations leading to commercialization of irradiated foods is being studied. Chicken will be one of the first items studied when such a plant becomes a reality (Joint Committee on Atomic Energy, 1965).

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