

SOME FACTORS THAT AFFECT CHANGE IN
WEIGHT OF FRESH CHILLED POULTRY

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ABSTRACT

SOME FACTORS THAT AFFECT CHANGE IN WEIGHT OF FRESH CHILLED POULTRY

by Daniel Eugene Bigbee

This study was conducted to determine some of the factors that affect changes in weight of processed poultry, and to determine whether those factors could be controlled to minimize changes in carcass weights. Fryers, 8 to 10 weeks of age were slaughtered, eviscerated (roaster style), the giblets and neck sealed in plastic bags and replaced in the body cavity. The carcasses were then subjected to various chilling periods and ice-pack holding conditions. The changes in carcass weight and temperature were obtained by weighing the carcasses at various time intervals and by placing thermocouples in the carcasses and recording their temperature with a recording potentiometer. The moisture content of various carcass tissues, as affected by different chilling and holding conditions, was determined, and the water permeability was determined for chicken broiler skin held in slush ice.

The increase and decrease in weights during chilling and storage in ice-pack were directly proportional to the length of the chill period. A direct relationship was found between the weight of the carcass and the amount of change in carcass weight during chilling and storage in ice-pack. Carcass weight changes were influenced in a positive direction

by holding temperatures of 40° F. or above. However, when the chill time was reduced to 30 minutes similar results were obtained at 35° F. Carcass temperature apparently influenced the amount of weight decrease during the first 3½ hours of storage in ice-pack. An additional factor that appeared to affect weight changes was the amount of ice used in relation to the size of the carcasses, when the fryers were packed in ice. These results provided a basis for the theory that weight changes of processed poultry were due to and controlled by a relationship between length of the chill period, carcass weight, amount of ice used for ice-pack, carcass temperature and holding temperature.

Although the data were not conclusive, it appears that the moisture content of the skin was changed in a positive direction during storage in ice-pack, regardless of the length of the chill period. This was supported by the fact that one hour was required for water to pass through the skin, when the subcutaneous fat was removed. When the skin was left intact, 4 to 6 hours of immersion in slush ice were required before any evidence of passage of water through the skin was obtained.

A maximum level of water uptake by the fryers was reached between 72 and 120 hours of slush ice chilling. Carcasses chilled with giblets increased in weight by 29.9 percent while those without giblets increased in weight by 27.8 percent during the 120-hour chill period.

SOME FACTORS THAT AFFECT CHANGE IN WEIGHT
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By

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INTRODUCTION

Chilling processed poultry in slush ice has become an accepted commercial practice. It provides a rapid means of removing carcass heat and enhances the appearance and shelf-life of the poultry. Although, the application of this process for poultry is relatively new, much attention has been given to some of the problems considered to be associated with slush ice chilling.

When processed poultry began to be transported long distances to retail outlets, more rapid chilling and more satisfactory holding methods were needed. Preservation was a major problem and it was found that liquid cooling methods and packing in ice for storage and shipment could substantially reduce spoilage losses.

Many systems of cooling were proposed. However, slush ice was used most frequently due to the relative ease of procuring ice and the efficiency from a cost standpoint of this method.

Although plumping¹ had been used for some time, there was an interest in the effects that slush ice chilling might have on the quality of processed poultry. It was soon determined that slush ice chilling enhanced quality, particularly in terms of carcass appearance. Later, it was found that flavor constituents were leached from carcasses chilled in slush ice. The evidence indicates, though, that the leaching that does occur is not of a magnitude to be significant, so

¹ - - - - -
The process where the poultry carcass was held in hot water to enhance its appearance so that it looked fresh to the consumer.

long as chilling is not unnecessarily prolonged.

More recently, the problem of carcass weight changes, due to uptake of water and its subsequent loss during fresh-pack holding has received much attention. It has been established that carcasses tend to take up water during chilling, then lose a portion of that water during ice-pack holding and shipping conditions.

Preliminary studies indicated that carcass weight changes and their control were associated with the length of chill, average carcass temperature, and the temperature of the storage cooler. It was believed that these factors were dependent, as well as independent in their influence on carcass weight changes. The assumption was made that the relationship between the carcass temperature and the cooler temperature could be adjusted to provide water, by melting the surrounding ice, for maintenance of carcass weights. The length of chill would influence the amount of water to be maintained as well as the amount of remaining carcass heat that could be applied toward the maintenance of that amount of water. On this basis, the following hypothesis was proposed:

That the changes in carcass weights due to slush ice chilling are associated with and can be controlled by a relationship between the length of the chill period, changes in the average internal carcass temperature, and holding temperature.

This study was conducted to test this hypothesis.

REVIEW OF LITERATURE

In 1939, Cook reported that precooling processed poultry in 32° F. water for two hours would reduce the total cooling time by about 60 percent below that required for refrigerated air cooling. Roberts and Robertson (1941), in comparing the efficiency of dry and wet cooling methods found that 33° F. water removed carcass heat more efficiently than did refrigerated air at a comparable temperature. They were able to chill broilers and fowl to an internal temperature of 33° F. in about one hour and turkeys in 6 to 8 hours.

With an increased interest in liquid cooling methods, other workers began investigating various applications of this principle to find which would remove carcass heat more efficiently. Sweet and Stewart (1942) suggested that poultry carcasses be subjected to a 20° F. brine spray for various lengths of time, depending on the size of the carcass, before transfer to a refrigerated air cooler. Esselin et al. (1954) studied the efficiency of agitated brine at various temperatures. They found that unpackaged broilers could be chilled to 40° F. in 16 to 27 minutes depending on the temperature of the brine. It appears that these methods, although relatively efficient did not prove to be practical at the processor level, since a large refrigeration capacity was necessary and corrosion of the equipment was a serious problem. Due to a lack of adequate refrigeration, at that time, many processors began using a mixture of ice and water for chilling poultry. Ice as a refrigerant was obtained with relative ease and the effi-

ciency of liquid chilling was accomplished without expensive refrigeration equipment.

Bailey, Stewart and Lowe (1948) cooled cockerels which had been New York dressed, whole eviscerated, or cut-up¹, in circulated slush ice. They found New York dressed cockerels weighing 3.75 pounds each required 110 minutes to chill to 45° F. while whole eviscerated carcasses required 50 minutes and the average time for cut-up carcasses was 20 minutes. In 1953, Orr reported that agitated slush ice was more efficient in removing body heat than still slush ice, running tap water or refrigerated air.

A chilling process in a commercial plant which tumbled the eviscerated broilers through a 47° F. water pre-chill and then through 32° F. slush ice was reported by Stratton (1958). This process reduced the total chilling time to 20 minutes and the overall chilling and packing operation required only 30 minutes. Klose, Pool and DeFremery (1959), and Kahlenberg et al. (1960) used this same method and found that the required carcass temperatures could be obtained in 20 to 30 minutes instead of the 50 minutes previously reported by Bailey, Stewart and Lowe (1948) and Esselen et al. (1954).

Roberts and Robertson (1941), Williams and Funk (1941), and Orr (1953) reported that cooling rates were influenced by the weight, size, shape, moisture content, fat content and

¹ - - - - -
 New York dressed - carcasses which have only the blood and feathers removed, and presently classified as Dressed.
 Whole eviscerated - carcasses that are completely eviscerated, and presently classified as Ready-to-cook.
 Cut-up - carcasses that have been separated into their various parts, such as breast, thigh, wings, etc.

exposed surface per unit of weight of the carcass. In 1954, Connolly, Miller and Stewart found that the position of the carcass in relation to the direction of flow of the cooling liquid influenced the cooling rate. They stated that when the flow of the liquid was directed into the body cavity the cooling rate was increased.

When liquid chilling methods first came into use studies concerning effects on carcass quality, and appearance were undertaken. Cook (1939) evaluated poultry pre-cooled in cold water and found no adverse effects on carcass appearance. Many advantages were attributed to wet cooling methods over dry methods in terms of carcass appearance (Roberts and Robertson, 1941). They found that birds pre-chilled in 35° F. water for one hour then held in wire baskets over the water had better market appearance and were equal to or superior in flavor to those chilled in air.

