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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY—Circular No. 64.
H. W. WILEY, Chief of Bureau.

STUDIES OF POULTRY FROM THE FARM TO THE CONSUMER.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., August 15, 1910.

SIR: The accompanying report on "Studies of Poultry from the Farm to the Consumer" is presented for publication as a circular of this Bureau, in the belief that the data set forth are of great interest and usefulness to scientists working along these lines and to the many industries involved in the production and handling of these commodities. The report includes a review of the scientific work done on this subject, which is as yet very limited; a statement of the industrial application of refrigeration to the handling of dressed poultry and eggs, based on a careful study of existing conditions; and a very suggestive section on the application of the scientific data so far obtained to industrial uses. I recommend the publication of this report as Circular 64 of the Bureau of Chemistry.

Respectfully,

H. W. WILEY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

[Cir. 64]

CONTENTS.

	Page.
Introduction	5
Review of the scientific work done in the United States.....	6
Chemical and histological data on frozen poultry.....	6
Action of low temperatures on chicken fat.....	11
Formation of ammoniacal nitrogen at freezer temperatures.....	12
Bacterial content of frozen flesh.....	13
Examination of storage eggs.....	13
Industrial application of refrigeration.....	14
Chilling poultry.....	15
Chill rooms.....	15
Circulation of air.....	16
Time required for chilling.....	18
Chilling for long or short hauls.....	18
Containers.....	19
Transportation.....	21
Holding for shipment.....	21
Poultry refrigerator cars.....	22
Mixed cars.....	23
Insulation of cars.....	23
Thermograph records.....	24
Refrigeration in the market.....	27
Frozen poultry.....	29
The refrigeration of eggs.....	33
Scientific data applied to the industrial use of refrigeration.....	38

ILLUSTRATIONS.

	Page.
FIG. 1. Corridor showing entrance to freezer and chill room	16
2. Chill room showing piping on side walls and racks for holding poultry	17
3. Broiling chickens packed breast up	19
4. Roasting chickens, side-packed	20
5. Small cartons containing two chickens each	21
6. "Staggered" boxes	22
7. Temperature records in three parts of a single car with imperfect insulation	25
8. Temperature record of preparation and shipment of a carload of dressed poultry	26
9. Market house showing chilled show case	28

[Cir. 64]

STUDIES OF POULTRY FROM THE FARM TO THE CONSUMER.

INTRODUCTION.

Until quite recently the study of the effect of long continued low temperatures on poultry and eggs was conducted by those connected with the industry, and for industrial ends. Advances in the quality of the product were made, but the methods of obtaining them were known only to the individual or the firm experimenting, and then, except where mechanical engineering was concerned, they were purely empirical. Because the underlying principles of refrigeration, as shown by chemical, bacteriological, and histological studies of flesh, have been unknown, it has been impossible for the industry to explain and remedy the varying quality of the stored products, which, though entering the freezer in apparently uniform condition, differ in quality after a given period of time.

The fact that the changes undergone by poultry at temperatures below freezing are of a different character from those undergone at ordinary temperatures, as indicated by appearance, flavor, odor, etc., has led to the assumption on the part of the industry that changes in composition do not occur. The fact, too, that the changes are so subtle that the best scientific methods obtainable at present are only just beginning to detect them, together with the further fact that, for the most part, the investigations have up to this time not gone far enough to elucidate the means by which the changes noted are brought about, renders the problem from both the scientific and the technical viewpoint one of great difficulty as well as interest.

The general public agitation in the United States in recent years concerning "cold-stored" foods, in the sense of foods kept in a frozen condition for long periods, has been productive of more scientific experimentation and closer technical observation of such products than has been accorded to flesh foods kept at or a few degrees above the freezing point; yet the quality of perishable stuffs of all kinds so kept would demand that this phase of refrigeration be studied quite as thoroughly, if not more thoroughly, than the former.

In the following review of the work in the United States on refrigeration of poultry and eggs, an endeavor will be made to present (1) the salient points gleaned by scientific workers from a purely

scientific point of view, since it is to these facts that the industry must look for the stable betterment of its output; (2) the application of refrigeration as at present practiced by the industry in the handling of poultry and eggs; and (3) a discussion of the application of the scientific findings to the practical keeping of poultry and eggs in a fit condition for food.

REVIEW OF THE SCIENTIFIC WORK DONE IN THE UNITED STATES.

CHEMICAL AND HISTOLOGICAL DATA ON FROZEN POULTRY.

Since this paper deals with the subject solely from the viewpoint of the United States, the review of the scientific work done on poultry and eggs will also be limited to the investigations made by its workers. While there is, in American literature, a long list of papers recording observations on the effect of low temperatures on poultry and eggs, but few of them include the chemical, bacteriological, and histological findings upon which such statements must be based if they are to be accepted as scientific work in the strict sense of the term. That such is the case can scarcely be wondered at when one considers the long periods of experimentation involved in tracing changes in flesh held at temperatures below zero, the equipment necessary for the maintenance of such temperatures, and the comparatively recent interest in the scientific side of the subject.

The first presentation of American work was almost simultaneous for several of the communications. In January, 1908, at a meeting of the American Association for the Advancement of Science, Wiley^a and his associates made a statement outlining the work then in progress on chickens, quail, and eggs, and gave a brief report, with lantern illustrations, of the histological changes occurring in the muscle fibers of chickens kept below freezing for varying periods of time.

The Journal of the American Chemical Society received in June, 1908, and published in its October issue, a paper by W. D. Richardson and Erwin Scherubel, entitled "The deterioration and commercial preservation of flesh foods,"^b and treating of experiments on frozen beef. In the last paragraph of the paper, after summing up the analytical evidence to show that there is no chemical change in beef kept in a frozen condition for more than five hundred days, this sentence occurs: "We may say that similar tests of frozen poultry have resulted similarly." It is greatly to be regretted that the details of

^a Science, 1908, 27: 295.

^b Richardson and Scherubel, J. Amer. Chem. Soc., 1908, 30: 1515-1564.

[Cfr. 64]

the work on frozen poultry were not given. The same paper, with some additions and modifications, and entitled "The cold storage of beef and poultry," was presented in abstract at the First International Congress of Refrigerating Industries and published in full in the proceedings of the congress issued during the spring of 1909. In this communication, in addition to microphotographs of frozen beef muscle, there are several showing chicken breast muscle sectioned in a frozen condition. The authors state that during freezing the mechanical action is such that the liquid portion of the muscle fiber is forced through the sarcolemma, which, for the time being, is supposed to assume a reticular character, at least for chemical particles, and that this liquid collects in spaces between the fibers. Slow thawing, the authors believe, causes a resorption of the exuded materials without detectable alteration of the fiber either by chemical, physical, or histological evidence.

On page 314 of volume 2 of the proceedings of the congress just cited, the authors state that "It is not necessary to give detailed tables showing the analytical results (chemical) on cold-storage chickens, inasmuch as the results are in general similar to those obtained in the case of beef." A little later it is said that "The figures indicate no bacterial action whatever (uniform ammoniacal nitrogen) and no increase in proteoses (absence of marked enzym action) up to eighteen months." Again, it is to be regretted that the authors give none of the data on which their statements are based, since, in the present extreme paucity of analyses of cold-stored flesh of any kind, and our lack of knowledge concerning the composition of fresh chicken flesh, as well as frozen, all information is of value.

Under the caption of "Unrendered animal fats in freezer storage" it is stated that the abdominal fat of fresh chickens holds 0.20 per cent of free fatty acid; that three chickens four and one-half months old showed, respectively, 0.40, 0.40, and 0.56 per cent of free fatty acid, a practical doubling of the content of free acid, though both quantities are low. After nineteen months two samples showed, respectively, 0.96 and 0.48 per cent of free fatty acid. With only two analyses from two chickens, one can not make conclusive deductions, but the indications are that Richardson obtained a rise in free fatty acid even after four months of storage.

In the proceedings of the same congress Pennington^a reported some of the work which Wiley and associates in January, 1908, had stated to be in progress. Much of this report was published in November, 1908, as Bulletin 115, United States Department of Agri-

^a Pennington, M. E., A Chemical, Bacteriological and Histological Study of Cold-stored Poultry, Proceedings of First International Congress of Refrigerating Industries, 1909, 2: 216-260.

culture, Bureau of Chemistry, as well as other matter which will receive attention in its proper place. The investigations given in the bulletin of the histology of cold-stored chicken muscle deal with market birds only of which no history previous to storage was obtainable. The studies reported at the congress, however, were chiefly based upon the examination of birds of known history, killed and dressed and stored under known conditions, and examined at intervals of one month for a period of a year. The muscle of birds which had deteriorated at temperatures above freezing was also studied. A series of characteristic post-mortem changes in structure was observed, which differed from those prevailing in dead muscle at temperatures above freezing and which were progressive. They were more pronounced in the market fowls than in those of known history, as was to be expected, since those from the market were certainly not treated with the care before freezing that was given the experimental specimens. The changes in the former were referable both to bacterial growth (an invasion which occurred, doubtless, before storage) and to enzym action both before and during storage. In the latter the changes were due, apparently, to enzymes and to a coagulation of protein caused probably by long contact with air. The changes were evidenced by shrinkage and extreme brittleness of the fibers, by a striking intensification of the cross markings and a glassy appearance of the whole fiber, all of which might be referable to coagulation, and by a disintegration of the fiber substance resulting in a structureless mass, entangling connective tissue fibers and broken-down nuclei, and staining a different color from the fibers which were intact—hence, indicating a change in the chemical constitution.

