THE DEVELOPMENT OF BACTERIA ON DRAWN AND UNDRAWN POULTRY AT TEMPERATURES ABOVE AND BELOW FREEZING

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Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1933

Submitted to the Department of Poultry Husbandry

Oklahoma Agricultural and Mechanical College

In Partial Fulfillment of the Requirements

For the Degree of

Master of Science

1938

APPROVED:

In charge of Thesis

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ACKNOWLEDGMENTS

The author wishes to acknowledge and express sincere appreciation for the many valuable suggestions and assistance given him by Prof. R. B. Thompson, Head of the Poultry Department, Oklahoma Agricultural and Mechanical College. His obvious interest in this problem has been very encouraging.

Full credit is due the other members of the Poultry Department for their cooperation and assistance.

Full credit is also due Dr. Geo. F. Stewart, Research Department, Omaha Cold Storage Company, Omaha, Nebraska for his valuable suggestions. Dr. Stewart also supervised the preparation of the fowl used to study the different methods of freezing.

Dr. Rose Ostroff and Dr. E. E. Harnden of the Bacteriology Department have helped to make this problem possible through their valuable supervision and instruction in the methods used.

Acknowledgment is also due Mr. W. A. Stolzer, Manager, Swift and Company, Enid, Oklahoma, for his cooperation in securing the fowl.

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INTRODUCTION

During the first ten years of this century, many cities and states passed laws which made it unlawful for dressed poultry containing the viscera to be sold. These laws were passed because public health authorities believed that bacteria penetrated the walls of the intestines and contaminated the flesh. The packers maintained that drawn poultry was less attractive and deteriorated much more rapidly than undrawn poultry.

The laws mentioned above were never enforced to any extent. As a result, packers continued to sell their poultry without removing the viscera. Recently, a few packers have been marketing a small quantity of fully drawn poultry. This practice is growing very rapidly; however, the great bulk of dressed poultry is still marketed undrawn. Whether it is better to market poultry in a drawn or undrawn state is still much discussed among packers.

From a bacteriological standpoint, a review of the literature indicates that little has been done concerning the relative keeping quality of drawn and undrawn poultry. Neither does the literature show that any extensive work has been done to ascertain the storage temperature that best controls bacterial growth on dressed poultry. Since poultry is such an important food product, more knowledge is needed on these subjects. The purpose of this problem is to study the development of bacteria on drawn and undrawn poultry,

at 5° F. and 35° F. These temperatures were used because they were the ones available. The refrigerating machine was thermostatically controlled which made it possible to keep the birds at a uniform temperature.

REVIEW OF LITERATURE

Lochhead and Landerkin (14), in 1935, examined 144 birds which were stored at 30° and 32° F. They found that birds acquired a surface odor before there was any apparent decomposition or any significant increase of bacteria in the muscle tissue examined. Surface odor appeared when the bacterial count reached approximately 2,500,000 per square centimeter. Birds held at 32° F. acquired an odor at four weeks. Those held at 30° F. acquired an odor at five weeks. The predominating types of bacteria developing on the skin during storage were of the genera Micrococcus, Flavobacterium, and Achromobacter, six species being described, all cold-tolerant rather than cold-loving.

Experimenting with Long Island Ducks, Heitz and Swenson (10) found that the bacterial count, after six months storage, was much greater in samples taken from ducks frozen by the slow freezing process than by the quick freezing.

In 1933, Haines(7) found that organisms divide themselves into two groups, those having optimum temperatures for growth at 37° C. cease growth, or grow very slowly, in the range plus 5° to 0° C. Those organisms which have an optimum temperature for growth around 20° C. usually grow well at 0° C. Most strains of Pseudomonas and Achromobacter grew slowly at a -3° C., but not below. One strain of Pseudomonas grew, however, at -5° C. in ten weeks on supercooled agar.

The same investigator (6) found in 1934 that the death rate of Coli communis Escherich was most rapid at a temperature in the range of -1° to a -5° C. and not at a -20° C.

Berry (3), in 1933, found the temperature of -2° C to -4° C. resulted in a greater destruction of microorganisms than -20° C. In 1934, Berry and Magoon(2) stated that cold had a very marked destructive action on bacteria. The germecidal effects were noted particularly during the early stages of the refrigeration process, and continued, though at a diminished rate, for many months. Complete destruction has been attained, but rarely. Any microbial growth below -10° C. seems unlikely.