Bailey, Stewart and Lowe (1948) studied the effects of circulated slush ice chilling on the quality of processed poultry. Under their test conditions, they observed no differences in flavor, odor, juiciness and tenderness of carcasses chilled in slush ice and those chilled in refrigerated air. They also found that the slush ice chilled carcasses had slightly higher cooking yields. Gwin (1951) reported that chilling and holding birds in refrigerated air resulted in an undesirable carcass appearance while slush ice chilling and ice-pack storage helped to maintain a desirable appearance.

Even though earlier work had indicated no adverse effect

on flavor, Pippen and Klose (1955) found that flavor constituents were leached from carcasses held in slush ice for 3 hours. Flavor evaluations made on broth from these carcasses indicated a loss of flavor from the slush ice chilled poultry. However, when the fried or roasted meat was evaluated, no differences in flavor were detected. Hurley et al. (1958) concurred with these findings. They found leaching of organic salts from carcasses chilled in distilled water and differences in flavor of broth made from birds chilled in air for 18 hours. However, they indicated that the differences may be due to water extraction of flavor constituents during cooking.

Gwin (1951) reported that water-logging of carcasses, due to prolonged slush ice chilling, would reduce the acceptability of the poultry in regular market channels. Cooking and thawing losses were increased due to prolonged slush ice chilling according to Froning, Swanson and Benson (1958). They also indicated that carcasses chilled for prolonged periods had higher juiciness scores but were rated low on flavor.

Fortunately, the law of diminishing returns can be applied in terms of the economies of prolonged slush ice chilling of poultry as reported by Henry and Fromm (1958). They found that any increased returns at the time of delivery, due to carcass weight increases during prolonged chilling, were largely offset by the increased cost of prolonged slush ice chilling. However, they stated that net returns could be increased from 3 to 12 cents per hundred weight of unchilled

poultry depending on the wholesale price and the extent of prolonged chilling. Even so, a discount of one-eighth of a cent per pound would make prolonged chilling unprofitable at some of the highest wholesale prices experienced at that time.

Roberts and Robertson (1941), Bailey, Stewart and Lowe (1948) and Orr (1953) established the fact that carcasses chilled in liquid mediums increased in weight due to liquid uptake during chilling. However, much of the weight increase due to liquid uptake was lost during storage and cooking as reported by Bailey, Stewart and Lowe (1948).

It was observed by Fromm and Monroe (1958) that the amount of moisture uptake was directly proportional to the time carcasses were held in slush ice and that there was a direct relationship between length of chilling time and the amount of absorbed water lost within 48 hours after chilling. Baker (1959) reported that the greatest loss of moisture occurred within the first two hours after removing the carcasses from the chill tank and that the loss in weight had stabilized after 24 hours of ice-pack holding. Lentz and Rooke (1958) found that approximately one-half of the moisture uptake was lost during subsequent drainage. The greatest loss occurred during the first 15 to 30 minutes and the rate of loss was relatively low after 1 to 2 hours.

The degree of agitation of the slush ice also influences the amount of moisture uptake during chilling. In 1956, Tarver, McGhee and Goff studied various methods of agitating slush ice and found that when carcasses were chilled for the same period of time in vats of slush ice, those chilled in

aerated slush gained more than those chilled in pump circulated or non-agitated slush, in that order. Klose, Pool and DeFremery (1959), Kahlenberg et al. (1960), and Kotula, Thomson and Kinner (1960a) reported that a rapid chilling process, which involved a high degree of agitation of both slush and carcasses resulted in higher carcass moisture uptake, as compared to carcasses chilled in agitated slush ice in vats or tanks. However, Kotula, Thomson and Kinner (1960a) indicated that the moisture was loosely bound or held and that the apparent carcass weight gains differed only slightly from those of birds chilled in tanks after drainage.

Roberts and Robertson (1941) found that the higher the scalding temperature, the greater the water uptake during chilling, while Gwin (1951) stated that birds scalded at high temperatures absorbed less water. The results of Tarver, McGhee and Goff (1956), and Thomson, Kotula and Kinner (1961) indicated that carcass size or weight influenced the amount of water absorbed. They reported that small-sized carcasses had a larger percentage increase in weight due to water uptake than did large-sized carcasses.

The form the carcass is in at the time of chilling (New York dressed, eviscerated, or cut-up), also influences the amount of water absorbed. In general, the water uptake increases as the amount of processing increases. Bailey, Stewart and Lowe (1948) stated that in 135 minutes of chilling in ice water, New York dressed, eviscerated, and cut-up carcasses increased in weight by 1.5, 7.4, and 9.4 percent, respectively. Tarver, McGhee and Goff (1956) found that

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eviscerated carcasses absorbed more water than New York dressed birds when cooled in water.

Bailey, Stewart and Lowe (1948) indicated that the colder the chilling water, the greater the moisture uptake by the carcass. On the other hand, Thomson, Kotula and Kinner (1961) found that birds pre-chilled in running water (70° F.) for one hour then slush ice chilled for 2 hours gained more than those chilled for 3 hours in slush ice.

Another factor which appears to influence the amount of water uptake is whether the giblets are in or out of the body cavity during chilling. Baker (1959) studied this factor and found that birds chilled without giblets had less water uptake than those chilled with the giblets in the body cavity. This influence was reportedly not due to the presence or absence of the giblets per se, but that the giblet wrapping material absorbed water and the shape of the package formed pockets in the body cavity which trapped water. He also reported that there was little difference between the amount of moisture absorbed by carcasses crowded into the chill tank and those which were not crowded during chilling.

Kotula, Thomson and Kinner (1960a,b) pointed out that the method of opening the carcass abdomen decidedly influenced moisture uptake. When the skin between the thigh and rib cage was cut while opening the abdomen, water uptake was increased. This exposed area formed a pocket which trapped water in relatively large amounts.

Lentz and Rooke (1958) determined where the moisture taken up during chilling was held by the carcass. They

reported that 75 percent of the water was loosely held in lenses or pockets between the thighs and rib cage, muscles, and the tissues under the skin of the neck and back. The water content of the skin was increased by 10 to 15 percent, while that of the muscle increased by 1 to 2 percent during 24 hours of slush ice chilling.

PROCEDURE

Fryers, eight to ten-weeks of age were used in 19 experiments. In each experiment, the birds were eviscerated (roaster style) and allowed to hang until the evisceration process was completed for all birds. The giblets and neck from each bird were cleaned, sealed in polyethylene bags, and replaced in the body cavity without regard to which carcass they came from. Each carcass was then weighed and all carcasses to be chilled in slush ice were placed in the chilling medium at the same time. The slush ice mixture was maintained with at least four inches of ice, and agitated with a Gordon Johnson circulating pump¹. Those carcasses chilled in an ice-pack² were processed as above, and all carcasses were placed in ice-pack at the same time. Upon completion of the prescribed chilling time, those carcasses in slush ice were removed from the tank, weighed, then placed in ice-pack for the duration of the experiment. In experiments 1 through 3, a ten-minute draining period was allowed before the carcasses were weighed. However, in the remaining experiments, the giblets were removed from the body cavity to facilitate the removal of any trapped water, replaced, and then the carcasses were blotted to an acceptable dryness with paper toweling before weighing. Evaluations of weight changes were made by

¹ - - - - -
Manufactured by the Gordon Johnson Company, Kansas City, Missouri.

² The commercial practice of packing fresh chilled poultry carcasses in wire-bound boxes with a layer of chipped ice on the bottom and another layer over the top of the carcasses.

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converting the weights to a percentage of the warm eviscerated carcass weight.