The thawing of the specimens for histological examination was carried on in cold air, and required at least twenty-four hours for its accomplishment, hence there was time for the absorption of exuded materials and a return to the normal if the fibers of the chicken muscle were capable of doing so. Such histological changes as were observed under the microscope were confirmed by coincident chemical analyses of both market chickens (see Bulletin 115) and chickens of known history stored for four months.^a In both publications the findings of the chemical analyses of both fresh and cold-stored chickens are fully given. The study of the nitrogenous constituents of the flesh includes the determination of the total amount of nitrogen present, the amount of nitrogen soluble in cold water, the quantity of such nitrogen which is coagulable by heat, the nitrogen in the form of albumose and amino acid, and, by difference, the quantity of peptone nitrogen and nitrogen insoluble in water. Light and dark meat were analyzed separately. The fats were examined for the

^a Proc. Int. Cong. of Ref. Ind., 1909, 2: 248.

iodin, saponification and Hehner number, the acid value, ester value, and index of refraction. A general analysis of the flesh, including water, ash, intimate fat, etc., was, of course, made for all types of chickens studied.

The results of the study of the distribution of various forms of protein nitrogen, especially as illustrated by the study of chickens of known history, dry picked, cold-air chilled, and put into a "sharp" freezer twenty-four hours after killing, would indicate that proteolytic changes do take place, though they do not follow the usual course as observed in changes occurring in flesh at temperatures above freezing. For example, the protein soluble in water commonly decreases after long storage; the nitrogen in the form of protein soluble in water and coagulable by heat also decreases; the albumose may remain constant in quantity, even after many months of storage; while the peptone decreases and the amino bodies increase. This is especially noticeable in the white meat; the changes in the dark meat, while essentially the same, are seldom so pronounced and commonly approach nearer to the usual course of flesh proteolysis. The chemical analyses were made on seven lots of fresh chickens; seven lots of market storage chickens, aged 14, 17, and 24 months, respectively; and twelve lots of chickens of known history in storage at 12°-15° F. (-10° C.) for four months.

In 1908 Boos^a reported the analysis of drawn and undrawn fowl cold-stored for more than nine months. These birds were examined according to the methods of Brieger and of Bowmann and von Udranszky for ptomains. None were found. Skatol, indol, phenol, and cresol were looked for with negative results. Drawn and undrawn cold-stored fowls, commercially prepared, were thawed at 68° F. and kept at that temperature for six days. The undrawn birds kept better than the drawn.

In July, 1909, a paper appeared by Emmett and Grindley,^b entitled "A Preliminary Study of the Effect of Cold Storage upon Beef and Poultry." In this communication the authors present the results of the analyses of one lot of fresh chickens and four lots of storage chickens. Two of the latter—one drawn before storage, the other undrawn—were kept in the freezer for four months; another lot, undrawn, was kept twenty-one months; while the storage period of the remaining lot of poultry, which was drawn, was unknown. No details of preparation are given, except that the poultry was put into a storage warehouse the same day that it was killed. Since Chi-

^a Chemical Examination of Drawn and Undrawn Poultry Kept in Cold Storage, Thirty-ninth Annual Report of the Massachusetts State Board of Health, 1907.

^b J. Ind. Eng. Chem., 1909, 1: 413.

cago, where the chickens were killed, is a market in which scalded chickens prevail almost exclusively and the bird is killed by breaking the spinal column near the head and bleeding is accomplished by gashing the throat from the outside, hoping thereby to cut both jugular veins, the animal heat being removed by soaking in cold water, or finally ice water, it is fair to assume, in the absence of specific statements, that this was the method employed.^a

Light and dark meat were analyzed together. The nitrogen of the flesh was determined as nitrogen soluble in cold water and coagulable by heat; noncoagulable (proteoses and peptones), and nonprotein nitrogen (amino bodies). The total nitrogen soluble in water is the sum of these constituents; the total nitrogen in the meat itself, less the nitrogen soluble in water, being considered as insoluble protein nitrogen.

While the analyses of the flesh both by Pennington and by Emmett and Grindley were for essentially the same constituents, the different methods of stating results make comparisons difficult. Emmett and Grindley do not calculate results to a water-free basis, but they do recalculate the findings in the case of the storage chickens to the water content of the one lot of fresh chickens examined, taking this as the original water content for all. Since the water content of the flesh of fresh fowls is quite variable,^b this is a doubtful procedure for the drawing of very accurate conclusions. It has been shown (*loc. cit.*) that there may be a maximum variation of at least 2.2 per cent in the moisture content of light meat and of 4.2 per cent in the dark meat, which would make a decided difference in such calculations.^c

While the methods for the study of flesh protein used by Emmett and Grindley and by Wiley and Pennington were based upon the same general plan, the latter adopted certain mechanical devices in the interest of thoroughness and speed (since enzym action during long extraction periods must be reckoned with), such as shaking machines and centrifuges, which rendered extraction and filtration rapid and complete.^d

^a It has been shown (Pennington, address before the American Warehousemen's Association, December, 1909) that of all the methods, so far studied, of preparing poultry for cold storage, the above procedure gave the most irregular and most unsatisfactory results.

^b Pennington, *Proc. First Int. Cong. Ref. Ind.*, 1909, 2: 243.

^c Later work on 82 fresh broiling chickens gave a maximum water content of the light meat as 75.76, a minimum of 73.32, and a mean value of 74.79. For the dark meat the maximum was 75.94, the minimum 71.75, and the mean 74.84. Twenty roasting chickens gave a maximum for the light meat of 75.73, a minimum of 73.30, and a mean of 74.14. For the dark meat the maximum was 75.86, the minimum was 73.02, and the mean 74.30.

^d U. S. Dept. Agr., Bureau of Chemistry Bul. 115.

In the work of the latter albumoses were separated from peptones—a separation which has given valuable information because, though the albumose is likely to remain practically constant throughout long periods of storage, the peptone generally decreases markedly.

A comparison of the nitrogenous constituents of the flesh of chickens from various sources and of various ages is rendered difficult by the differing water content of the flesh. To eliminate this factor, Pennington (loc. cit.) has expressed the quantities of the protein nitrogen cleavage products in terms of their relation to the total amount of that substance, taking the latter as unity. On such a basis the water content of the flesh is without effect, and, since no nitrogen is lost, its redistribution can be directly compared with that previously prevailing. It is of interest to compare the results obtained so far by the different analysts when calculated on this basis.

Average nitrogenous constituents of chicken muscle.

[Expressed as per cent of total nitrogen present.]

Description.	Total nitrogen.	Total nitrogen in aqueous extract.	Coagulable nitrogen in aqueous extract.	Albumose nitrogen.	Peptone nitrogen (by difference).	Amino acid nitrogen.
Fresh chicken, mixed meat (Emmett and Grindley)	3.265	18.28	6.49	0.673		11.12
Fresh chicken (7 analyses, Pennington):						
Light meat	3.900	24.88	11.01	.624	4.63	8.44
Dark meat	3.570	18.05	8.04	.558	2.16	7.21
Stored chicken (4 months), mixed meat (2 analyses, Emmett and Grindley) ...	2.970	16.62	5.99	.522		10.07
Stored chicken (4 months), 12 analyses, Pennington:						
Light meat	3.970	24.73	10.77	.733	4.37	8.95
Dark meat	3.640	20.54	9.87	.990	2.55	7.24
Stored chicken (21 months), mixed meat (Emmett and Grindley)	3.356	22.47	9.95	.894		11.62
Stored chicken (time unknown), mixed meat (Emmett and Grindley)	3.433	21.62	8.91	1.165		11.53

Emmett and Grindley (loc. cit.) have determined the phosphorus content of the flesh of chickens stored for four months and for one sample of unknown storage time. The results are given as soluble organic and soluble inorganic phosphorus. Unfortunately, corresponding analyses were not made on the fresh chicken; hence comparisons can not be drawn.

ACTION OF LOW TEMPERATURES ON CHICKEN FAT.

