Brine Immersion Cooling and Freezing of Ready-to-Cook Poultry

This Method Speeds Up Cooling Time for Packaged and Unpackaged Poultry, and Simplifies the Handling Operation, Particularly for Freezing

W. B. Esselen, A. S. Levine and I. J. Pflug
University of Massachusetts
Amherst, Mass.
and
Lyle L. Davis
Biological Science Branch
Agricultural Marketing Service, USDA
Washington, D. C.

Reprinted from the July 1954 issue of REFRIGERATING ENGINEERING, official publication of the *American Society of Refrigerating Engineers*

Brine Immersion Cooling and Freezing of Ready-to-Cook Poultry

This Method Speeds Up Cooling Time for Packaged and Unpackaged Poultry, and Simplifies the Handling Operation, Particularly for Freezing

W. B. Esselen, A. S. Levine and I. J. Pflug
University of Massachusetts
Amherst, Mass.

and

Lyle L. Davis*
Biological Science Branch
Agricultural Marketing Service, USDA
Washington, D. C.

IN the production of wholesome, fresh and frozen ready-to-cook poultry, the importance of rapid cooling to remove body heat is generally recognized. Methods of cooling in commercial use include ice chilling in a tank of slush ice and air chilling in a refrigerated room with moderate air currents. Regulations of the United States Department of Agriculture (1953) call for an internal temperature of the carcasses of 36 to 40 F within 24 hours. Freezing rooms should be equipped to freeze ready-to-cook poultry solid in less than 60 hours at temperatures of —10 to —40 F.

The object of the present investigation was to study the feasibility of using brine immersion to cool packaged warm eviscerated ready-to-cook poultry to 40 F and freeze it. Such procedures, involving packaging prior to cooling and combining the cooling and freezing operations in one step, are appealing from the standpoint of (1) minimizing contamination of poultry during handling operations, (2) reduction of overall handling and labor costs, (3) more rapid cooling than is realized by a slush ice or air chilling, and (4) elimination of a leaching of flavor from poultry during slush ice cooling as has been suggested by Pippen[7] (1953). Such chilling would result in less shrinkage as compared to the air blast system, and also it should result in more uniform cooling and a higher quality end product compared to the variable results associated with tank cooling methods. In addition, it is believed that immersion cooling methods should make for a more effective utilization of refrigeration equipment.

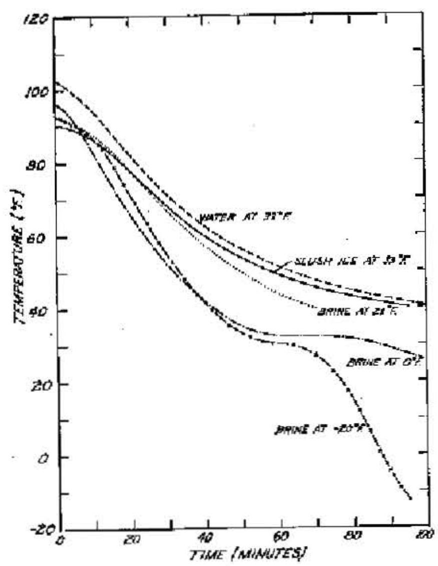

Fig. 1. Chilling and freezing rates of packaged broilers in different cooling media.

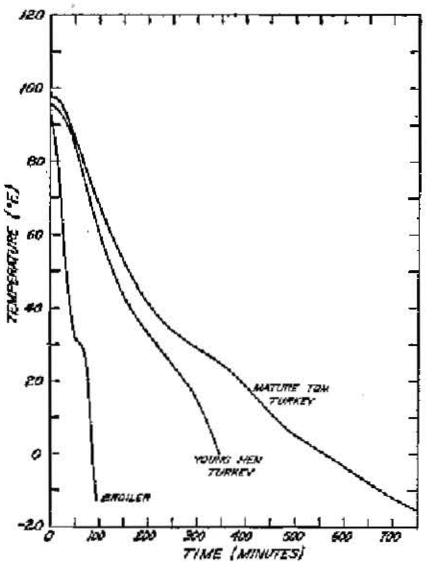

Fig. 2. Chilling and cooling rates of different weight classes of packaged poultry in brine at —20 F.