In experiments 4 through 18, the changes in internal carcass temperature were obtained by means of copper-constantan thermocouples and a recording potentiometer. The thermocouples were placed approximately 1/8th to 1/4th-inch from the rib cage in the thickest portion of the pectoral muscles of eight out of 24 carcasses used per treatment. In Experiments 4 through 13 different carcasses were used for the temperature evaluations and for the weight change determinations. In Experiments 14 through 18, the same 24 carcasses were used for both evaluations.

Changes in Carcass Weights and Temperature

Experiments 1 and 2:

Ten carcasses were used for each of four treatments. In Experiment 1 carcasses for Treatment A were initially placed in ice-pack and held in a room maintained at 35° F. for 96 hours. Carcasses for Treatments B, C, and D were chilled in slush ice for 2, 4 and 24 hours, respectively, placed in ice-pack and held at 35° F. for the remainder of the 96 hour experiment. Each carcass was weighed when removed from the chill tank, and was re-weighed at 48 hour intervals from the beginning of the experiment through 96 hours.

Experiment 2 was conducted in the same manner as Experiment 1, except that the carcasses for each treatment were re-weighed at intervals of 24 instead of 48 hours.

Experiment 3:

In this experiment, ten birds were used in each of five

treatments. The carcasses for Treatment A were initially placed in ice-pack and held at room temperature for 96 hours. Carcasses for Treatments B, C, D and E were chilled in slush ice for 2, 4, 6 and 12 hours, respectively, then placed in ice-pack and held at room temperature through 96 hours. The carcasses in each treatment were weighed at 24 hour intervals throughout the experiment.

Experiments 4 through 18:

Twenty-four birds were used for each treatment in these experiments. The respective chilling periods, holding temperatures, and weighing intervals are reported in Table 1.

Experiment 19:

Ten birds were used in each of two treatments in this experiment. The giblets were placed in the body cavity of the carcasses in Treatment A, while those in Treatment B did not contain giblets. The carcasses in both treatments were then weighed, placed in slush ice, and held for 120 hours. Carcass weights were determined at hourly intervals through the first 12 hours, then at 24, 48, 72 and 120 hours.

Water Transfer

Three experiments were conducted to determine the mode in which poultry carcasses take up water during slush ice chilling. Experiment 20 was initiated to study the moisture content of various carcass tissues as affected by the length of time the carcass remained in the chilling medium. Experiment 21 was conducted to study the effect of chilling and storage conditions on the moisture content of various carcass tissues. In Experiment 22, the water permeability of the

Table 1. The respective chilling treatments, holding temperatures, and weighing periods for all birds in Experiments 4 through 18

Experiment no.	Chill treatment	Holding temp. (°F.)	Weighing times (hours after start of chill)
4	Ice packed	35	24 and 48 hrs.
5	" "	60	1-12, 24 and 48 hrs.
6	2 hrs. slush ice	35	"
7	" " " "	40	"
8	" " " "	60	"
9	30 min. slush ice	35	30 min., 2-12, 24 and 48 hrs.
10	" " " "	40	" " " "
11	" " " "	60	" " " "
12	45 min. slush ice	35	45 min., 2-12, 24 and 48 hrs.
13	" " " "	40	" " " "
14	" " " "	35	45 min., 48 hrs.
15	" " " "	40	" "
16	" " " "	35	" "
17	" " " "	40	" "
18	1 hour slush ice	35	1, and 48 hrs.

carcass skin was studied.

Experiment 20:

Twenty-four 8 to 10-week-old fryers were used in each of two treatments and three birds were used as controls. In Treatment A, the carcasses were chilled in slush ice for twelve hours and moisture analysis of the skin, muscle, and skin and muscle were determined at 1, 2, 3, 4, 6, 8, 10 and 12 hours. In Treatment B, the carcasses were initially placed in ice-pack and held at 60° F., and tissue moisture analysis determined as for Treatment A. A moisture analysis of the various carcass tissues was made of the control birds to estimate the initial moisture content of all carcasses used in both treatments.

Three carcasses from each treatment were selected at random for moisture analyses at the different sampling periods. Each carcass was blotted to an acceptable dryness¹ with paper toweling and a $\frac{1}{2}$ x $\frac{1}{2}$ -inch plug of skin and muscle was taken from the thickest portion of the pectoral muscles on each side of the breast. Each sample was taken so that the skin surface consisted of about equal areas of pectoral feather tract and the lateral trunk space. The skin was removed from one plug and the separate tissues used to estimate the moisture content of the skin and the muscle of the carcass. The combined tissues of the other plug were used to estimate the total carcass moisture content. The various tissues were re-weighed after drying at 100° C. in a hot air

¹ Uniform removal of the excess adhering water to a point where the carcass still had an appealing moist appearance.

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oven and the difference between the initial and final sample weights was taken as the moisture content of the various tissues.

Experiment 21:

Eighteen 8 to 10-week-old fryers were used in each of three treatments and three birds were evaluated to estimate the initial moisture content of all the birds used in the experiment. In Treatment A, the carcasses were chilled in slush ice for 30 minutes, drained, then ice-packed and held in a refrigerator maintained at 35° F. through 24 hours. In Treatments B and C, the carcasses were chilled in slush ice for 2 and 6 hours, respectively, then held under the same conditions as those in Treatment A. A random sample of three carcasses was taken from each treatment upon completion of the prescribed chilling period and at 2, 4, 6, 12 and 24 hours after chilling in slush ice. After treatment, each carcass was blotted to an acceptable dryness, packed in a Cryovac¹ bag which was sealed, identified, and then the packaged carcass was frozen in a 0° F. agitated propylene glycol-water mixture. The frozen carcasses were then held at 0° F. until subsequent moisture analyses of the skin, muscle, and total carcass were made.

Prior to moisture analysis, the packaged individual carcasses were partially thawed in cold running water, allowing the carcass skin to be removed readily. Each carcass was then removed from the bag and divided into two equal halves

¹ Manufactured by the Cryovac Division of W. R. Grace and Company, Simpsonville, South Carolina.

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using a band-saw. The skin was removed from one-half and placed in a Cryovac bag, after which the skinless half was sawed into chunks which were passed through a 1/8th-inch grinder plate for three times. The ground mass was placed in a separate Cryovac bag and sealed. The other half, with the skin on, was sawed into chunks, ground and packaged in the same manner. The skin from the first half was removed from its Cryovac bag and cut into small pieces with a knife, then replaced in the bag and sealed. Three 10-gram samples were taken from each mass of tissue or composite and their moisture content was determined by means of a Brabender apparatus. The samples were heated in the apparatus for six hours at 100° C.

Experiment 22:

Six 8 to 10-week-old broiler-fryers were sacrificed and the skin was removed from each carcass. Each carcass skin was then split in half between the two breast areas. A section of skin from one-half was kept intact, while the other half had an area over the pectoral feather tract and lateral trunk space scraped to remove the subcutaneous fat layer. The designated skin areas were then placed, exterior side out, over one open-end of specially prepared size 303 tin cans, secured with string and the excess skin sheared away. The loose edges of the skin and the securing string were then sealed with melted paraffin. The can plus skin section was weighed and then the exposed skin portion was immersed in slush ice. Observations were made at 1/2, 1, 1½, 2, 3, 4, 5, 6 and 7 hours regarding weight changes or evidence

of water passing through the skin.

RESULTS

The first three experiments were of a preliminary nature designed to evaluate the effect of length of chill, and ice-pack storage on carcass weight changes. It became evident that the critical period for evaluation of weight changes was during the first 24 hours of chilling and ice-pack storage. Due to the differences in weight changes between carcasses initially placed in ice-pack or slush ice chilled and held in ice-pack at room temperature, and those chilled and held in ice-pack at 35° F., observations on changes in carcass temperature were deemed necessary. Experiments 4 through 18 were conducted to determine the effects of various chilling times and holding room temperatures on changes in carcass weights and temperature. Experiment 19 was carried out to determine the maximum moisture uptake of broiler carcasses during slush ice chilling under laboratory processing procedures.