The work done by Richardson on the fat of chickens, kept for four months and nineteen months, respectively, has already been quoted in full (see p. 6). The fat of market cold-stored chickens was studied by Wiley and Pennington and their findings reported in

Chemistry Bulletin 115. Pennington reported the analysis of the fat of chickens of known history, stored for four months, at the First International Congress of Refrigerating Industries (Proc., vol. 2, p. 252). A rise was observed in the acid value in all twelve lots examined, in some cases closely agreeing with the rise reported by Richardson (loc. cit.) and in other cases exceeding it. A decrease in the iodine number is generally found, representing a loss of unsaturated acids, as well as a loss in the Hehner number, which would indicate a solution of acids originally insoluble.

The question of acidity in crude fat, both fresh and cold stored, has been further studied by Pennington and Hepburn,^a in an effort to find chemical criteria by which aging food fat might be judged. Incidentally, among the samples of fat examined were some from cold-stored fowls of known history and carefully prepared. A rise in free fatty acid was observed which, in the same lot of chickens, tended to increase with the length of the storage period.

FORMATION OF AMMONIACAL NITROGEN AT FREEZER TEMPERATURES.

It will be recalled that Richardson (loc. cit.), in the brief statement of his work on cold-stored poultry, asserts that change during storage did not occur, because there was a uniform ammoniacal nitrogen content. In his work on beef Richardson very properly lays great stress on the presence of loosely bound ammoniacal nitrogen, and studies in detail several of the methods for its estimation. He finally adopted boiling with magnesium oxid as the preferable course to pursue. Pennington and Greenlee,^b studying flesh decomposition, repeated the work of Richardson, but without success, because it was not possible to reach a point where the loosely bound nitrogen ceased to be evolved, even though many distillations were made; and because, with the most exact conditions obtainable, there was a discouraging discrepancy between the quantities of such nitrogen from chickens of similar though not identical history. The authors therefore adapted the Folin method for ammoniacal nitrogen to chicken meat, with a gain in differentiation and accuracy.

The study of dry-picked chickens, chilled for twenty-four hours at 32°-38° F. (0° C.-3° C.), shows that the quantity of loosely bound nitrogen in the flesh varies from 0.011 to 0.012 per cent of the fresh substance. Similar chickens, stored for one year, showed 0.019 per cent; for two years, 0.027 per cent; for two years, but in bad condition, 0.036 per cent; for the same period of time but in excellent condition, 0.023 per cent. A fowl properly chilled, then kept nine days in a

^a J. Amer. Chem. Soc., 1910, 32: 568-572.

^b J. Amer. Chem. Soc., 1910, 32: 561-568.

house refrigerator, gave 0.017 per cent of ammoniacal nitrogen. These stored fowls had been kept at from 10–15° F. (–12 to –9° C.) and were analyzed after thawing in a house refrigerator. Whether such loosely bound nitrogen is a product of bacterial growth, as is commonly held, or of enzymic activity, its formation at temperatures so far below freezing is of both scientific and practical interest.

BACTERIAL CONTENT OF FROZEN FLESH.

The bacterial content of the flesh of cold-stored poultry was not touched upon by Richardson except in the general statements already quoted. Emmett and Grindley confined themselves strictly to the chemical side of the subject, hence the work of Wiley and his coadjutors is the only specific American work on the question. Stiles (Bulletin 115) established the fact that bacteria not only persisted in a viable state in the flesh of frozen poultry of known history after two years of storage, but that this resistance was common to a wide variety of species. Pennington (Bulletin 115) showed that a quantitative determination of the number of organisms in the flesh of cold-stored market chickens indicated the same condition, and also that while long holding in a frozen condition tends to kill a certain proportion of the germs, the period required for so doing is beyond that commercially practiced. And, also, by the time storage has been sufficiently long to destroy the bacteria the eating quality of the flesh is greatly lowered.

Pennington (Proceedings First International Congress of Refrigerating Industries) also showed that the presence of a few bacteria twenty-four hours after death, even with careful and rapid chilling, could be demonstrated in the muscle of breast and thighs by the use of special quantitative methods. Hence the fowls are not sterile when they enter the freezer, though promptness, care, and cleanliness may reduce the number of the organisms to a minimum.

EXAMINATION OF STORAGE EGGS.

The study of fresh and cold-stored eggs, chemically and bacteriologically, is practically a new field. A report by F. C. Cook (Bulletin 115) gives observations on five samples of stored eggs, varying in age from 3.5 to 19.6 months. The characteristic "storage" odor was noticed after 12.6 months; the separation of whites and yolks was difficult at the end of 7.5 months, the whites becoming more and more watery as time progressed.

It was observed that the boiled stored eggs gained water in both white and yolk, the yolk finally containing considerably more water than when fresh. Storage eggs, analyzed after boiling hard, show an

increase in the lower nitrogen bodies, proteoses, and peptones. There is also a decrease in the coagulable nitrogen and in the amino bodies. The lecithin phosphorus was observed to decrease in stored eggs after 3.5 months.

Howard and Read (Bulletin 115) observed characteristic rosette crystals in the yolk of eggs stored 12.6 months. The composition of these crystals was not determined, but the fact that they were not tyrosin was established.

The bacterial content of storage eggs has been examined by Stiles (Bulletin 115). He reported a fairly numerous but varying number of organisms after three months' storage. Then a decrease took place until about twenty months, when the sample was sterile. A number of common saprophytic species of organisms were isolated from the shorter storage samples.

As a preliminary to the study of the effects of handling on the quality of eggs, Pennington^a has reported the chemical composition and bacterial content of fresh eggs, whites and yolks separately, from both Leghorn and Plymouth Rock hens. The species of the organisms found in the eggs was also determined.

INDUSTRIAL APPLICATION OF REFRIGERATION.

The knowledge of the application of mechanical refrigeration to the poultry industry has been, until recently, confined to comparatively few. Those few have acquired what information they possess by selecting and applying practices which carried the poultry to the consumer in "good order." But, since standards of excellence vary, the term "quality," as used by the various packers, is variable in meaning.

A close study of conditions resulting in good or bad quality, so far as decomposition is concerned, has now been instituted by the United States Department of Agriculture in cooperation with all the branches of the industry. For instance, the killing and dressing of the fowls is studied with the packer; their transportation to market is being worked out with the cooperation of the railroads of the United States; the study of the cold-storage question is facilitated by every means which the cold-storage warehousemen have at their disposal; and the marketing of the goods is studied in the establishments and with the help of commission men, jobbers, and retailers throughout the country.

Since this article endeavors to set forth the practical application of refrigeration to the handling of dressed poultry in the United States, the subject will be treated in chronological order, beginning with the slaughterhouse and the removal of animal heat by chilled air. Then

^a J. Biol. Chem., 1910, 7: 109-132.

will follow the discussion of the environment of the fowls during their transportation in refrigerated cars, which may take them to the cold-storage warehouse, where they will sojourn for a number of months before they reach the hands of the middlemen; or, if they are to be consumed without storage, the railroad haul will take them directly to the commission men and thence they will go to the retail merchants. The discussion of the handling of eggs will proceed according to a similar plan and will follow that on poultry.

Before the days of mechanical refrigeration the shipper of dressed poultry killed and sold most of his stock in the fall and winter months, when nature could generally be depended upon to remove the animal heat. Even now the small, or conservative, packers frequently adhere to this old-time principle, which is most excellent when the weather conditions are just right; that is, when the air is dry and of a temperature between 30° and 35° F. (—1° and 2° C.). Unfortunately, however, such conditions can not be depended upon in so variable a climate as that of the United States. The temperature may suddenly rise, in which case the animal heat is not removed and decomposition will follow with undue haste; or it may fall below the freezing point of the flesh, when the external parts will cool too rapidly, so preventing the radiation externally of the animal heat and resulting in a rapid putrefaction of the viscera.

CHILLING POULTRY.

CHILL ROOMS.

That an equable desirable temperature may be maintained continuously, the most progressive poultry dressers have now adopted an artificially cooled chill room, in which they place their poultry immediately after killing and dressing and hold it there until the temperature of the body cavity of the fowls is the same as that of the surrounding atmosphere.

The construction of these rooms commonly includes a wooden lining, though cement is coming more and more into favor. Either must be kept scrupulously clean, since it completes the inner surface of a system of insulation which may be composed of cork, felt, or any other suitable material.

Two chill rooms are not only far more desirable and more efficacious in their results, but after the first cost of installation they are more economical to operate than is a single room if any quantity of fresh poultry is to be handled on successive days. The advent of freshly killed stock into a room containing partly or wholly chilled poultry means a rise in the temperature and a consequent warming

up, or sweating, of the chilled portion—two conditions which are always to be avoided if possible. It is far better, therefore, to maintain one chill room between 35° and 40° F. (2° and 4° C.), allow the birds to remain in it for several hours, or until the greater part of the animal heat has been removed, and then transfer them to the second room, which is maintained below 35° F. (2° C.), preferably at about 30° F. (-1° C.), for the final chilling. In this room, too, it is advisable to do the packing.