In 1935, Smart (23) isolated 26 species of bacteria, yeasts, and molds which had lived in frozen fruit held at 16° F. for three years. Freshly made agar slant cultures of each species were held at 16° F., for one year. Eight species were able to produce growth. Thirteen species, while showing no growth at 16° F., did produce growth when the cultures were removed to room temperature and allowed to incubate for twenty-four hours. Only 5 species out of 26 failed to survive the storage period of one year.

Ewell (5), in his article, "The Cooler Storage of Beef" stated that Schmid, in 1931, showed high humidity in meat rooms greatly reduced the loss of weight, but it also increased the bacterial growth. Bacteria will not multiply at a humidity below 96 per cent. Ewell cites (3) that

according to Walters, mold would not grow with a humidity below 85 per cent. Carbon Dioxide at a concentration of from 10 per cent to 20 per cent and ozone at 1 to 3 parts per million gave good results in retarding bacterial and mold growth.

Lea and Smith (13) reported in 1934 that the use of carbon dioxide for prevention of mold and bacterial growth on poultry in cold storage rooms was very unfavorable due to certain chemical decomposition which resulted in the softening of the wall of the belly.

An article in "Refrigerating Engineering, May, 1938,(22) points out that a new type of lamp, called the sterilamp, is a very efficient generator of wave lengths that are instantly destructive to bacteria and molds. This lamp is a long slender tube which emits energy in a relatively narrow band in the ultra-violet region. It operates at a temperature but a few degrees above room temperature.

PREPARATION OF THE FOWL FOR EXPERIMENT

Since this experiment deals with the problems of commercial poultry, only the best grade fowls, secured from a near-by packing plant, were used. They had been dressed by the semi-scald and wax method. In order to secure a representative sample, the birds were chosen from a large group of fowl which had been dressed by the regular plant procedure. They were packed in boxes and transported to the refrigerator in the Oklahoma Agricultural and Mechanical College Poultry Plant, and held over night at about 35° F.

The semi-scald and wax method consists of hanging the birds on an endless chain, which takes them through all the different stages of dressing. First, they are killed and carried through the scalding vat. They are now ready to be roughed, which means the removal of the major portion of the feathers. They are thoroughly dried in a drying tunnel, so that the wax, in which they are immediately dipped, will adhere to the feathers. They pass through a spray of cool water which hardens the wax. When it is thoroughly hardened, it is broken and peeled off. With the wax comes the remaining feathers, the down, and the pin feathers. Finally they are rinsed and hung on a rack to dry. After drying for 15 minutes, they are placed in the chilling room.

TABLE I

Time Required For Each Step And The Temperature Of Each Operation In Preparing Fowl For Experiment

	Time	Temperature
Scalding vat	35 seconds	129° F.
Roughing	4 minutes	75° F.
Drying	8 minutes	
Dipping in wax	5 seconds	129° F.
Spraying to harden wax	6 minutes	75° F.
Peeling off wax	5 minutes	75° F.
Spraying with tap water	30 seconds	75° F.
Total dressing time	33 minutes	
Drying carcass	15 minutes	75° F.
Chilling room	2 hours	36° F.
Transporting to Ref.	1½ hours	80° F.

About six hours elapsed from the time the birds were killed until they were placed in storage.

A total of 186 birds was secured. Six birds were examined while fresh. Eighty-four of the remaining 180 birds were drawn. After drawing each bird, the hands and apparatus were washed with soap and rinsed with sterile water. The birds were then divided into 4 lots. Each lot was divided into groups of six and placed in storage in such a manner that six birds from each lot could be removed every ten days for examination.

Lot 1 contained 42 drawn birds; Lot 2 contained 42 undrawn birds; both lots were stored at 5° F. Lots 3 and 4 contained 48 drawn and undrawn birds, respectively. These lots were stored at 35° F.

The precautions in the drawing of the birds and the wrapping in sterile cellophane bags were necessary in order that the qualitative test for bacteria would be as nearly representative of commercial conditions as possible.