Since changes in carcass weights should be related to changes in carcass moisture content, it was theorized that such weight changes might be more closely associated with a change in the moisture content of one specific carcass tissue than another. The last three experiments were conducted to test this theory.

Changes in Carcass Weight and Temperature

Experiment 1:

Ten carcasses were used for each of four treatments. Fryers used for Treatment A were placed initially in ice-pack

and held in a refrigerator maintained at 35° F. Those for Treatments B, C, and D were chilled in slush ice for 2, 4, and 24 hours, respectively, before they were ice-packed and held at 35° F.

Figure 1 shows the weight changes of fryers chilled and held through 96 hours in a refrigerator maintained at 35° F. Carcasses held in slush ice for two hours increased in weight by an amount equal to 4.75 percent of their initial weight and those chilled for 4 and 24 hours increased by 5.19 and 8.31 percent, respectively. Initially ice-packed fryers continued to increase in weight during the entire 96-hour period at which time they had increased by 2.22 percent of their warm eviscerated weight. The greatest and most rapid loss in carcass weights, of the carcasses chilled in slush ice, occurred during the first 48 hours of the experiment, when their weights were 4.13, 3.78 and 6.11 percent greater than the warm eviscerated weights for carcasses chilled for 2, 4, and 24 hours, respectively. These data show that under the conditions of this experiment, when the maximum chilling time was 24 hours, the longer the chill time, the greater the increase in carcass weight and the greater the subsequent loss during ice-pack storage. This concurs with the findings of Fromm et al. (1958).

Experiment 2:

This experiment was similar to Experiment 1, the only difference was that the weighing intervals were reduced from 48 to 24 hours. Increases in carcass weights of 5.70, 6.12 and 8.95 percent were obtained during the respective chilling

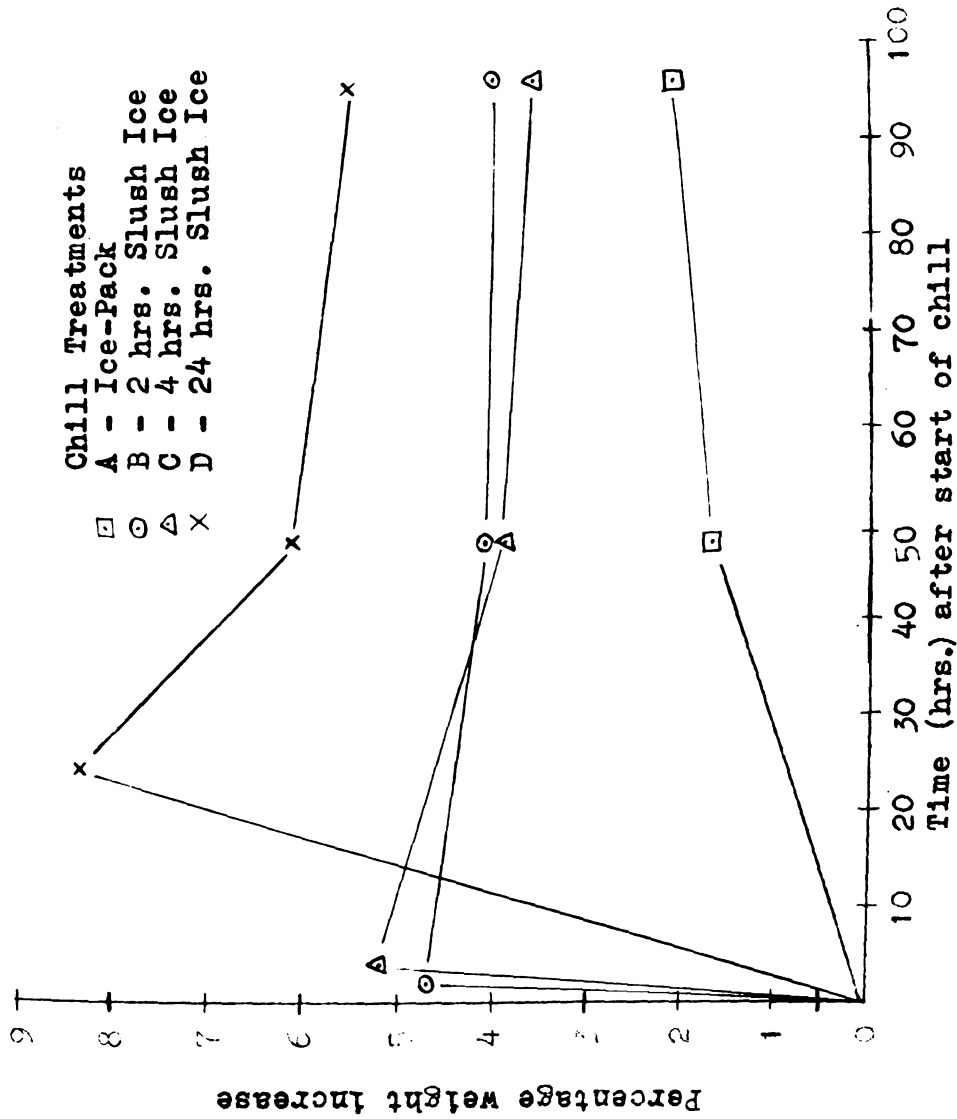


Figure 1: Weight change of fryers chilled under various conditions, and held in ice-pack at 35 F., to 96 hours. (Experiment 1).

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periods of 2, 4 and 24 hours (Figure 2).

The most rapid and largest percentage losses in weight, however, occurred during the first 24 hours of storage in ice-pack. Carcasses chilled for 2 and 4 hours had net increases in carcass weight of 3.80 and 3.40 percent at 24 hours, respectively, while those chilled for 24 hours had a net weight increase of 5.70 percent after having been ice-packed for 24 hours. However, in Experiment 2, carcass weights tended to stabilize after the 24th hour of the experiment rather than the 48th hour as shown in Experiment 1. This was demonstrated by net increases in carcass weights of 3.86, 2.75 and 4.09 percent for carcasses chilled for 2, 4 and 24 hours, respectively, at the 96th hour of the experiment. As in Experiment 1, carcasses initially ice-packed continued to increase in weight through 96 hours of holding at 35° F.

Experiment 3:

In this experiment, 10 carcasses were used for each of 5 treatments. The carcasses were initially packed in ice for treatment A, and were chilled in slush ice for 2, 4, 6 and 12 hours for treatments B, C, D and E, respectively.

The data plotted in Figure 3 show that carcass weights increased by 3.48, 3.94, 4.75 and 5.45 percent during the respective 2, 4, 6 and 12-hour slush ice chilling periods. However, it was found that carcass weights continued to increase during ice-pack holding at room temperature. At the termination of the experiment (96 hours), increases in carcass weights of 5.20, 6.29, 5.92, 5.95 and 5.90 percent were observed for carcasses initially ice-packed, or chilled in