CIRCULATION OF AIR.

A very desirable method of chilling is a combination of the direct and indirect systems, thereby insuring a circulation of air throughout

FIG. 1.—Corridor showing entrance to freezer and chill room.

the room and preventing the blanketing of the warm material by a failure to draw from around it the heat which it radiates; or the pipes carrying the brine may be so distributed and inclosed that a constant circulation of air is maintained and the efficiency of the chill room thereby greatly increased. Where exposed piping is placed on the side walls, which is the method most commonly used, it has been found advantageous to put fans in different parts of the room to keep the air in circulation. Temperatures taken at different levels will

FIG. 2.—Chill room showing piping on side walls and racks for holding poultry.

show a progressive rise as one goes from floor to ceiling or a decided increase in the immediate vicinity of freshly killed poultry. Hence it is desirable to place a number of fans near the floor with their blades so set that the current shall be driven upward, thereby replacing the warm air which collects at the upper part of the room by the cooler air from the floor.

TIME REQUIRED FOR CHILLING.

In practical work twenty-four hours are generally required to remove the heat from the entire body of an undrawn fowl of ordinary size. The fact that it is removed is determined by inserting a thermometer through the vent and up the intestine as far as it will easily go, waiting a few minutes until the mercury shall have fallen, and then noting the temperature at which the column stands. If this test is applied to the largest fowl in the most unfavorable part of the room, as, for example, near the door or on the topmost layer of the rack, and the temperature of the body cavity is found satisfactory, it can safely be assumed that smaller, better-placed birds are also chilled.

CHILLING FOR LONG OR SHORT HAULS.

It is scarcely practicable to assert that the animal heat of a chicken is not removed until it has been cooled to a certain fixed temperature, because the thoroughness with which the fowl should be chilled depends largely on its destiny. If the poultry is to be consumed in the immediate neighborhood of the packing house, and if the time before consumption is to be a matter of a few days only, a temperature between 35° and 40° F. (2° and 4° C.) will generally carry the goods through the market in fair order, providing, of course, the middlemen are equipped with adequate refrigeration, a subject which will be discussed further on in this paper. If, however, the chickens are to be transported for long distances or to a market where delays may occur, the initial chilling must be more thorough and the body temperature of such fowls should not exceed 32° F. (0° C.) when they are packed.

The final chill-room temperature, too, is influenced by the temperature of the refrigerator car if the poultry is to be so shipped. It is impossible, in refrigerator cars which are ordinarily cooled by ice, or salt and ice, to maintain a temperature as low as that of mechanically cooled chill rooms. If, therefore, poultry be loaded at a temperature much below that of the chilled car, it will sweat in transit, and reach its destination in less desirable condition than if it had left the chill room a few degrees warmer. This question will be discussed further when transportation is considered.

CONTAINERS.

The question of containers for dressed poultry between the packing house and the retail merchants is one that has been greatly modified since the introduction of mechanical refrigeration into the industry. Formerly, large boxes, holding between 100 and 200 pounds, or more commonly, barrels holding 250 pounds at least, were used almost exclusively to carry the chickens from the killing place to the market, because the large package is more economical and more convenient when layers of ice between the layers of birds is the source of refrigeration.

FIG. 3.—Broiling chickens packed breast up.

The heavy weight of the contents of such a package induces decay. Uncleanliness is also a great objection, as will be discussed later, and it has additional disadvantages. When the temperature can be depended upon for satisfactory chilling and maintenance of refrigeration, these barrels are frequently used by those who practice ice packing customs with the ice omitted; and they are sometimes used by

packers whose plants are equipped with mechanical refrigeration, but usually for low-grade stock only.

The prevailing method at the present time, where facilities for refrigeration are available, is to pack the chickens in small boxes holding a dozen each. If the birds are of the broiling type, they are commonly packed with the breast up and the feet hidden (see fig. 3); if fowls or roasting chickens, they are packed two layers in a box and laid on the side (see fig. 4); while the chickens for export trade to England are "squatted," though this is an undesirable position in

FIG. 4.—Roasting chickens, side-packed.

that it pushes the bird into a compact mass, thereby delaying the radiation of the animal heat.

The tendency is now to use smaller and smaller packages. Two layers of chickens in a box, even in the case of fowls, are being discarded for a single layer, it being recognized that refrigeration is more perfect if flesh is not superimposed on flesh and if pressure on such a tender tissue as chicken muscle is eliminated as far as possible. On this account heads are wrapped in parchment paper and turned back, where they rest against the bony structure rather than against

the soft flesh of the breast or thighs. The carton for the single chicken, or for a pair at most, is the most recent advance (see fig. 5), and is one which has a foundation on scientific fact that will be discussed later.

TRANSPORTATION.

HOLDING FOR SHIPMENT.

It is of course necessary before packing the birds in the boxes that they should be thoroughly chilled. Large packing houses, or a house

FIG. 5.—Small cartons containing two chickens each.

of the ordinary size during the season of excess production, will ship three or four carloads a week, in which case the holding of the birds in the packing-house chill room is for a minimum time only. If, however, they must be held for several days before the carload is accumulated, as is the case in a small house or in the dull season, it has been found advisable to box as soon as the stock is thoroughly chilled and then to hold at the lowest available chill-room atmosphere; or, if a freezing room is part of the packing-house equipment, to transfer

the boxes to it for from twenty-four to forty-eight hours before loading in the refrigerator car.

When the freezer, between 0° and 15° F. (-18° to -9° C.), is to be used for holding, the boxes should be so placed in it that the air circulates freely around each one. This is accomplished generally by leaning the boxes at a sharp angle in a horizontal row rather than by placing them in a perpendicular pile, shifting each box forward or back of the median line in order to leave as much as possible of that box uncovered by its successor. This is known in the trade as "staggering" boxes, and is pictured in figure 6.

Forty-eight hours in a good freezer will very thoroughly harden birds of the ordinary size packed not more than 12 to the box, and a

FIG. 6.—"Staggered" boxes.

number of such boxes in a refrigerator car is a valuable aid in the maintenance of an equably cold temperature.

POULTRY REFRIGERATOR CARS.

The facilities of a refrigerated killing and packing house such as here discussed will avail but little in the getting of good poultry to market if it is not supplemented by a system of transportation which will maintain a constant low temperature for a sufficient length of time to carry the chilled goods to the market center. It is the aim of the refrigerator-car service to maintain such temperatures for such lengths of time that products which are a thousand miles or more from the point of consumption can be conveyed there in good order.

For the satisfactory transportation of dry chilled poultry it is advisable to use fine ice mixed with from 10 to 15 per cent of salt in the bunkers of the refrigerator cars the year round. If the car is built with sufficient insulation and if it is in good order—that is, with tight-fitting doors, unbroken lining, etc.—ice and salt will maintain a temperature in the middle of the car, 4 feet from the floor, of 40° F. (4° C.) or under. If the car is to be filled with poultry alone, and

if part of the carload has been in a freezer for forty-eight hours or more, the loading is a comparatively simple matter, because the most recently killed stock is put in the lowest layers next the bunkers, where the temperature will frequently fall to 10° F. (-12° C.). Often the air around the top layer, 4 feet from the floor, next the bunker, will have a temperature not exceeding 30° F. (-1° C.). The boxes which have been in the freezer are then loaded in the central part of the car and packed together as tightly as possible, serving as a source of cold where it is most needed, namely, in the middle of the car, where the refrigeration from the bunkers is least.

MIXED CARS.

If the car is to be loaded with a mixture of poultry and eggs, as very frequently happens, the problem is much more complicated. If ice and salt are used in the bunkers, and if the poultry and eggs go into the car well chilled, the temperature may be sufficiently low to crack the eggs. If, on the other hand, salt is not used with the ice, it becomes a difficult matter to keep the poultry sufficiently cold to carry without deterioration if the haul is a long one. If such mixed cars are to be handled, and this is oftentimes a commercial necessity, it is advisable to chill the poultry as thoroughly as possible, piling the boxes low in the car and against the ice bunkers. The eggs should be artificially chilled to as low a temperature as possible before they are shipped, and they should then be placed in the middle and upper layers of the load.

Since the ice bunkers are at either end of the car, it follows that every additional foot away from them will mean a rise in temperature; and since there is no method of inducing artificial circulation in general use, by which the heavy cold air at the bottom of the car can be forced to the upper part, it follows also that every foot above the floor means a rise in temperature. The mistake is frequently made of packing goods too high in a refrigerator car. Where great efficiency is necessary, as in the handling of poultry, the height of the load should be not more than 4 feet.

The railroads have established icing stations where the cars are inspected and iced as conditions demand or as the instructions of the shipper specify.

INSULATION OF CARS.