Review of Literature

Much has been published on the cooling of poultry. In this paper only a selected portion of the literature will be cited in order to show the means available for chilling poultry and the problems involved. Sweet and Stewart[10] (1942) described a method of chilling poultry by means of a brine spray. When brine at 20 F was used, chickens and turkeys were chilled in 25 to 35 percent of the time required in air at 35 F. Stewart, Hanson, and Lowe[9] (1943) employed brine spray (Zarotschenzeff process) at —5 F to freeze dressed poultry. They found that birds which are brine spray frozen within five hours after dressing could be stored up to six months before eviscerating with good retention of appearance.

The freezing of poultry has recently been reviewed by Koonz[5] (1952) and Goree[4] (1953). It was pointed out that the air blast system with an air temperature of about —30 F was commonly used. Mensing and Morris[6] (1953) reported ice chilling of broilers could be hastened by pumping air through the slush ice in cooling vats. More rapid chill-

Contribution No. 938, Massachusetts Agricultural Experiment Station.
* Most of the work reported here was performed while under the supervision of the former Poultry Branch, PMA. The work was supported in part by funds allocated under authority of the Agricultural Marketing Act of 1946 (RMA Title II).

ing was said to be a major step in the production of more uniform, better quality poultry. A so-called "jet-freezing" system was described by Simons[8] (1953). This system of air freezing was originally devised to increase freezing efficiency and freezer capacity for poultry.

Baker[1] (1953) found that the rate of freezing had an important bearing on the color and appearance of frozen turkeys. Rapidly frozen birds were light in color and attractive in appearance. The birds were progressively darker in color as freezing temperatures were raised from —20 to 0 and 5 F. He recommended that turkeys be frozen at a temperature as low as —20 F with good air circulation. Dunker and Hankins[3] (1953) showed that the freezing rates of meat were significantly affected by the type of wrapping material used. Some wrapping materials were found to reduce the freezing rates as much as 50 percent.

Experimental

Preparation and Packaging of Poultry—The classes of poultry used in this investigation are summarized in Table 1.

Table 1. Classes of Poultry Used

Class	*Ready-to-cook weight range* *Minimum*	*Maximum*
Broilers, New Hampshire	1 lb 10 oz	3 lb 13 oz
Fowl, " "	2 lb 15 oz	5 lb 12 oz
Stags, " "	4 lb 9 oz	7 lb 6 oz
Young hen turkeys, Bronze	9 lb 2 oz	13 lb 1 oz
Mature tom turkeys, "	22 lb	27 lb 9 oz

The broilers, fowl, and stags were obtained from a nearby poultry grower and processor. The chickens were killed, scalded at 126 F, and the feathers removed at his poultry

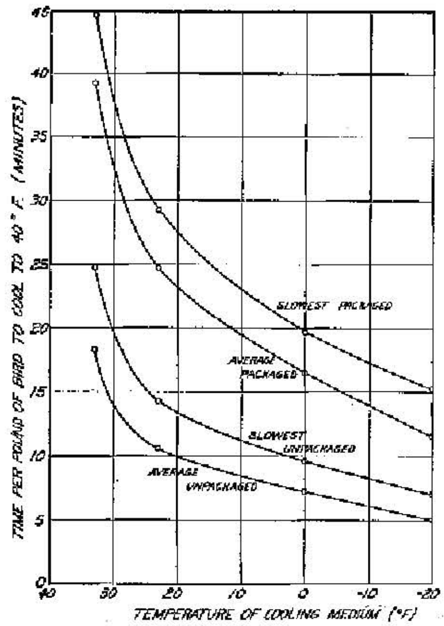

Fig. 3. Time per pound of bird to cool to 40 F in different cooling media.

plant. The dressed birds were then immediately brought to the laboratory where they were eviscerated. The turkeys were killed, dressed, and eviscerated at a nearby turkey farm. Immediately after being eviscerated, they were placed in insulated containers and brought to the laboratory. These handling procedures resulted in a minimum loss of body heat prior to packaging and cooling.