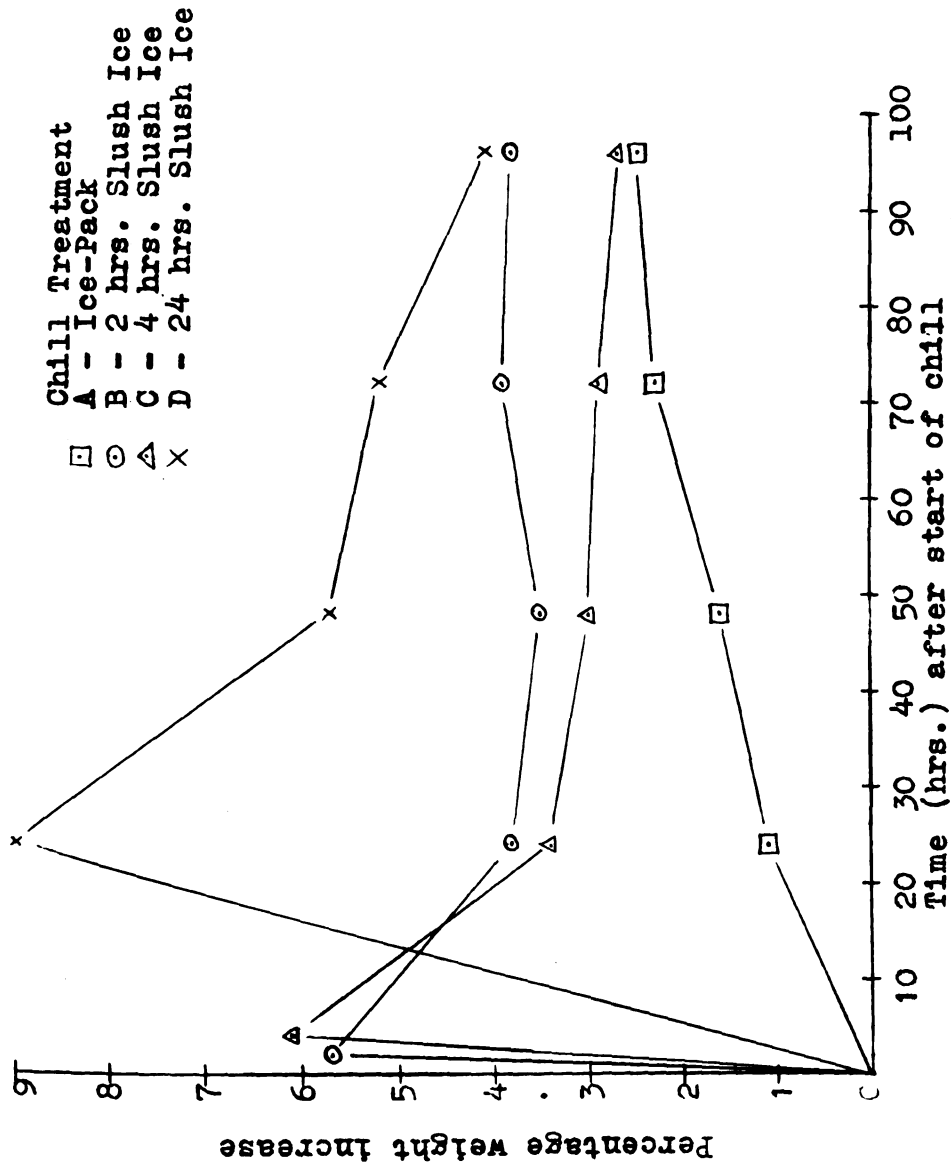


Figure 2: Weight change of fryers chilled under various conditions, and held in ice-pack at 35 F., to 96 hours. (Experiment 2).

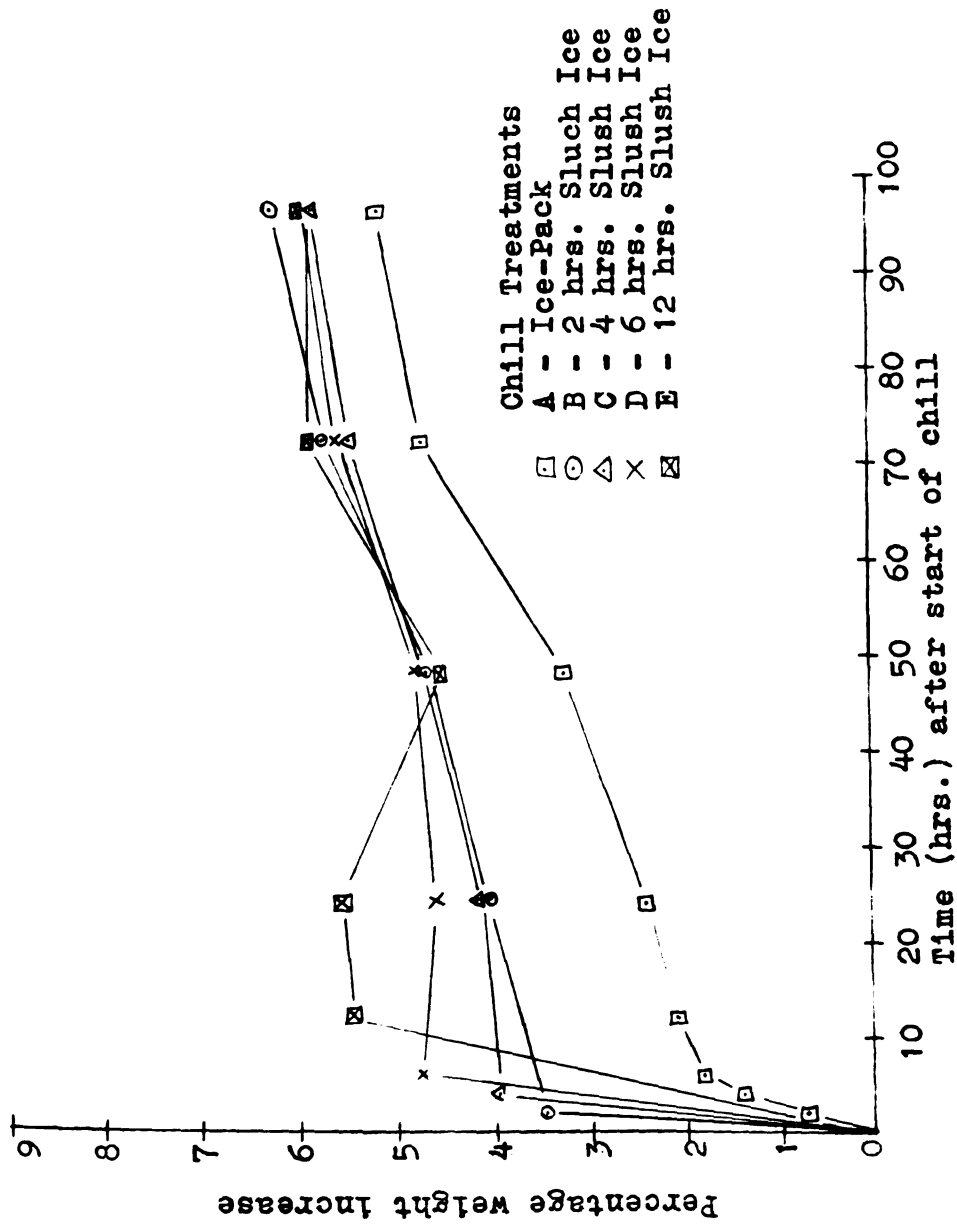


Figure 3: Weight change of fryers chilled under various conditions, and held in ice-pack at room temperature, to 96 hours. (Experiment 3).

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slush ice for 2, 4, 6 and 12 hours, respectively. The loss in weight that occurred between the 24th and 48th hours for carcasses chilled for 12 hours was due to complete melting of the ice surrounding those carcasses during that period of the experiment.

Experiment 4:

Two lots of twenty-four carcasses were used in Experiment 4 to determine the changes in internal carcass temperature and carcass weights when initially placed in ice-pack and held in a room maintained at 35° F. for 48 hours. The data are presented graphically in Figure 4. The average initial internal temperature of these carcasses was 63.5° F. and 17 hours of holding had elapsed before a low of 31.7° F. had been reached. This temperature was maintained for the next 8 hours of storage, after which it began to increase at a very slow rate to 32.2° F. at the conclusion of the 48-hour chilling and holding period. Carcass weights of birds in the second lot, chilled and held under similar conditions, increased by 1.10 percent of their initial weight after 24 hours and 1.66 percent after 48 hours of storage.