The temperature throughout long hauls and in different parts of the car has been studied by means of thermographs. Great variations are observed, due, of course, to the construction of the car, the atmospheric temperature, and the temperature of the goods being carried.

The refrigerator cars used by the various railroads, or even by the same road, differ chiefly in the degree of insulation furnished. Thus the cars may vary in efficiency because of lighter construction and insulation or because of a variation in the insulating material itself. The tendency on the part of the railroads at the present time is to increase insulation. Cars are built more heavily, and much greater care is given to the selection and amount of the insulating material. There is considerable variation, also, in the construction of the compartments at the ends of the car for holding the ice, or the ice and salt, upon which refrigeration depends. These "ice bunkers" are built with the hope that their construction will produce some circulation of the cold air in the loaded car. At the present time this is one of the problems at which the railroads are diligently working, and there are numbers of types of experimental cars now being tried, all having this object in view.

The efficiency of a car is affected also by its ability to withstand the usual wear and tear of traffic. Frequently doors are jarred, rendering the insulation about them imperfect; joints crack, or the shipper, to prevent his load from shifting, may drive heavy spikes into the walls of the car, thereby doing great damage to the insulation.

THERMOGRAPH RECORDS.

Curves are reproduced (see fig. 7) to show the variation in temperature in a single car which had suffered hard usage and which was very badly insulated about the doors. It was iced for twenty-four hours before loading with finely chopped ice mixed with 10 per cent of salt, and loaded in the center with eggs which had been chilled before shipping, while at the bunker ends were boxes of chilled poultry.

Figure 7A shows the temperature record of the air of the car around the upper layer of poultry boxes next to the eggs, which occupied about the width of the door space in the middle of the car. It will be observed that the temperatures here varied between 45° and 50° F. (7° and 10° C.), and that nearly nine hours were required before the minimum temperature was reached. Figure 7B shows the car temperature in the upper layer of boxes at the bunker ends. Here the temperature varied from 25° to 35° F. (-4° to 2° C.), with generally the maintenance of a temperature less than 30° F. (-1° C.). Figure 7C shows the temperature maintained on the floor of the car next to the ice bunker, and here the general average would lie between 10° and 20° F. (-12° and 7° C.), while the maximum is not over 25° F. (-4° C.).

The type of car now prevailing, if it is in good condition, will maintain a temperature of less than 40° F. (4° C.) opposite the doors

A. Upper layer of boxes middle of car.

B. Upper layer of boxes next to ice bunker.

C. Floor of car next to ice bunker.

FIG. 7.—Temperature records in three parts of a single car with imperfect insulation. 1-2. Cooling of poultry in packing-house chill room. 2-3. Haul. 3-4. Unloading car at destination showing drop in temperature because car door was closed during dinner hour.

the temperature within a space of five hours dropped to 34° F. (1° C.), and this was maintained uniformly to the end of the haul.

When the car arrived at its destination, and the boxes were opened, the poultry had so much moisture condensed on the surface that it was distinctly wet, a condition known in the industry as "sweating." This condition is undesirable in that it induces the growth of mold and hastens decay, unless the surfaces of the birds are promptly dried. It was caused by the fact that there was a difference of 17° F. (9° C.) between the temperature at which the birds left the packing house and the highest temperature reached during the haul. It would have been better in this case had the birds left the chill room with a temperature of 32° F. (0° C.).

REFRIGERATION IN THE MARKET.

In the handling of poultry the facilities of the middlemen and retailers, for holding the goods in a chilled condition, are of great importance. Artificial refrigeration in the packing house may give excellent chilling facilities; the railroad refrigerator car may maintain the necessary low temperature throughout the haul, and yet, between the arrival of the poultry at the market and its final sale to the consumer inadequate refrigeration may render the previous good work valueless.

Having chilled or frozen the poultry the low temperature should be constantly maintained until the product is consumed. Fluctuating temperatures cause a condensation of moisture and a consequent activation of bacteria and enzymes, with resulting decomposition. Such being the case, cold storage warehouses and large dealers in poultry have found it almost a necessity to have railroad trackage at their own receiving platforms, thereby eliminating the wagon haul and an extra handling of the packages. If wagons must be used to transfer the goods from the car to its next destination, the load should be covered with canvas or otherwise insulated as perfectly as possible.

The most efficient method for the wholesaler to adopt for carrying large quantities of dry-packed poultry between receipt and disbursement is the use of a mechanically refrigerated chill room of the same type as that of the packing house, and maintaining temperatures below 40° F. (4° C.). If frozen stock is to be handled, a room maintaining a temperature which is below 15° F. (-9° C.) should also be available.

The recognized need and advantage of refrigeration for both large and small dealers in dressed poultry has led establishments which produce large quantities of a low temperature refrigerant to supply

it through underground pipes, at definite cost, to dealers in perishable goods, thereby saving them the maintenance of refrigerating machinery. A considerable number of city blocks are frequently traversed by these pipes, and large markets as well as individual

FIG. 9.—Market house showing chilled show case.

shops are thus supplied with the refrigeration required for the especial kind of produce carried. Not only are insulated rooms so chilled, but holders of market stalls may have boxes mechanically cooled for holding supplies and show cases for the display of goods. Figure 9

shows a market house in which mechanically refrigerated boxes have entirely replaced ice boxes, and which provides chilled show cases.

The temperature of a first-class ice box is, ordinarily, about 45° F. (7° C.). Ice and salt, with a system which enables the brine to circulate, gives temperatures approximating the chill room and can be advantageously used by the middlemen if mechanical refrigeration can not be obtained or when ice is cheap.

The installation of mechanical refrigeration of one type or another is growing rapidly among the more progressive middlemen. The retailer still depends almost exclusively on an ice box for the keeping of his stock. Many retail merchants doing a large business are adopting the practice of obtaining fresh supplies daily from their wholesaler's chill room, especially if they deal in dry-packed poultry. Those who still cling to the old methods of ice packing generally use zinc-lined, drained boxes in which poultry and fine ice are mixed together.

When it is recalled that, including the time consumed in the haul, the time required by the commission man to dispose of his stock, the time that the retailer keeps his goods before all are sold, and the day or two that the housewife may keep the fowls before cooking them, about three weeks elapse between the date of killing and the time of consumption, it will be recognized that every step in the handling of dressed poultry demands perfection of detail if the product in our markets is to be good.

About three weeks is the amount of time commonly needed for the marketing of chilled poultry in the large cities of the East, North, and Far West. In the Middle West, which is nearer the sources of abundant production, the marketing time is shorter; and in the South climatic conditions and a general lack of refrigerating facilities necessitate prompt movement of perishable stuff of all kinds.

FROZEN POULTRY.

Freezing poultry during the season of excess production, and holding it in that condition until the season of shortage arrives, has become a trade practice in the United States. Goods so kept are commonly called "cold-stored," though it is a difficult matter to draw a sharp distinction between produce which is held for weeks in a chill room, yet is accepted on the market as "fresh," and that which is frozen for transportation or marketing purposes and held, possibly for several weeks, in a frozen state, and goes, therefore, as "storage."

Unfortunately, "cold-stored" poultry has too frequently been synonymous with market stocks, held for sale in an unfrozen condition until the last minute, then put into the freezer in undesirable packages and already showing evidences of decomposition. Usually the

owner intends to remove and sell such goods within a few days. Too often it is weeks and months before they reach the market. Deterioration has progressed while in the frozen state—slowly, it is true, but nevertheless unmistakably—and decomposition hastens after thawing. Hence the consumer gets a low-grade article and the reputation of all cold-stored produce suffers.

The blame for such practices is often to be laid at the door of the commission man or the retailer. The packer who prepares goods for storage is generally careful to see that the products enter the freezer in good condition. Not only that, but he is apt to grade more carefully when goods are to be held for a length of time in a frozen condition than when they are to go on the market for immediate consumption.

It is very desirable that the poultry which is to be put in cold storage should be dry picked and dry chilled. Poultry which has been cooled in water shows blistered areas and an unsightly drying out of the skin after comparatively short periods of storage, while the scalded fowls have not only unsightly skins but a deepening of the color over legs and thighs which is very undesirable. It has been observed by the more experienced of the members of the industry, and confirmed by scientific investigation also, that scalded poultry does not keep as well as that which is dry picked; neither does the water-cooled product keep as well as that which has been air chilled.

Larger packing houses at the present time aim to have not only a chill room, such as has been discussed, but also a room maintaining a temperature below 0° F. (-18° C.). In this room the chilled birds in boxes are kept until hard frozen. They may be carried by the packer hard frozen at 10° to 15° F. (-12° to -9° C.) until sold, or they may be shipped immediately after freezing to a warehouse which is in proximity to their final market.