The temperature of the birds during cooling and of the cooling medium was measured at 5-minute intervals by means of 24-gage copper constantan thermocouples and a 24-point Brown Indicating Electronik Potentiometer. Preliminary tests indicated that the points of slowest cooling in broilers, fowl, stags, and turkeys were in the thick portion of the breast and thigh. Thermocouples were located in each of these sections of each bird tested. In the packaged birds the thermocouples were located at the inside surface of the body cavity, and in unpackaged birds the thermocouples were located midway between the inside and outside walls of the bird at the areas of slowest cooling.

The packaged birds were packed in moisture-vapor resistant* bags. Two thermocouples were passed through a hole cut in the bottom of the bag and were located in the carcass of the bird, which was then trussed with string. The bird was then placed in the bag. Portions of the bag at the bottom, where the thermocouples were introduced, were wrapped around the lead wires and sealed with a metal clip. The bag was then vacuumized, sealed, and shrunk in the usual manner. In the unpackaged birds, the thermocouples were set in position and held in place by the trussing string.

Chilling and Freezing Methods—The equipment employed in making the chilling and freezing tests consisted of an insulated rectangular steel tank (100-gal capacity), a refrigeration unit, a 24-point indicating potentiometer, a 6-point recording potentiometer, and a resistance-type temperature controller. The tank was equipped with perforated pipes in the bottom to permit air to be bubbled through the cooling medium to assure good temperature distribution. An evaporation coil was located above the perforated air pipes to provide the necessary refrigeration. The coil was con-

* An oriented plastic film copolymer of vinylidene chloride and vinyl chloride, supplied by Dewey & Almy Chemical Co., Cambridge, Mass.

Table 2. Chilling and Freezing of Poultry in a Liquid Medium

Poultry	*No. of birds*	*Ready-to-cook weight* *Avg* *lb*	*Avg* *oz*	*Min* *lb*	*Min* *oz*	*Max* *lb*	*Max* *oz*	*Packaging **	*Cooling medium*	*Time to chill to 40 F, min*	*Time to freeze to 15 F, min*
Broiler	10	2	2¼	1	15¼	2	6¾	packaged	33 F slush ice	95	—
Broiler	10	2	1¾	1	10	2	7	unpackaged	33 F slush ice	50	—
Broiler	10	2	6¼	2	2½	2	12	packaged	33 F water	105	—
Broiler	10	2	6½	2	2¼	2	11½	unpackaged	33 F water	60	—
Broiler	10	2	5	2	2½	2	10¾	packaged	23 F brine	70	—
Broiler	10	2	4	1	12	2	11	unpackaged	23 F brine	27	—
Broiler	10	2	2	1	11½	2	6½	packaged	0 F brine	42	135
Broiler	10	2	1½	1	13½	2	6½	unpackaged	0 F brine	24	55
Broiler	10	2	14½	2	8	3	13	packaged	—20 F brine	35	85
Broiler	10	2	11½	2	5	3	1½	unpackaged	—20 F brine	16	35
Fowl	10	4	10	3	6	5	12½	packaged	33 F slush ice	190	—
Fowl	10	4	¾	3	½	4	15	unpackaged	33 F slush ice	90	—
Fowl	10	4	7½	3	13	5	8	packaged	33 F water	195	—
Fowl	10	4	3½	3	1½	5	12	unpackaged	33 F water	100	—
Fowl	10	3	10	2	15½	4	2½	packaged	23 F brine	105	—
Fowl	10	3	7	2	15	4	½	unpackaged	23 F brine	38	—
Stags	10	6	2¾	5	5	6	14½	packaged	33 F slush ice	220	—
Stags	10	5	13	5	4	7	6	unpackaged	33 F slush ice	95	—
Stags	10	6	¼	5	6½	6	13½	packaged	33 F water	235	—
Stags	10	5	14	4	11	6	13	unpackaged	33 F water	135	—
Stags	10	5	15¼	5	5½	7	4	packaged	23 F brine	165	—
Stags	10	5	4½	4	9½	6	2	unpackaged	23 F brine	55	—
Young hen turkey	10	11	7	9	2	13	1	packaged	0 F brine	215	500
Young hen turkey	10	11	7¾	9	5	12	7	unpackaged	0 F brine	110	280
Young hen turkey	10	11	10½	11		12	13	packaged	—20 F brine	160	290
Young hen turkey	10	12	1¼	11	6	12	15	unpackaged	—20 F brine	60	140
Mature tom turkey	5	23	13	22	½	27	9	packaged	—20 F brine	205	425