Experiment 5:

In this experiment, carcasses were initially placed in ice-pack in the same manner as those for Experiment 4 and held in a refrigerator maintained at 60° F. A minimum average carcass temperature of 37.8° F. was obtained after eight hours of storage, from an initial temperature of 73.9° F. (Figure 5). The average carcass temperature then increased gradually to 47.8° F. by the 24th hour, at which time the

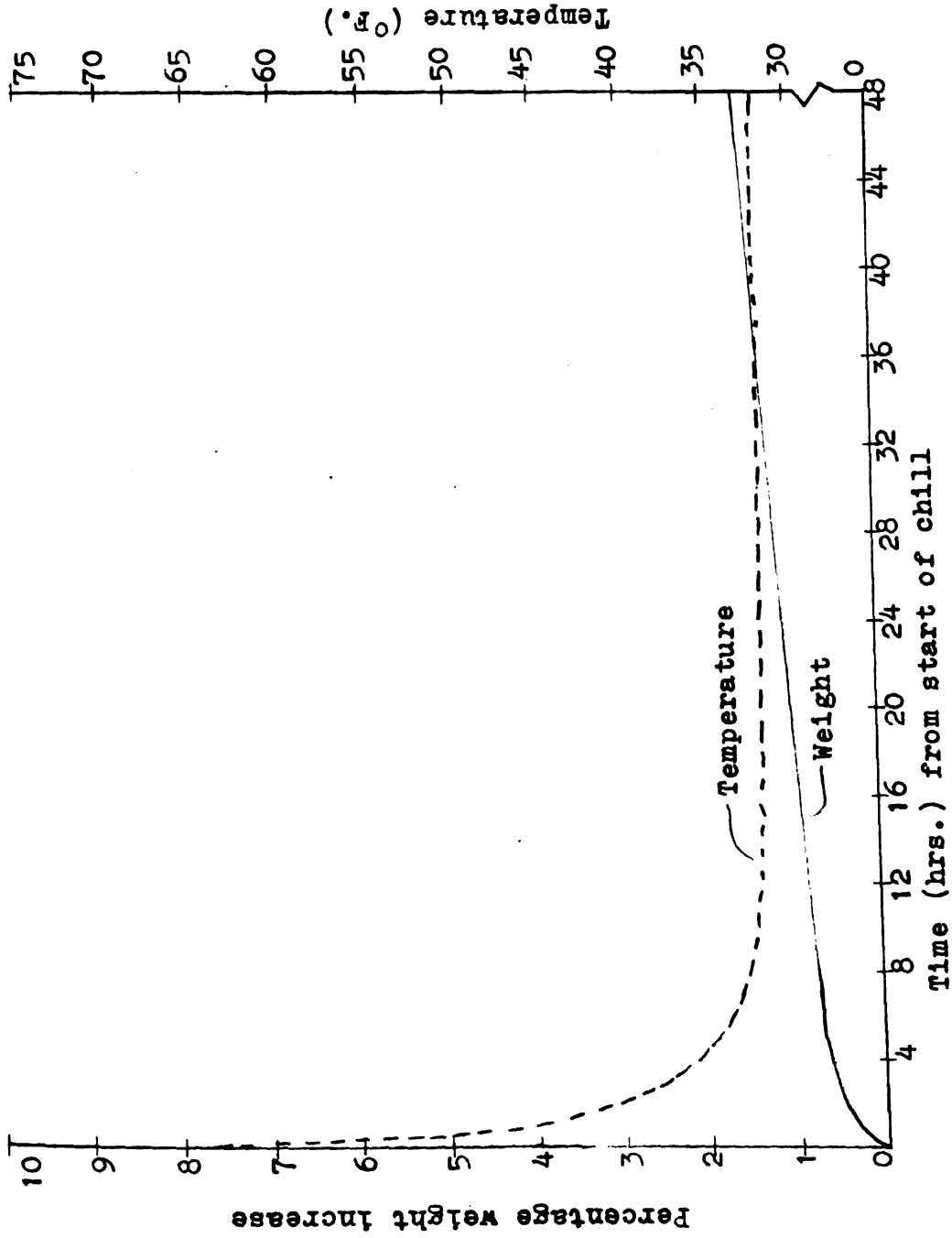


Figure 4: Weight change and average carcass temperature of fryers initially placed in ice-pack and held at 35 F., to 48 hours. (Experiment 4).

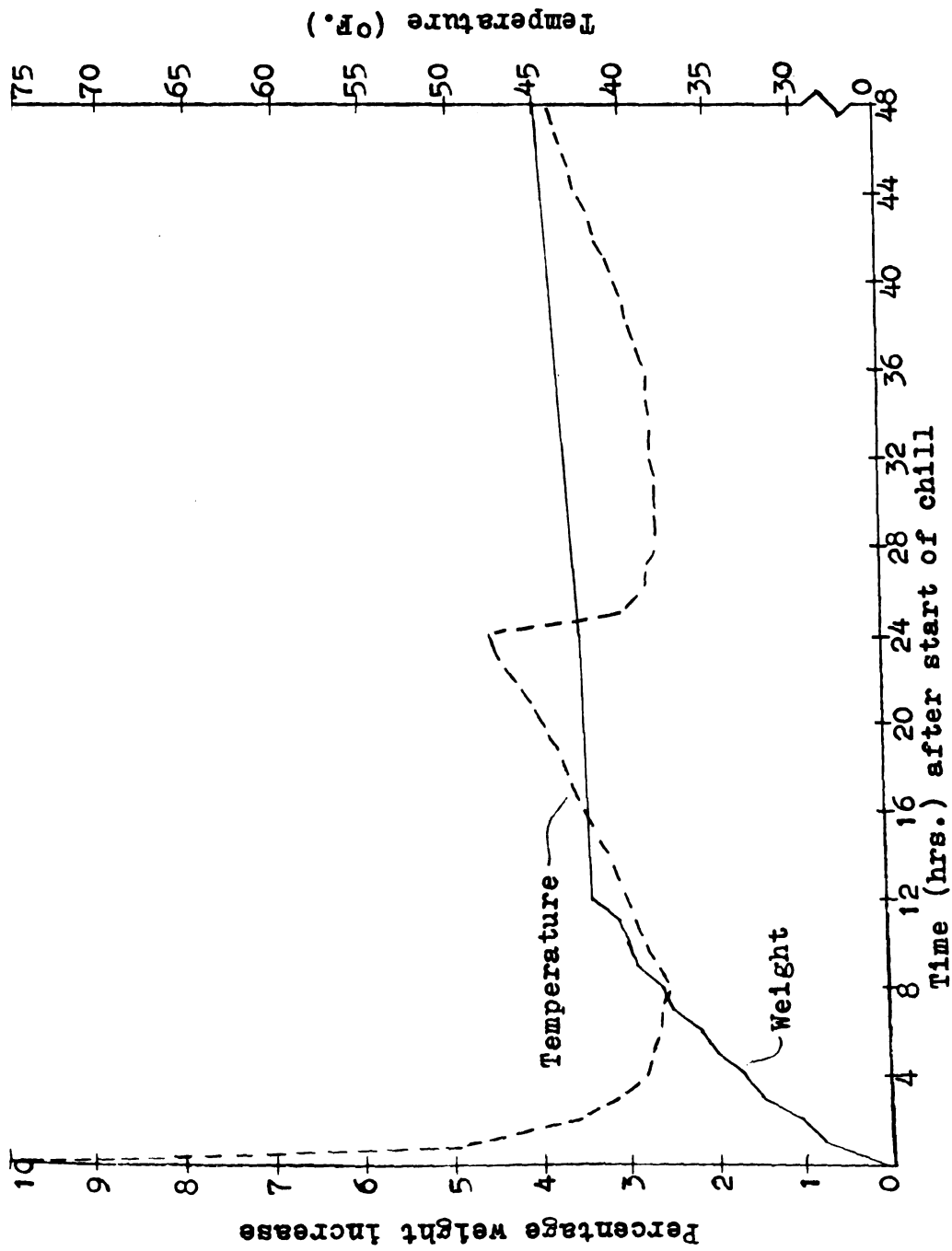


Figure 5: Weight change and average carcass temperature of fryers initially ice-packed and held at 60 F., to 48 hours. (Experiment 5).

carcasses were re-iced. The average carcass temperature declined to 37.9° F. in five hours then increased again until it reached 44.0° F. after 48 hours of storage at 60° F. Similar carcasses held under these conditions increased in weight by 3.40, 3.52 and 4.00 percent after 12, 24 and 48 hours of storage, respectively.