In order to allow more time for the handling of the birds at each sampling period, one day was allowed to elapse between the securing of the birds stored at 5° F. and those stored at 35° F.

TABLE II

The Division Of The Fowl Used

Lot No.	Storage Temp.	Drawn or Undrawn	No. in each lot.	Groups in each lot.
Lot 1	5° F.	Drawn	42	A B C D E F G
Lot 2	5° F.	Undrawn	42	H I J K L M N
Lot 3	35° F.	Drawn	48	AA BB CC DD EE FF GG HH
Lot 4.	35° F.	Undrawn	48	II JJ KK LL MM NN OO PP

PRELIMINARY STUDIES

Considerable preliminary work was done to determine a technique which would be suitable for evaluating the bacterial changes occurring in poultry stored at 5° F. and 35° F.

Tests were conducted to determine the best means of dislodging the bacteria from the skin and abdominal tissue. Three general methods were tried. The first consisted of shaking the sample for five minutes in a 200 cc Erlenmeyer flask containing 20 cc of sterile distilled water and 75 sterile glass beads. The second method was to grind the sample for five minutes in a mortar containing a small amount of sand and water. The last method tried was identical with number one except broken glass was used instead of glass beads. The first method was considered best for this problem because it consistantly gave a higher and more uniform count.

Bacterial counts were made from a square centimeter of skin taken from the breast, back, thigh, and rump. A comparison of these counts confirms the work of Lochhead and Landerkin(14) who found that the counts from the thigh were generally higher than those from other locations of the body.

Tests were also conducted on poultry which had been held at 5° F. and 35° F. to estimate the dilutions which should be plated. It was found that samples taken from poultry stored at 35° F., due to the large number of bacteria, required a much higher dilution than samples taken from poultry stored at 5° F.

METHODS OF SAMPLING USED IN THIS EXPERIMENT

Skin samples were taken from one group(six birds) of each lot every ten days. Each skin sample was composed of four square centimeters of skin from each bird. These pieces of skin were taken from the breast, back, thigh, and rump. Sterile tin squares, exactly one square centimeter in size, were used to measure these pieces of skin. The samples were cut with razor knives and transferred with sterile forceps to a 200 cc Erlenmeyer flask. Each flask contained 20 cc

Photograph showing where one square centimeter of skin was removed

sterile distilled water and 75 glass beads. After transferring the samples to these flasks, they were shaken for five minutes. Care was taken to shake each sample in as nearly the same manner as possible. The proper dilutions were then made and duplicate plates prepared from each dilution.

Bacterial counts were made on the fourth and seventh day.

TABLE III

Dilutions Used For Skin Samples On Birds

Stored at 5° F.

Days stored when sampled	Dilutions			
0	1-100	1-1,000	1-10,000	1-100,000
10	1-100	1-1,000	1-10,000	1-100,000
20	1-100	1-1,000	1-10,000	1-100,000
30	1-100	1-1,000	1-10,000	1-100,000
60	1-100	1-1,000	1-10,000	1-100,000

TABLE IV

Dilutions Used For Skin Samples On Birds

Stored at 35° F.

Days stored when samp.	Dilutions			
0	1-100	1-1,000	1-10,000	1-100,000
10	1-1,000	1-10,000	1-100,000	1-1,000,000
20	1-100,000	1-1,000,000	1-10,000,000	1-100,000,000
30	1-100,000	1-1,000,000	1-10,000,000	1-100,000,000
40	1-100,000	1-1,000,000	1-10,000,000	1-100,000,000
50	1-100,000	1-1,000,000	1-10,000,000	1-100,000,000

Immediately after the skin samples were taken, abdominal samples were taken from the drawn birds. Each abdominal sample was composed of 2 grams of the abdominal muscles, Obliquus abdominis externus, and Obliquus abdominis internus. The samples were taken by weight because it was found that a more specific amount of surface could be measured by this method. In all calculations, abdominal samples were reduced to .5 gram because this weight, by experimentation, was found to be the equivalent of 1 square centimeter of surface. Each sample was transferred to a separate flask and given the same treatment described for the skin samples.

View of the Laboratory and a Portion of the the Equipment Used.

Nutrient agar, having the following constituents, was used.