The packer who is not supplied with a freezer ships his carefully graded and boxed stock in a refrigerator car, with every precaution against bad treatment, to a cold-storage warehouse, where the birds are frozen and where they are kept until marketed. It is the aim of the packer or the warehouseman to freeze the birds as promptly as possible, since upon this, in a considerable measure, depends the retention of their clear color and fresh appearance. Hence it is not unusual now to find warehouses which maintain rooms 10° below zero (-23° C.), into which the stock is put for two or three days or until completely frozen. It is then transferred to a room having a temperature of about 10° F. (-12° C.) where it is carried.

In order to freeze quickly boxes must not be piled tightly one upon another, and it is desirable to keep them as near the floor of the freezer as possible. Hence they are tilted one against the other,

resting on the floor of the room in long rows, boxes being pushed alternately from side to side of a center line so that the maximum portion of each is exposed freely to the cold air of the room, as shown in figure 6.

Since quick freezing is so important an item, it can be readily seen that large containers, such as barrels, are undesirable for long storage. It is advisable also to exclude air from the birds after they are chilled; hence tight packages are coming more and more into use. To protect the birds from rubbing against one another in the box, or freezing into a solid mass, high-grade stock generally shows each fowl wrapped separately in parchment paper.

If the packer possesses a suitable freezer, he may prefer to freeze his storage stocks, in which case, when shipping, he will find it necessary to salt the ice for refrigerating the car very heavily and to see that it is thoroughly chilled before loading. Boxes of frozen poultry are packed tightly, and the load may, for additional safety, be covered with a heavy canvas to protect it from the warmer air of the upper part of the car. Such a precaution is seldom necessary except in very warm weather.

The haul from the railroad car to the warehouse, if platform facilities are not available, should be performed with all the expedition possible and with as much insulation as the wagons permit. Much of the poultry which lacks "bloom"—that is, the clear, fresh, bright quality of the skin—does so because of the several superficial thawings and refreezings to which it is subjected during transportation and marketing.

It is a comparatively simple matter to keep birds in good condition from one season of production to the next in a well-constructed cold-storage warehouse, provided those birds are received at the warehouse properly dressed, chilled, and packed, and with such promptness that decomposition has not obtained even a slight foothold. Under such conditions the responsibility of the warehouse is the maintenance of cleanliness and a constant temperature which is not above 15° F. (—9° C.), and which preferably should be nearer 10° F. (—12° C.). If, on the other hand, the poultry is not properly prepared for storage, or if decomposition has begun (even though it may be scarcely perceptible to any of the senses), it is impossible with the lowest temperatures obtainable to prevent deterioration.

Poultry, even in the best condition, is not improved by being kept frozen for any length of time. About the sixth month of carrying a careful observer, judging by the taste alone, can tell the difference between frozen poultry and that which is freshly killed. Up to nine months, however, this difference is so slight that it is of scarcely more than scientific interest. But after nine months, though undoubtedly

the flesh is wholesome and nutritious, there is a loss in flavor the degree of which is dependent upon the length of time for which the storage has been continued.

The thawing of the frozen chicken preparatory to its use as food is a matter of great importance if the good qualities of the fowl are to be preserved. It was formerly customary to thaw birds by throwing them into cold water. This method, on a commercial scale, is practically certain to result in thawing in dirty water, thereby so contaminating the flesh that decomposition proceeds very rapidly. It is also deleterious, in that it extracts a considerable part of the flavor of the flesh. This being the first attribute of the fresh chicken to be lost by cold storage is the one which should be most carefully guarded. To preserve it, as well as the appearance of the fowl, thawing should be accomplished by hanging the bird in cool air, if possible at the temperature of an ordinary ice refrigerator for twenty-four hours. This time is sufficient to thaw a bird of the usual size. A slightly longer period may be required for large roasting chickens. There should also be some circulation of air, that the moisture which settles on the skin of the chicken may evaporate. So thawed, a bird well prepared and stored for a reasonable length of time—that is, from one season of production until the next as a maximum—will have a clear, fresh color in the skin, which will be soft in texture, slipping easily from the muscles beneath it. The flesh of breast and thighs may be very slightly deeper in color than in the fresh specimen, but so little that the change is negligible from a practical viewpoint. The fat is generally a little deeper in color and may have a slight taste and odor of rancidity.

The practice of thawing poultry for selling and then, in event of a lagging market, returning the thawed stock to the freezer for a second wait there is one of the unfortunate habits of the trade, but, happily, it is decreasing among the more careful. Refreezing is never a success, and the loss in quality after the second thawing has led to a strong disapproval of the practice by all who are acquainted with the results. While the refreezing of poultry thawed in air is decidedly deleterious, that which is thawed in water and refrozen is in a much worse condition.

The interval between the thawing of cold-stored poultry and its receipt by the housewife can not be too short in the interests of good, wholesome food. It is far preferable to deliver the goods to the consumer hard frozen, permitting the thawing to take place in the house ice box. If the poultry is frozen by the packer and maintained in frozen condition until received by the consumer, it will need to be “ripened” for several days in the ice box before eating, else it will have the flat flavor so disappointing to the epicure. If, on the other

hand, it is sent chilled to the warehouse to be frozen, a trip requiring in many cases several days, it will be found of good eating quality after the twenty-four hours required for the ice-box thawing.

THE REFRIGERATION OF EGGS.

The preservation of eggs has for centuries been a problem, since they, probably more than any other food staple, are dependent upon seasons and conditions for production. In the temperate zone the sequence of seasons results in the production of a large proportion of the whole year's lay during the spring months. In the winter months the production, as compared with consumption or demand, is extremely small. Hence the necessity of preserving eggs from April until December in a wholesome condition, retaining as much as possible of their freshness of flavor.

Of all the various methods for the preservation of eggs, cold is, so far, the best. Its application to the keeping of eggs, however, must be along definite lines. As has been stated when discussing the application of refrigeration to the marketing of poultry, it is efficacious in maintaining high quality for a reasonable period of time if the eggs are put into the cold room in prime condition. Cold does not make them better, whether of low or of high grade, and when deterioration has already begun cold does not retard the process to the extent that it does when the eggs are fresh. The use of cold, therefore, as a preservative of eggs depends very largely for its success upon the condition of the goods when they come to the cooling room or the storage warehouse. The range of temperatures used in the handling of eggs, however, is very small by comparison with that commonly used in handling poultry, and temperatures low enough to freeze the egg, even superficially, are disastrous.

Industrial practices in handling poultry have so progressed that artificial refrigeration is of wider application and of greater importance to both the consumer and the trade when used to preserve freshness during the routine of marketing than when used to carry goods for long periods in a frozen condition. As applied to eggs, however, the reverse is true from the viewpoint of industrial practice. Artificial refrigeration is more extensively used when eggs are to be kept for the season of shortage than for the preservation of high quality and the prevention of deterioration during routine marketing. Happily for the consumer, however, the industry is beginning to recognize the value and importance of keeping eggs cold throughout their entire journey from the hen to the table; happily, too, for the industry, since the application of practical chilling methods will in a large measure wipe out the losses which are now so prevalent.

The great egg-producing section of the United States is coincident with the corn-raising territory; that is, it comprises the Central States and the entire Mississippi Valley, with the exception of its extreme northerly and southerly portions. The numerous small farms and suburban producers in the Middle Eastern and the North-eastern States ship their output to near-by cities generally for prompt consumption, storing only when the supply is exceptionally large, and then only when weather conditions are favorable to the good keeping of the product during its transportation to the warehouse. Hence the small farmer of the East has concerned himself chiefly with production, the question of handling being scarcely considered, and the methods in vogue have not been essentially changed in many years. On the other hand, the producing section of the West, far from its market, busy with large farming operations, has allowed its chickens to breed and feed as best they could except for the few winter months, when some care must be given them. The packer, however, has centralized the output of eggs, just as he has the output of poultry, and has developed methods for handling which will carry his product to market in good condition, even though the haul is a week or more in duration.

It has been shown that the need for artificial refrigeration in the handling of poultry begins as soon as the bird is killed and picked; that is, in the packing house. Eggs also need refrigeration in every phase of handling, but at present it is not available until they are received by the packer. The farmer, the country storekeeper, and the small shipper have no facilities for cooling the eggs. They are careless, moreover, in that they do not collect the eggs with sufficient frequency, and, having gathered and concentrated them, they permit them to stand for days in hot sheds or rooms. Hence, during the hot weather the losses due to incubation are enormous, and general deterioration with loss of flavor is almost universal. The packers themselves are but slowly grasping the fact that eggs, during the hot months, demand refrigeration for the preservation of freshness quite as much as poultry. Too many packing houses are still without facilities for chilling eggs as promptly, completely, and continuously as dressed poultry is chilled. When the packer receives the eggs at the packing house in a fresh condition, puts them immediately into a chill room which is 38° to 40° F. (3° to 4° C.), grades and packs them at that temperature, and ships in a refrigerated car, deterioration is reduced to the minimum that our present knowledge of egg handling affords.