* All packaged poultry were packed into moisture-vapor resistant bags which were vacuumized, clip-sealed, and shrunk by dipping into water at 205 F. Unpackaged poultry were not wrapped in any material but were placed directly in the cooling medium.

nected to a Freon-12 condensing unit located adjacent to the tank. A temperature controller was used to maintain the bath temperature for the 23, 0, and —20 F tests. Calcium chloride brine was used as the cooling medium for tests below 32 F. The top of the tank was covered and insulated with a blanket.

Tests Conducted

Time to Chill to 40 F and Time to Freeze to 15 F—Ten packaged birds and ten unpackaged birds of each class of poultry except the mature tom turkeys were employed in each test as summarized in Table 2. Five packaged mature tom turkeys were also used in each experimental variable. Chilling and freezing data were obtained for broilers, fowl, stags, young hen turkeys, and mature tom turkeys in the following cooling media: (1) slush ice at 33 F; (2) water at 33 F; (3) brine at 23 F; (4) brine at 0 F; and (5) brine at —20 F.

Data were not obtained for each weight class of poultry under all conditions. However, an effort was made to cover extreme conditions.

Temperature Equalization — In order to determine the practicability of chilling packaged poultry in —20 F brine for a short time, followed by holding under refrigeration at 36 F until the birds were cooled to 40 F, the following techniques were employed: Broilers, young hen turkeys, and mature tom turkeys, in sets of five birds of each class, were packaged in plastic bags and held for varying lengths of time in brine at —20 F. Three sets of broilers were immersed for 4, 6, and 15 minutes; three sets of young hen turkeys for 20, 45, and 80 minutes; and three sets of mature tom turkeys for 30, 45 and 60 minutes respectively. Upon removal from the brine, the birds were rinsed with cold water, placed in fiberboard cartons, and held in a 36 F walk-in refrigerator until no further cooling, attributable to the chilling at —20 F occurred. Each of the sets of five broilers was held in a flat carton of 6-bird capacity. The turkeys were held in individual cartons. One set of broilers and a set of young hen turkeys were not boxed and were used as controls for this phase of the test.

Results and Discussion

A summary of results obtained in this investigation is presented in Tables 2 and 3.

Results of the chilling and freezing tests for the various classes of

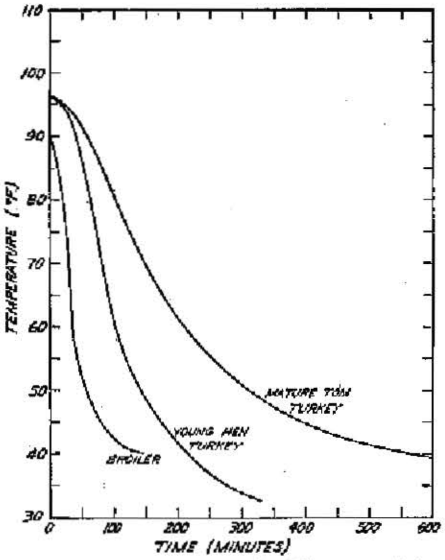

Fig. 4. Cooling rates of different weight classes of packaged poultry chilled in brine at —20 F, then held in refrigerator at 36 F in cartons.

poultry studied are summarized in Table 2. Data presented represent those obtained with the slowest cooling bird in each instance. These results are presented graphically in Figures 1 and 2.