1000 cc distilled water

5 grams beef extract

10 grams peptone

5 grams of sodium chloride

17 grams Agar agar

After adjusting the pH to 7.2, the media was sterilized by heating in an autoclave at 15 pounds pressure for 30 minutes. The final pH was 7.0

TABLE V

Dilutions Used For Abdominal Samples

On Birds Stored At 5° F.

Days stored when sampled	Dilutions			
0	1-100	1-1,000	1-10,000	1-100,000
10	1-100	1-1,000	1-10,000	1-100,000
20	1-100	1-1,000	1-10,000	1-100,000
30	1-100	1-1,000	1-10,000	1-100,000
60	1-100	1-1,000	1-10,000	1-100,000

TABLE VI

Dilutions Used For Abdominal Samples

On Birds Stored At 35° F.

Days stored when samp.	Dilutions			
0	1-100	1-1,000	1-10,000	1-100,000
10	1-1,000	1-10,000	1-100,000	1-1,000,000
20	1-100,000	1-1,000,000	1-10,000,000	1-100,000,000
30	1-1,000,000	1-10,000,000	1-100,000,000	1-1,000,000,000
40	1-10,000,000	1-100,000,000	1-1,000,000,000,	1-10,000,000,000
50	1-10,000,000	1-100,000,000	1-1,000,000,000	1-10,000,000,000

RESULTS AND DISCUSSION

Birds stored at 5° F.

The results obtained in this problem plainly indicate that from a bacteriological standpoint, there is very little difference in the keeping quality of drawn and undrawn poultry, when stored at 5° F. The undrawn birds tend to have a higher number of bacteria on the skin at all the different storage periods.

TABLE VII

Average Number Of Bacteria Per Square Centimeter On Poultry held at 5° F.

Days stored	Skin (undrawn)	Skin (drawn)	Abdominal
0	292,800	292,800	207,000
10	444,000	239,000	194,000
20	389,000	184,000	60,000
30	376,000	174,000	59,000
60	97,000	89,000	52,000

By the tenth day, there was a noticeable increase of bacteria on the skin of the undrawn bird. At the same sampling period, the bacteria on the skin of the drawn birds slightly decreased. A plausible explanation for the increase and decrease in bacteria seems to be the difference in the time required to freeze the drawn and undrawn birds; the additional time required to freeze the undrawn birds may have permitted bacterial growth to continue for some time

after the birds were placed in storage. It seems likely that the drawn birds, due to the removal of the viscera, would be frozen quickly enough to prevent any further multiplication of bacteria.

The general decline in the bacteria on all birds sampled throughout the experiment agreed with the work of Berry and Magoon(2) who found that cold produced a germicidal effect on bacteria.

Micrococcus and Achromobacter were the predominating type of organisms until the 60th day. At this time, a spreading type, which was not identified, appeared in greater numbers than Micrococcus and Achromobacter. The explanation for this is not attempted; however, on May 29 and 30, the temperature in the refrigerator raised to about 25° F. This may offer a solution. Certain bacteria (7) continue growth several degrees below freezing, while the same temperature may be highly destructive to other types. Therefore, it is altogether possible that one type of organism may have multiplied or at least withstood the temperature of 25° F., while the other types may have been killed.

At the end of sixty days, all of the birds were in excellent condition. The undrawn birds were slightly darker in appearance, otherwise there was no noticeable difference.

TABLE VIII

Statistical Analysis of Birds Stored At 5° F.