Experiment 6:

In this experiment, two lots of birds with an average weight of 2.32 pounds were used to evaluate the effect on carcass weight and temperature changes of two hours of slush ice chilling and ice-pack storage in a refrigerator maintained at 35° F. One lot of birds was used for weight change evaluations, and the other for changes in average internal temperature. The average initial temperature declined from 72.3° F. to 33.3° F. during the two-hour chill period (Figure 6). By the eleventh hour of the experiment (2 hours in slush ice plus 9 hours in ice-pack), a minimum temperature of 31.5° F. was reached and this temperature was maintained through the 38th hour. During the remaining ten hours of the experiment, the average carcass temperature gradually increased to 31.9° F.

During the chill period, similar carcasses had a 5.15 percent increase in weight. After four hours of storage in ice-pack the birds had lost weight so that the net increase in weight was only 4.17 percent of the initial carcass weight. Carcass weights began to increase gradually at this point, with the result that the net increase in weight after 14 hours was equal to 4.36 percent of the initial warm eviscer-

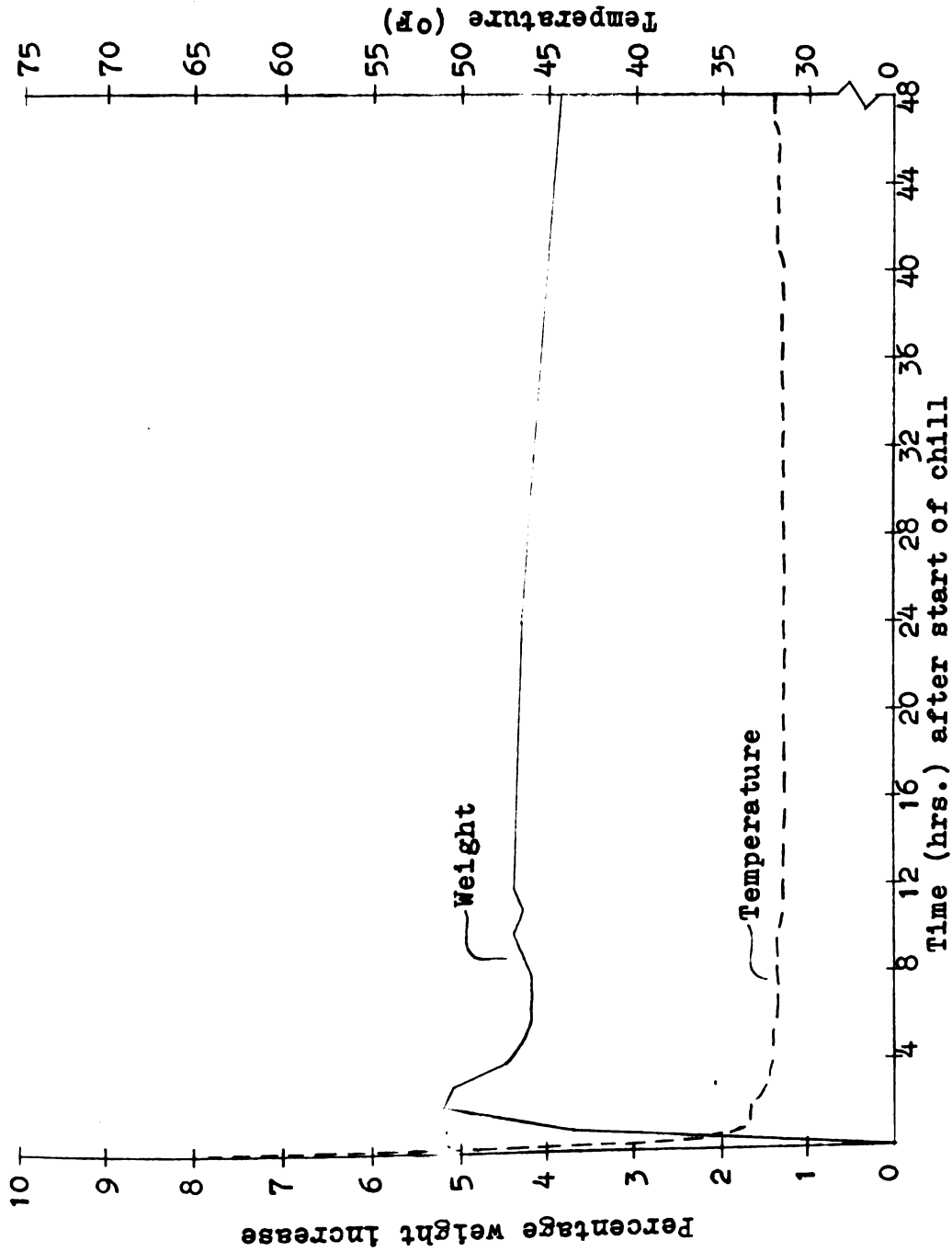


Figure 6: Weight change and average carcass temperature of fryers chilled in slush ice for 2 hours, placed in ice-pack and held at 35 F., to 48 hours. (Experiment 6).

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ated weight. During the remaining 36 hours of the experiment the carcasses gradually lost weight, which resulted in a final net increase in weight of 3.88 percent.

Experiment 7:

Carcasses with an average weight of 3.19 pounds were chilled in the same manner as those in Experiment 6 and held in ice-pack in a refrigerator maintained at 40° F. Those carcasses used for temperature evaluations had a decrease in average temperature from 66.4° F. to 34.0° F. during the chill period of two hours (Figure 7), however, the lowest average internal temperature of 33.6° F. was not reached until the fifth hour of the experiment. The average carcass temperature then began to increase gradually until a temperature of 34.5° F. was attained at the completion of the experiment.

The carcasses from which the weight change data were obtained increased in weight by 2.91 percent during the chill period, then decreased to 2.54 percent of their warm eviscerated weight by the fifth hour. A gradual increase in weights was observed after this time so that the net increase in weight was 2.77, 2.76 and 2.95 percent at 12, 24 and 48 hours, respectively.

Experiment 8:

This experiment was conducted utilizing the same chilling procedures as for Experiments 6 and 7, using carcasses with an average weight of 2.64 pounds and holding them in ice-pack in a refrigerator maintained at 60° F. During the two-hour chill period (Figure 8) the average carcass temp-