The poultry in each weight class, packaged in the moisture-vapor resistant bags, cooled more slowly than did the unwrapped birds. This difference in cooling rates is attributed partly to the fact that in the unwrapped birds the cooling medium in the body cavity is also very effective in heat removal, whereas in the packaged birds cooling was only from the outside of the bird. For a given cooling medium and bird class, it took from about two to three times as long to chill the packaged birds as the unwrapped birds to 40 F. However, if one regards these data in the light of present-day poultry chilling practice, which is the use of slush ice, the packaged poultry chilled in low temperature brines compares quite favorably with unwrapped birds in 33 F slush ice in attaining 40 F body temperature rapidly. It should be pointed out that, because of the use of calcium chloride to lower the freezing point in the medium, immersion of unwrapped birds would present the problem of removing the calcium chloride brine from the surface and cavity of the bird. Until procedures are developed for complete removal of calcium brine, it seems unwise to cool nonpackaged birds in calcium chloride brine.

During the course of these investigations, careful observations were made on the effect of this method of cooling in brine on the packages. No failures of the packages were noted on approximately 200 birds that were so packaged. This is noteworthy because each bag had to be cut and resealed at the bottom to accommodate the thermocouple lead wires. Also, no special care was taken to prevent rough handling during the packaging and cooling operations. Extensive taste tests conducted on many of the birds showed no evidence of off-flavor caused by the brine. It would thus appear from these results that brine cooling would provide an effective means of removing body heat from packaged hot eviscerated poultry.

In those studies where the birds were left in the lower temperature brines long enough to freeze throughout, a carcass temperature of approximately 15 F was taken as the end point in the freezing time determination. Here again, it took approximately twice as long to freeze broilers and young hen turkeys in the plastic bags as it did the unwrapped birds. But it took only five hours to freeze packaged 12-pound turkeys in —20 F brine. This is in marked contrast to the upwards of 60 hours required in some air freezing operations. Again, the major consideration is not the packaging, but the comparison of

Table 3. Cooling Rates of Packaged Broilers and Turkeys Chilled in Brine at —20 F, Then Held in Refrigerator at 36 F in Cartons[1]

Poultry	*No. of birds*	*Ready-to-cook weight* Avg *lb*	Avg *oz*	Min *lb*	Min *oz*	Max *lb*	Max *oz*	*Time at —20 F, min*	*Time for temp to equalize during holding at 36 F, min*	*Equalization temp, F*	*Time to chill to 40 F, min*
Broiler	5	3	15½	3	11	4	4	4	195	49½	—
Broiler	5	3	7¾	2	14	3	13½	6	170	41	200[2]
Broiler[3]	5	3	8½	3	—	4	4	6	210	43	—
Broiler	5	3	10½	3	3	4	4	15	140	33	75
Young hen turkey....	5	11	15	11	9	12	6	20	270	49½	—
Young hen turkey[3]...	5	11	6½	10	11	11	15	20	270	49	
Young hen turkey....	5	11	6½	11	—	12	2	45	325	33	225
Young hen turkey....	5	11	11½	11	9	12	4	80	325	32	190
Mature tom turkey...	5	23	6	22	2	26	9	30	800	41	—
Mature tom turkey...	5	24	7½	22	11	25	14	45	760	37	540
Mature tom turkey...	5	24	1¼	23	7	25	4	60	760	34	385

[1] Broilers in fiberboard cartons of 6-bird capacity; turkeys in individual cartons.
[2] Estimated time. [3] Not in cartons.

the relatively rapid brine cooling technique as compared with the present commercial practices of slower freezing in air. It appears that a one-step operation for cooling and freezing eviscerated birds would result in some noticeable saving in time, labor, and handling.

These investigations on cooling and freezing rates have yielded considerable data which, while interesting and useful, require a common basis for comparison and application in practice. Such a comparison can readily be made from Figure 3, which presents the data graphically on the basis of time to chill to 40 F per pound with cooling media of different temperatures. In most cases rather good agreement was obtained for the different weight classes of poultry in a given cooling medium. In using this curve the time required per pound of bird to cool to 40 F needs only to be multiplied by the weight of the bird to arrive at the total cooling time required for a bird of given size.