Thorough chilling of the usual package of 30 dozen eggs in paste-board "fillers" containing 3 dozen each, packed in a case made of an odorless wood, is not accomplished easily nor speedily. The cases

should be stacked with air spaces of at least an inch around each, and from twenty-four to seventy-two hours will be required for chilling, depending upon the size of the room and the number of boxes.

The condensation of moisture on the shell of an egg, due to its passage from a lower to a higher temperature, is quite as disastrous to its good keeping as it is to that of dressed poultry. Hence, until the egg reaches the cold-storage warehouse it is advisable to maintain a temperature of 40° F. (4° C.), since this is more readily approximated in refrigerator cars, commission houses, refrigerators, etc., than is a lower temperature.

Large egg dealers are now providing not only chill rooms for short holdings, but a room as near 40° F. (4° C.) as possible for the candling and sorting of the eggs. The more progressive men at the receiving points are transferring eggs from the freight stations to their establishments with all the expedition and care that is given dressed poultry, especially during the latter part of the season of excess production, when prices are suitable for storage but quality is apt to be low because of warm weather.

Already the packers who have installed refrigeration for eggs, who are grading carefully in refrigerated rooms, shipping in refrigerated cars to jobbers with refrigerated receiving rooms, are setting a new standard in the markets. Formerly eggs were graded very largely by the locality from which they came, those nearest to the market being generally accepted as freshest, while eggs from the South were graded lower merely from the name on the end of the box. Receivers are learning, however, that a good flock of hens supplemented by good handling, in Virginia or Tennessee, means just as good eggs in New York as when they are sent from northern Illinois or from Michigan; and careless handling in Pennsylvania or New Jersey results in just as many rots, spots, and bad-flavored stocks as come from more distant points where care and refrigeration preserve quality.

The problem of getting eggs to the consumer in the hot season in good condition is a proposition which can not be solved by refrigeration alone, yet it is one in which refrigeration plays a part second only to the education of the farmer and that of the country storekeeper in determining the quality of eggs. Every packer who installs refrigeration becomes a center of improvement in his community, since he urges better handling prior to his receipt of the eggs, knowing that his chilling system will take care of them afterwards until they reach the market. Such tendencies are already launched in the egg industry. Within the next few years it is probable that rapid advances will be made in the conservation of this most important food, not only in greater production, but, what amounts to the same thing, the saving and making available in a wholesome condition of a large proportion

of what is at present one of the most extravagant wastes of a people who have never had to be very careful of their food supply.

It has already been stated that, while refrigeration in the broad sense has but recently played a widespread part in the marketing of eggs, it has been used far more generally for the preservation of eggs until the season of shortage. The early spring eggs, after danger from frosting is over, are considered most desirable for long storage. Whether this is due to an inherent condition of the egg, referable to the physical state of the hen, or to weather conditions which are favorable to egg preservation at that season, scientific research will have to decide. The fact remains that the desirable storage stocks are those which are put early into the egg-storage rooms, and it is these which can be held longest.

According to trade practices, eggs are graded during the early part of the laying period by size and cleanliness, packed into a rather heavier filler than is used for current consumption, and stored in odorless wood boxes, 30 dozen to a box, at temperatures ranging from 28° to 32° F. (−2° to 0° C.), depending upon the locality and the preference of the owner. Later in the season grading is dependent upon the appearance of the egg before the candle, evidences of incubation excluding it from storage. It is at this period, when the quality is going down and the storage space is still unfilled, that great care must be exercised in selecting eggs for long keeping. At best, it is the custom to remove the later eggs from storage when the first demand in the autumn arises, and in spite of careful storage conditions deterioration will be found to have made more headway in them than in the earlier lots. Hence, very careful candling must precede their entrance to the market.

The questions of temperature and humidity and cleanliness are of great importance in the successful cold storage of eggs. The temperature must not permit freezing of even the most superficial kind, yet the colder the eggs can be kept without congelation the better. Fresh eggs which are thick bodied, as laid by well-fed hens, can be held advantageously at 28° F. (−2° C.); on the other hand, thin eggs, or those which have begun to deteriorate, may require 32° F. (0° C.) for safety. It is scarcely necessary to say that the latter will not keep as long as the former. A constant temperature within small limits in long storage is an absolute necessity. The majority of warehouses permit a maximum fluctuation of not more than 4° F. (2° C.) after the stock has ceased coming in. Some maintain even greater exactness than 4°.

Humidity in egg keeping is a subject which is much in need of close scientific investigation. It would seem, from the experience of the industry, that the relative humidity of the atmosphere desired is

variable and depends to a certain extent, at least, upon the construction of the storage room, the quantity of eggs stored, and the environment in general. Where refrigeration is by brine pipes only, and rooms are well filled, it is generally too moist rather than too dry for the best results; but, on the other hand, when a dry, cooled air system supplements the brine pipes, or where this is the exclusive source of refrigeration, a drying out of the contents of the egg must be carefully watched.

In practice the growth of a fine, white mold on the eggshell is a good indicator of moisture conditions. This mold does not penetrate the shell; it is snow white, woolly, very delicate, and is removed by the slightest touch. The degree of humidity which permits a very slight growth of this fungus is a desirable one for egg preservation. A luxuriance of growth means too much moisture. A lack of it is very apt to indicate an undue drying out of the contents of the shell.^a Each warehouse storing eggs is a law unto itself, and must continue so until careful scientific studies of egg keeping under refrigeration have correlated such factors as temperature, moisture, and fresh air.

Eggs absorb odors. Therefore, every effort is made to keep the egg-storage rooms free from them. No other commodity should be put into the same room, and in the offseason many warehouses that make a specialty of egg storage let the rooms lie idle rather than risk the absorption of foreign odors which might, later, contaminate the eggs. A plentiful coating of lime over wooden surfaces, freshly applied before the eggs are received, is the most common method of keeping walls and floors odorless.

The length of time that eggs can be kept in cold storage depends very largely upon their condition when they enter it. As has been stated, eggs laid early in the season during cool weather keep best. Carefully graded, packed, and transported, such eggs are good food at the end of nine months. It is likely that they will not soft boil or poach with entire satisfaction at the expiration of that period, but for all the other methods of cooking they are available. If the eggs are of strictly first quality when they enter storage they will soft boil after six or seven months and compare satisfactorily with the "strictly fresh" eggs of the market. Indeed, when the lay falls off in the late summer and autumn, and farmers begin to hold eggs for high prices, good stored eggs from early lots are to be preferred to the average market offerings. This is also true of shipments to market in very hot weather, when incubation is observed in almost every egg. At such times the jobber who supplies a fastidious trade may be driven to draw upon his storage stocks for satisfactory sup-

^a This fungus is being studied at the present time in the Food Research Laboratory, Bureau of Chemistry.

plies. Yet with the education of the farmer in the care of the eggs produced and in the necessity for prompt sales, with refrigeration in the packing houses and refrigeration in transit and during marketing, it is merely a question of time and the extension of these new methods until the bad reputation of the "July egg" will be a thing of the past.

SCIENTIFIC DATA APPLIED TO THE INDUSTRIAL USE OF REFRIGERATION.

One after another the great industries of the world are coming to depend upon scientific methods for solving practical problems; one after another they are establishing laboratories and experimental plants for their own advancement. No industry can afford to ignore or slight any honest scientific research in the field of its endeavor, be the results, at first sight, laudatory or condemnatory of its practices. It is upon the basis of scientific research, frequently made without any idea of its practical application, that the greatest technical advances of the age have been founded.

So it must be with the refrigeration of foodstuffs. For twenty-five years the industry has struggled to achieve results, advancing by the aid of individual industrial experience only. The workers, naturally, have been men unskilled in close and accurate observations and untrained in connecting cause and effect in so complicated a problem. That they have reached their present degree of skill is greatly to their credit.

That great benefit, not only to the industry but to the consumer, does accrue by attacking the problems of refrigeration of foods from a scientific view point is abundantly illustrated in the change in the handling of fruits, resulting in practically a revolution in the market product, brought about by the pomologists of the United States Department of Agriculture. Results for which the industry could find no cause were explained. The remedy then became a comparatively simple matter. Practices which had the confidence of all were shown to be founded on errors of fact and were producers of unsuspected evils. They were promptly discontinued. With such guidance the handling and storage of vast quantities of fruit, bringing it within reach of all the people as in no other country outside the tropics, has progressed in the United States until it may well be considered a model for other industries.

Such scientific investigations of the chemistry, bacteriology, and structure of refrigerated poultry as have been reviewed in the opening section of this paper are laying the foundation for betterments in the handling of poultry and eggs under refrigeration, just as the

foundations were laid in the laboratory, with microscope and test tube, for the assistance of the fruit investigators. As in the study of the handling of fruit, the United States Department of Agriculture is taking an active part in the study of the handling of poultry and eggs, as influenced not only by refrigeration but by every phase of routine to which the produce is subjected. From the time the fowl is ready for killing, or the egg laid, until it reaches the consumer, it becomes an object of exact scientific investigation. Such a problem must of necessity require years of research, and results can not be expected to come quickly, especially when storage in a frozen condition is to be studied.