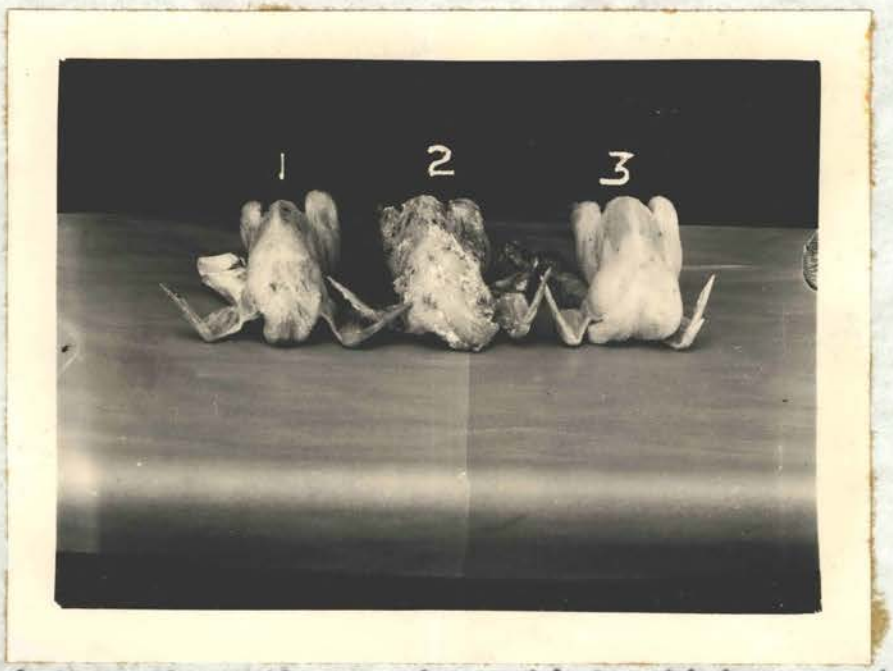
(Analysis of Variance)

Source of variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	89	2,280,624	
Within sub groups	75	776,080	10,347
Between drawn, undrawn and abdominal	2	581,979	290,989
Between times stored	4	629,521	157,380
Interaction	8	370,479	46,309

The methods used for the statistical analysis of this problem were taken from Snedecor(25)

The difference in the number of bacteria between drawn, undrawn, and abdominal samples was highly significant. The difference in the number of bacteria at different times stored was also highly significant. However, the actual number of bacteria present on any of the birds at any time was so small that there was no difference in outward appearance.

This picture shows three drawn birds which were stored for 50 days. Bird No. 2 was stored at 35° F Bird No. 1 was stored at the same temperature as No. 2, but was washed to remove the mold. No. 3 was stored at 5° F.



This picture shows three undrawn birds which were stored for 50 days. Bird No. 2 was stored at 35° F. Bird No. 1 was stored at the same temperature as No. 2, but was washed to remove the mold. No. 3 was stored at 5° F.

Birds stored at 35° F.

The number of bacteria on the skin and in the abdominal cavity mounted steadily for fifty days on the birds stored at 35° F. The deterioration had reached such a state on this day that further tests were considered useless.

TABLE IX

Average Number Of Bacteria (000 omitted) per square Centimeter On Poultry Held At 35° F.

Days stored	Skin (undrawn)	Skin (drawn)	Abdominal
0	292	292	207
10	32,663	51,208	40,196
20	41,875	79,473	471,533
30	74,750	66,187	18,925,000
40	240,000	231,000	44,375,000
50	318,000	347,500	48,691,000

All of the birds sampled on the 10th day were in fair condition. There was considerable darkening of the flesh but no noticeable odor had yet appeared. There was no appreciable difference in the general appearance of the drawn and undrawn birds.

On the 20th day, both drawn and undrawn birds had an objectionable odor. The general appearance of all of these birds was poor. Considerable mold was growing on the skin

and in the abdominal cavity. The undrawn birds were edible; however, the excessive mold growing in the abdominal cavity of the drawn birds made them unfit for human consumption. During the remaining period of study, the bacteria and mold continued to grow rapidly. On the 50th day of storage, mold had almost completely covered the skin of all the birds. The abdominal cavity of the drawn birds was literally filled with mold. The number of bacteria growing on the abdominal muscles was consistently greater than the number growing on the skin.

For further tests, abdominal samples were taken from six undrawn birds on the 50th day. The bacterial count from these birds was 13,375,000 per square centimeter as compared to over 43 billion on samples taken from the drawn birds.

Much of the unsightly appearance of the poultry stored at 35° F. was due to the excessive growth of molds. *The three most common types belonged to the genera Fusarium, Agpergillus, and Penicillium.

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*Molds identified by Tennyson, Gertrude, Assistant in Plant Pathology, Oklahoma Agricultural and Mechanical College.

TABLE X

Statistical Analysis of Birds Stored at 35° F.