In order to arrive at freezing times per pound of packaged bird, data for broilers, young hen turkeys, and mature tom turkeys frozen in brine at —20 F were analyzed. The time for the slowest cooling bird was taken as the time required per pound of bird to remove body heat and freeze to 15 F. Although there was some variation in the freezing time for different sizes of birds, the results obtained indicate that the freezing time per pound of bird submerged in —20 F brine is in the range of 20 to 30 minutes.

From the data summarized in Table 3 and from the cooling rate curves shown in Figure 4, it appears that chilling eviscerated, packaged poultry in —20 F brine, followed by holding at 36 F (normal refrigerated cold room), offers a rapid and effective method for removing body heat from poultry prior to freezing or distribution to the fresh market. On the basis of these data, chilling times in —20 F brine of 6, 35, and 45 minutes for ready-to-cook broilers, 12-pound ready-to-cook young hen turkeys, and 22 to 27-pound ready-to-cook mature tom turkeys, respectively, followed by holding in a refrigerator at 36 F, should provide adequate chilling.

Conclusions

Chilling and freezing rate data were obtained for packaged and unpackaged poultry ranging in size from chicken broilers to stags, and from young hen turkeys to mature tom turkeys cooled by immersion in various liquid media at temperatures ranging from 33 to —20 F. Data showing the time required per pound of hot eviscerated, packaged birds to chill to 40 F are also presented.

In general, the freezing time per pound of packaged ready-to-cook birds immersed in —20 F brine is in the range of 20 to 30 minutes. Thus, in —20 F calcium chloride brine, actual freezing times to 15 F observed for hot eviscerated, packaged broilers, 12-pound turkeys, and 25-pound turkeys were approximately 1½, 5, and 7 hours, respectively.

Chilling packaged, ready-to-cook poultry in —20 F brine, followed by holding in a cold room at 36 F, offers a rapid and effective method of removing the body heat prior to freezing or distribution as a fresh product. Immersion times in —20 F brine of 6, 35, and 45 minutes, for broilers, 12-pound turkeys, and 22 to 27-pound ready-to-cook turkeys, respectively, are indicated.

Immersion brine cooling provides an effective means of removing the body heat from and freezing packaged, ready-to-cook poultry. In practice, this process could be carried out in one operation.

References

1. Baker, R. C.; To Prevent Discoloration of Dressed Turkeys . . . Freeze 'Em Fast; *Turkey World*, vol 28, no 8, p 18, 1953
2. Davis, L. L.; Poultry Branch, U. S. Dept. of Ag. Personal communication, 1953.
3. Dunker, C. R., and O. G. Hankins; Rates of Freezing and Thawing Meats; *Food Techn*, vol 7, p 505, 1953
4. Gorec, C. P.; Freezing of Poultry; *Refrig Engg*, vol 60, no 8, p 855, 1952
5. Koonz, C. H.; Poultry and Egg Products; *Refrig Data Book*—Applications Vol. (4th Ed), p 6-01, 1952
6. Mensing, P. G., and C. L. Morris; Better Broilers Processed Better; *Food Eng*, vol 25, no 4, p 76, 1953
7. Pippen, E. L.; Effect of Selected Pretreatment on the Flavor of Chicken; Paper presented at meeting of Div of Agric & Food Chem, Am Chem Soc, Chicago, Sept. 6-11, 1953
8. Simone, E.; Jet-Freezing Newest Quick-Freeze System; *Food Engg*, vol 25, no 11, p 57, 1953
9. Stewart, G. F., H. L. Hanson, and B. Lowe; Palatability Studies on Poultry: A Comparison of Three Methods for Handling Poultry Prior to Evisceration; *Food Res*, vol 8, p 202, 1943
10. Sweet, M. H., and G. F. Stewart; Refrigerated Brine Sprays for Cooling Dressed Poultry; *U. S. Egg & Poultry Mag*, vol 48, p 261, 1942
11. U S Dept of Ag; Regulations Governing the Grading and Inspection of Poultry and Edible Products Thereof and United States Classes, Standards, and Grades with Respect Thereto; Federal Register, GPO-PMA 276, April 14, 1953