It has been observed that the industrial practices which give undesirable results in the course of the usual marketing of fowls are not only undesirable when those fowls are to be stored in a frozen condition, but the bad effects then are even more pronounced. Improvements in the handling of poultry for prompt consumption are likewise improvements if long storage is anticipated. On the whole, extra care and accuracy must be observed in the prestorage treatment if the best storage results are to be obtained.

For example, an incomplete removal of the blood of the chicken when it is killed results in a reduced stability of the flesh, as well as an undesirable appearance of skin and muscle. Even in prompt marketing the deterioration of a fowl incompletely bled is to the detriment of its value and flavor as food. When frozen, no matter how low the temperature nor how perfect the conditions of the storage warehouse, its discoloration increases and the time of its good keeping, so far as flavor and appearance go, is reduced as compared with its well-bled fellows. Hence the bleeding of a fowl is a matter of greater importance than might appear at first sight. An anatomical study of the blood vessels of the neck and head of the domestic fowl has already been made, and on the basis of this information a method of cutting to bleed has been recommended.^a

At least 30 per cent of all the chickens prepared for market, both for storage and for prompt consumption, are incompletely bled. Their value is reduced from 2 to 5 cents per pound thereby. Their keeping time is lowered to such an extent that it has been deemed advisable to make an accurate study of the matter, shipping under various conditions for long and short distances, marketing according to the customs of various dealers, storing in a frozen state, and marketing the frozen as well as the unfrozen birds. Such an investigation is already under way in the United States Department of Agriculture.

^a Pennington and Betts, How to Kill and Bleed Market Poultry, U. S. Dept. Agr., Bureau of Chemistry, Circular No. 61.

That there may be definite criteria for the gauging of the rate of decomposition, such methods as that of Folin for the estimation of the ammoniacal nitrogen, and that for the determination of the acidity of crude fat (see p. 12) have been adapted to the solving of the problems in hand. By the use of such methods gradations of quality are not dependent upon the usual inspection, which consists of the evidence of certain senses only, but are reduced to an impersonal accuracy.

The subject of refrigeration has a direct bearing on the study of the comparative merits of removing the animal heat from poultry by cold water and ice or by dry, cold air; and of maintaining the skins of the birds in a dry condition, or of carrying them in cracked ice throughout their marketing. The water cooling and ice packing, keeping as it does the skins of the birds always wet, enables the bacteria, which are universally present, to multiply and penetrate the skin or any abrasion with but slight hindrance, since the temperature maintained by cracked ice, when moisture is so plentiful, is not very efficient in inhibiting bacterial growth; and bacterial growth in flesh means decomposition of some kind, too frequently undesirable. A bacteriological study of skins of chickens chilled in dry air and in water and ice shows a marked preponderance of organisms in the latter after even a short keeping time,^a as marketing practices go. In accordance with the fact that, for keeping, flesh should be as nearly sterile as possible, chemical analyses of air-chilled and water-chilled chickens show that the former change more slowly.

As has been stated previously (p. 12), the development of acidity in the fat is a delicate indication of the aging of flesh and one that can be observed long before the senses can detect definite alteration. Applying this test to the body fat of chickens chilled in the two ways gives results as follows:^b

Acidity of fat as an index of freshness.

History of sample.	Acid value.	History of sample.	Acid value.
Broilers, air-chilled, 48 hours old	0.95	Broilers, water-chilled, ice-packed, 48 hours old	0.88
Same lot after 4 days, at 32° F.	2.10	Same lot, 4 days in ice	4.57
Same lot after 12 days, at 32° F.	4.74	Same lot, 7 days in ice	4.71
Fowl, air-chilled, 8 days at 32° F.	1.65	Fowl, water-chilled, ice-packed, 8 days ..	8.55
Same lot, 12 days, at 32° F.	2.41	Same lot, 10 days in cracked ice	8.86
Fowl, kept at 32° F. for 3 days.	.80	Fowl, kept in ice 3 days	2.20
Same lot, kept at 32° F. for 6 days.	1.41	Same lot, kept in ice 6 days	2.70

Such results indicate very plainly why it is possible to maintain high quality for longer periods when cold-air chilling is used than

^a Unpublished results, Food Research Laboratory, Bureau of Chemistry, U. S. Dept. Agr.

^b Pennington and Hepburn, loc. cit.

when water is used for the same purpose. This is a practical problem for the scientific investigator and one of the utmost importance from the view point of fresh, wholesome food.

If freezer storage is to be applied for long preservation it is the custom of the more progressive packers to air-chill the stock (see p. 30), though the more conservative men, or those not equipped for air chilling, habitually store large quantities of water-chilled poultry. Within a few months such poultry can be identified by small, dry, scaly areas, chiefly on breast and thighs, and by a loss of the color and translucency characteristic of fresh birds which have not been water-soaked. After thawing, whether in water or air, the flesh is not so firm nor the color so good as in the case of the air-chilled poultry.

If water-chilling poultry is detrimental to its good keeping, it can readily be seen that the custom of scalding poultry, which prevails in so many sections, must be even worse. Water-soaking the skin of a chicken destroys its histological integrity by an endosmotic bursting of cell walls and lowers its resistance to bacterial invasion by diluting the contents of the cells. The skin of a chicken chilled in water contains at least 18 per cent more moisture than when air chilled; hence the blisters which form after freezing the water-chilled fowls. Scalding the chicken for the removal of the feathers necessarily alters the structure of the skin far more than mere soaking. It reduces its protective properties, as far as bacteria are concerned, to almost nothing. Undoubtedly, too, its deleterious action is even deeper seated, since the keeping time of a scalded chicken is reduced to a very low figure, comparatively. The nature of this deeper action is now under investigation.

A study of the behavior of dry-picked and scalded fowls after freezer storage^a shows that the scalded specimens vary greatly in condition, even after three months' holding. Loss of color, texture, flavor, and general good quality is more rapid in scalded than in dry-picked chickens. If any delay occurs before storage, or any error in handling is made, the scalded birds show the effect very soon, even if hard frozen. Incipient decomposition, though retarded in a frozen scalded fowl, is not checked to the same extent as in the dry picked. Indeed, under the same disadvantageous conditions deterioration will have obtained a good foothold in the scalded stock before it has made any headway with the dry picked. On entering the freezer a scalded bird may show no signs of active decomposition, yet after six or nine months a distinct greening of the skin may be observed, and, while quick thawing may be accomplished without the appearance

^a Pennington, address before American Warehousemen's Association, December, 1909.

of an odor of putrefaction, yet it does come within a few hours and then increases with rapidity.

While discussing the boxing of chilled poultry (p. 21) the statement was made that the most recent advance in this respect lay in the growing use of a carton for a single chicken, or, at most, a pair. Experimentation in this line was begun more than three years ago by the United States Department of Agriculture, using a paraffined carton such as is commonly seen in the cracker trade, as well as a fairly tight tin box. It has been commonly held by the industry that fresh air is needed in the packages of frozen poultry if long keeping is desired; hence boxes have been far from tight. Experimentation, on the other hand, has shown that flavor, appearance, texture, and all-around quality have been enhanced by storage in a tin container, or even in a pasteboard carton,^a from which air is excluded. A number of these experiments have been made,^b using chickens dressed in various ways. The analyses of the flesh and a record of the general condition of the birds so packed, as compared with the usual box pack, are now in course of compilation.

Such analyses—bacterial, chemical, and histological—as were reviewed in the first chapter of this paper have been of great service in studying the comparative advantages of various methods of preparation of poultry for either the market or the freezer. By means of them it has become possible to state whether a bird entering the freezer in visually good condition is really so in the sense of maintaining quality for the maximum commercial keeping time. Since the object of the freezer is to preserve the flesh as nearly unchanged as possible, such methods must be resorted to for the recognition of differences which are minute when freezing is applied, more apparent when it ends, but striking before marketing is accomplished and the bird eaten. On the basis of such work improvement in present methods must follow and new practices will be devised. A large part of the poultry now lost as foodstuff by decomposition will be saved when the reasons for its spoiling shall have been made plain to both packer and receiver. And last, but not least, such work, brought to the attention of the public, must tend to do away with such prejudices as those which cause the consumer to demand scalded rather than dry-picked chickens and often to sweepingly condemn all cold-stored supplies regardless of quality or the impossibility of furnishing fresh produce when it is demanded out of season.

^a This has been adopted for commercial use by certain progressive packers.

^b Unpublished studies of Food Research Laboratory, Bureau of Chemistry, U. S. Dept. Agr.

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