(Analysis of Variance)

Source of variation	Degrees of Freedom	*Sum of Squares	*Mean Square
Total	89	18,678,972	
Within sub groups	75	6,394,117	85,254
Between drawn, undrawn, and abdominal	2	4,886,996	2,443,498
Between times stored	4	3,040,679	760,169
Interaction	8	4,357,228	544,653

*(000,000,000 omitted)

Birds frozen by slow and quick freezing process

An attempt was made to compare the number of bacteria growing on the skin of birds frozen by quick freezing and by slow freezing. Twenty-four birds were used. Twelve had been frozen in approximately eight hours in an open box at -15° F. and were known as "quick frozen". The other twelve were frozen in approximately forty-five hours in a closed box at -15° F. These were known as "slow frozen". All of these birds were held for seven months at -10° F.

These birds were prepared in a distant city and shipped to the poultry farm by express. Due to a delay of twenty-four hours in transit, they were completely thawed when they reached the laboratory. For this reason, the results obtained are of little value.

TABLE XI

Characteristics Of The Predominating Types of Bacteria

Found Growing On Skin Of Dressed Poultry Stored

At 5° F. and 35° F.

Cult. No.	Form	Spores	Motility	Gram stain	Acid (dext.)	Gas (dext.)	Gel. liq.	NO_3 red.	Indol	Act. in milk	Generic Classification
1.	coccus	–	–	–	–	–	–	–	–	–	Micrococcus
2.	coccus.	–	–	+	+	–	+	+	–	acid	Micrococcus
3.	coccus	–	–	+	–	–	+	+	–	–	Micrococcus
4.	rod	–	+	–	+	–	+	–	–	–	Flavobacterium
5.	rod	–	+	–	–	–	–	+	–	–	Pseudomonas
6.	rod	–	+	–	+	–	–	+	–	–	Achromobacter

SUMMARY

1. Poultry kept much better stored at 5° F. than at 35° F.

2. Poultry stored at 5° F. remained in excellent condition for the entire period studied. (60 days)

3. There was no difference in the keeping quality of drawn and undrawn poultry when stored at 5° F.

4. Drawn poultry stored at 35° F kept safely for ten days.

5. Undrawn poultry stored at 35° F. kept for 20 days.

6. The difference in appearance and keeping quality of drawn and undrawn poultry stored at 35° F. was internal rather than external.

7. The predominating types of bacteria on both skin and abdominal samples belonged to the genera Micrococcus, Flavobacterium, and Achromobacter.

8. The most common types of molds belonged to the genera Fusarium, Agpergillus, and Penicillium.

SUGGESTIONS FOR FURTHER STUDY

The number of bacteria on each bird of the individual groups and lots varied greatly. There was some particular cause for this wide variation. In an attempt to locate the cause, samples of water were taken from the scalding vat after each 100 consecutive birds was dipped. A count of these samples indicated that the water was highly contaminated with bacteria and that it became more highly contaminated as the number of birds scalded increased. Samples of water, taken from the scalding vat after each 100 consecutive birds passed through, contained the following number of bacteria per cc.

Before dipping	90,000,000
First dipping	140,000,000
Second dipping	198,000,000
Third dipping	225,000,000
Fourth dipping	251,000,000
Fifth Dipping	265,000,000

Tap water contained 45,000 bacteria per cc. Water which was used to cool the wax contained 50,000,000 per cc. The water which had been used to rinse the carcasses contained 175,000,000 per cc.

Samples of the wax in which the birds were dipped were also taken. The bacterial count showed that the wax contained only a few bacteria. The number did increase, however, as the number of birds dipped increased.

Samples of wax, taken from the vat after each 100 consecutive birds passed through, contained the following number of bacteria per square centimeter:

Before dipping	120
First hundred	160
Second hundred	200
Third hundred	280
Fourth hundred	430
Fifth hundred	600

Since these examinations were made on only one occasion, the results obtained are not conclusive. Further studies could be made of this interesting and valuable problem.

There are many other problems which need investigation

1. A comparison of a greater number of temperatures as to the keeping quality of both drawn and undrawn poultry.
2. A study of the critical temperature for the types of bacteria most commonly found growing on storage poultry.
3. A study of the control of bacteria by the use of chemical agents.
4. A careful study of the predominating types of organisms at different storage periods.
5. A thorough check of the cooling and packing room as a source of bacterial contamination.
6. A study of the methods of grading and packing poultry as related to bacterial contamination.

BIBLIOGRAPHY

1. Benjamin, Earl W. and Pierce, Howard C. Marketing Poultry Products. John Wiley and Sons, Inc.,1937

2. Berry, J. A. and Magoon, C. A., "Growth of Microorganisms At and Below 0° F. "Phytapathology, 24 (July,1934)

3. Berry, J. A., "Destruction and Survival of Microorganisms in Frozen Pack Foods." Journal of Bacteriology, 26 (1933) 459-70

4. Buchanan, Estelle D. and Robert E. Bacteriology for Students in General and Household Science. The Macmillan Company, 1924

5. Ewell, A. W., "The Cooler Storage of Beef." Refrigerating Engineering, 29 (Jan., 1935) 16-19

6. Ewell, A. W.,"Recent Meat, Fruit, and Vegetable Research." Refrigerating Engineering, 30 (Nov., 1935) 267-8

7. Haines, R. B., "The Minimum Temperatures of Growth of Bacteria." Report of the Food Investigation Board, Great Britian, for the year of 1933. 37-38

8. Haines, R. B., "The Freezing and Death of Bacteria." Report of the Food Investigation Board, Great Britian, for the year of 1934. 47-48

9. Haines, R. B., "The Freezing and Death Rate of Bacteria." Report of the Food Investigation Board, Great Britian, for the year of 1935. 31-34

10. Heitz, H. W. and Swensen,T. L., "The Quick Freezing of Dressed Poultry." Ice and Refrigeration, 85 (Oct., 1933) 163-65

11. Horne, G. A., "Aging and Tendering of Meat." Refrigerating Engineering, 33 (April, 1937) 236-7

12. Kaupp, B. F. The Anatomy of the Domestic Fowl. W. B. Saunders Company, 1918

13. Lea, C. H. and Smith, E. C. "The Storage of Poultry." Report of the Food Investigation Board, Great Britian, for the Year 1934. 49-5-

14. Lochhead, A. G. and Landerkin, G. B., "Bacteriological Studies of Dressed Poultry." Scientific Agriculture, 15, (July, 1935) 765-70

15. Mandeville, P., "Quick Freezing of Poultry." U.S.Egg and Poultry Magazine, 43 (Aug., Sept., and Nov., 1937) 464-67, 526,-29, and 692-98.

16. Pennington, M. E., "Changes Taking Place In Chickens in Cold Storage." U.S.D.A. Year Book (1907) 197-206.

17. Pennington, M. E., and Stiles, G. W. Jr. Bulletin No 115 Bureau of Chemistry, U.S.D.A.

18. Pennington, M. E. and Sherwood, C. M., "The Greening of Poultry." Poultry Science, 1 and 4, (April and May, 1922.)

19. Pennington, M. E. "Studies of Poultry From Farm to consumer." U.S.D.A. Bureau of Chemistry Cir. No. 64

20. Pool, Gardner, "Four Years Progress In Quick Freezing." Ice and Refrigeration 91, (1936) 213-17 300-03 and 388-89.

21. Prescott, S. C. and Greer, L. P., "Observation of Food Poisoning Organisms Under Refrigeration Conditions." Refrigerating Engineering, 33 (Oct.,1936) 211-12.

22. Rentschler, H. C. and Jones, R. F., "The Effects of Ultraviolet Radiation on Bacteria, Molds, and Yeasts." Refrigerating Engineering, 35 (May,1938) 348-50

23. Smart, H. F., "Growth and Survival of Microorganisms at Sub Freezing Temperatures." Science, 82 (Nov.,29, 1935) 525

24. Smith, E. C., "Storage of Chickens in Carbon Dioxide." The Report of the Food Investigation Board, Great Britian, for the year 1933. 48-49

25. Snedecor, G. W. Statistical Methods. Collegiate Press, Inc, 1937

26. Tanner, F. W. Bacteriology, A text-book of Microorganisms. John Wiley and Sons, Inc. (1928)

27. Zarotschenzeff, T. T. and Conn, C. J., "Preservation of Poultry, Quick Freezing vs Sharp Freezing." Refrigerating Engineering, 26 (Dec., 1933) 311

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