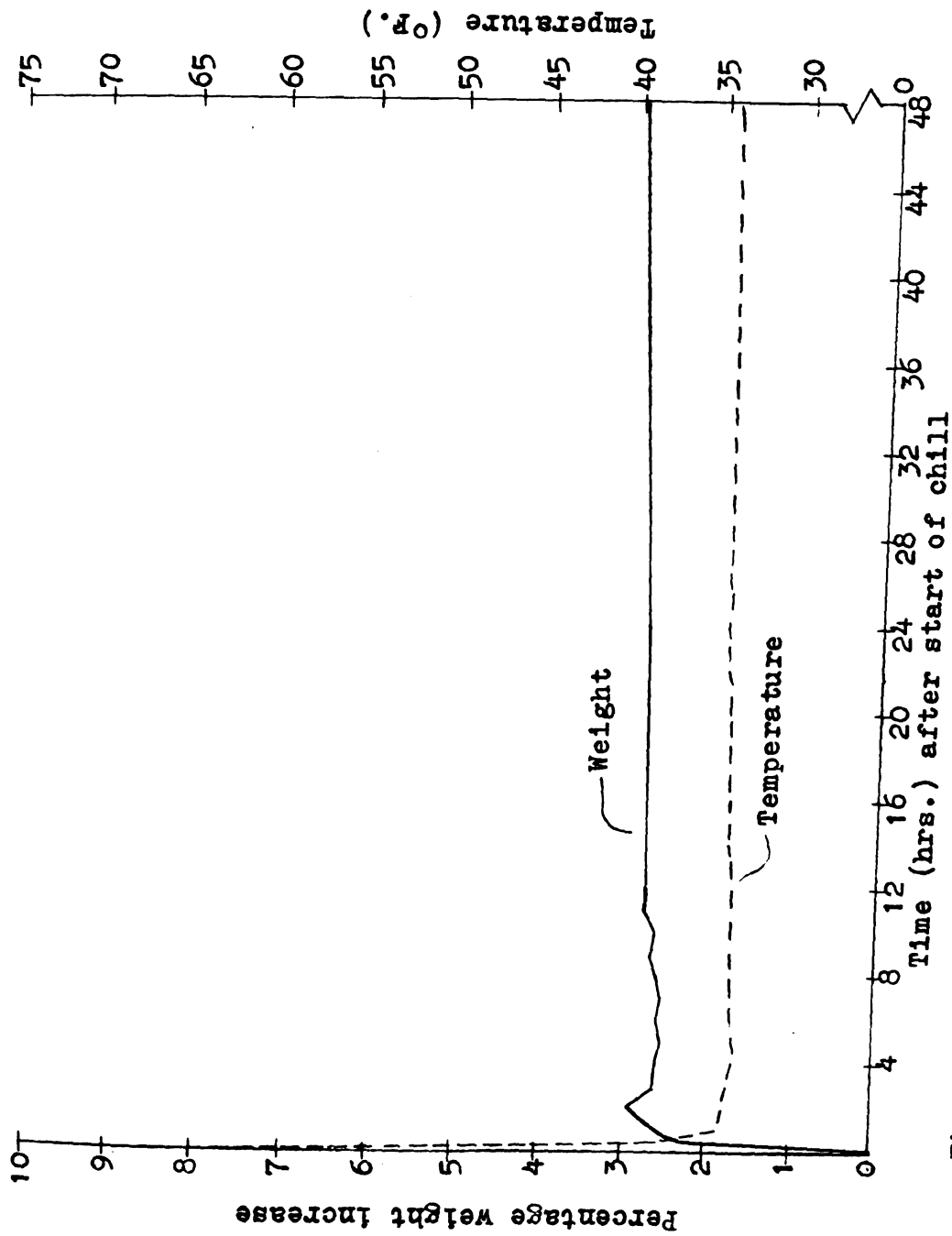


Figure 7: Weight change and average carcass temperature of fryers chilled in slush ice for 2 hours and held in ice-pack at 40 F., to 48 hours. (Experiment 7).

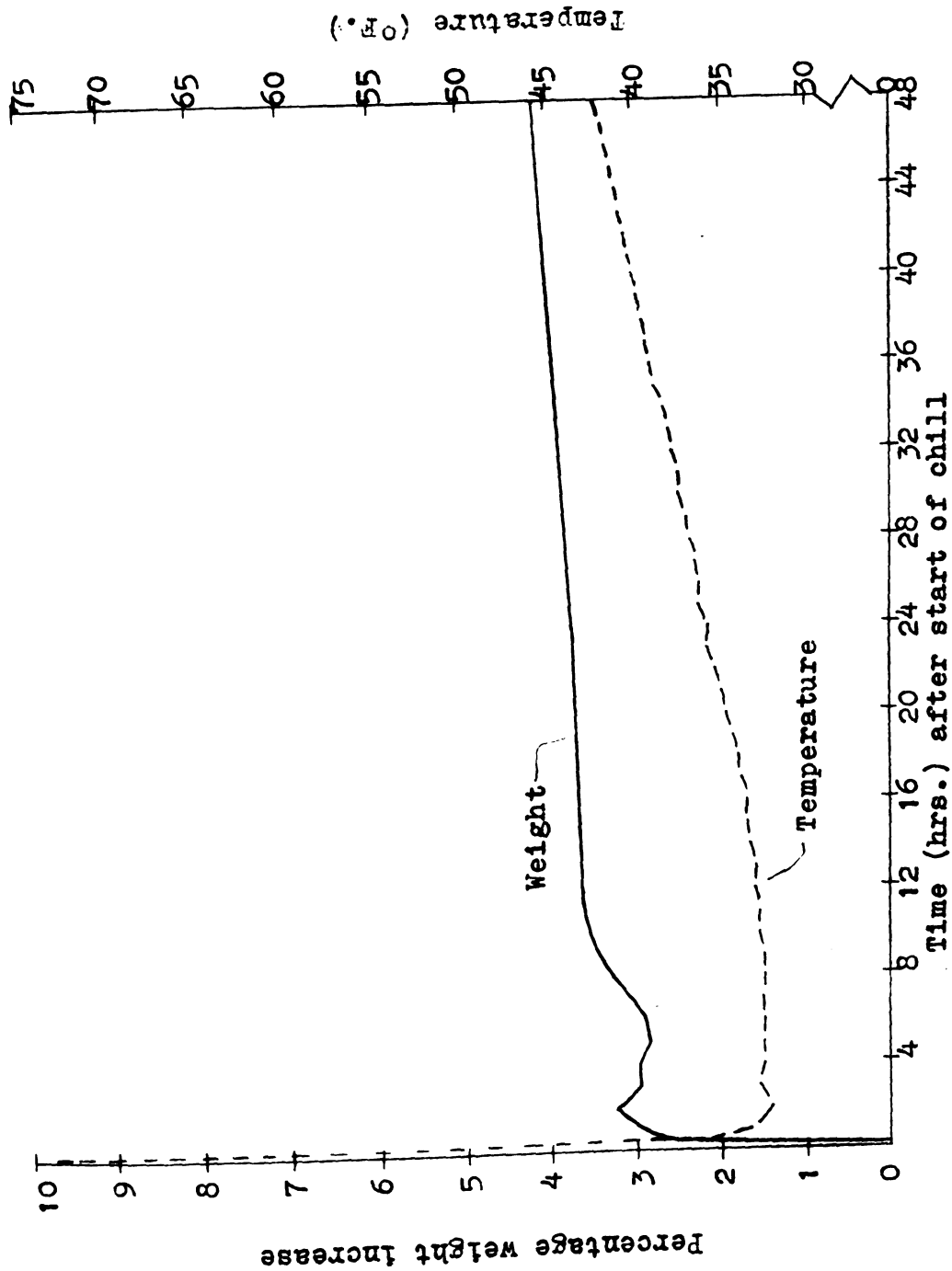


Figure 8: Weight change and average carcass temperature of fryers chilled in slush ice for 2 hours, placed in ice-pack and held at 60 F., to 48 hours. (Experiment 8).

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erature declined from 73.9° F. to 32.0° F. At this point, the carcass temperature began to increase until a temperature of 41.9° F. was reached at the termination of the 48-hour experiment.

During the chill period carcass weights increased by 3.25 percent and subsequently declined to 2.86 percent by the fifth hour of the experiment. After the sixth hour, carcass weights increased rapidly through the twelfth hour. From the twelfth hour through the 48th hour carcass weights increased gradually from 3.64 percent to 4.14 percent, respectively.

Experiment 9:

Two lots of carcasses, with an average weight of 2.81 pounds, were used to separately evaluate changes in carcass weights and average internal temperatures. The carcasses were chilled for 30 minutes in slush ice, placed in ice-pack and stored in a refrigerator held at 35° F. Figure 9 shows that the average carcass temperature decreased from 63.5° F. to 42.5° F. during the 30-minute chill in slush ice. By the fourth hour the temperature was 31.5° F. and remained there for the duration of the experiment.

Carcass weights increased by 2.60 percent during chilling and decreased to 2.34 percent by the second hour of the experiment. After the fourth hour carcass weights increased rapidly through the eighth hour to 2.95 percent of the initial carcass weights. From the twelfth through the 48th hour the carcass weights increased gradually to 3.04 percent of their warm eviscerated weight.

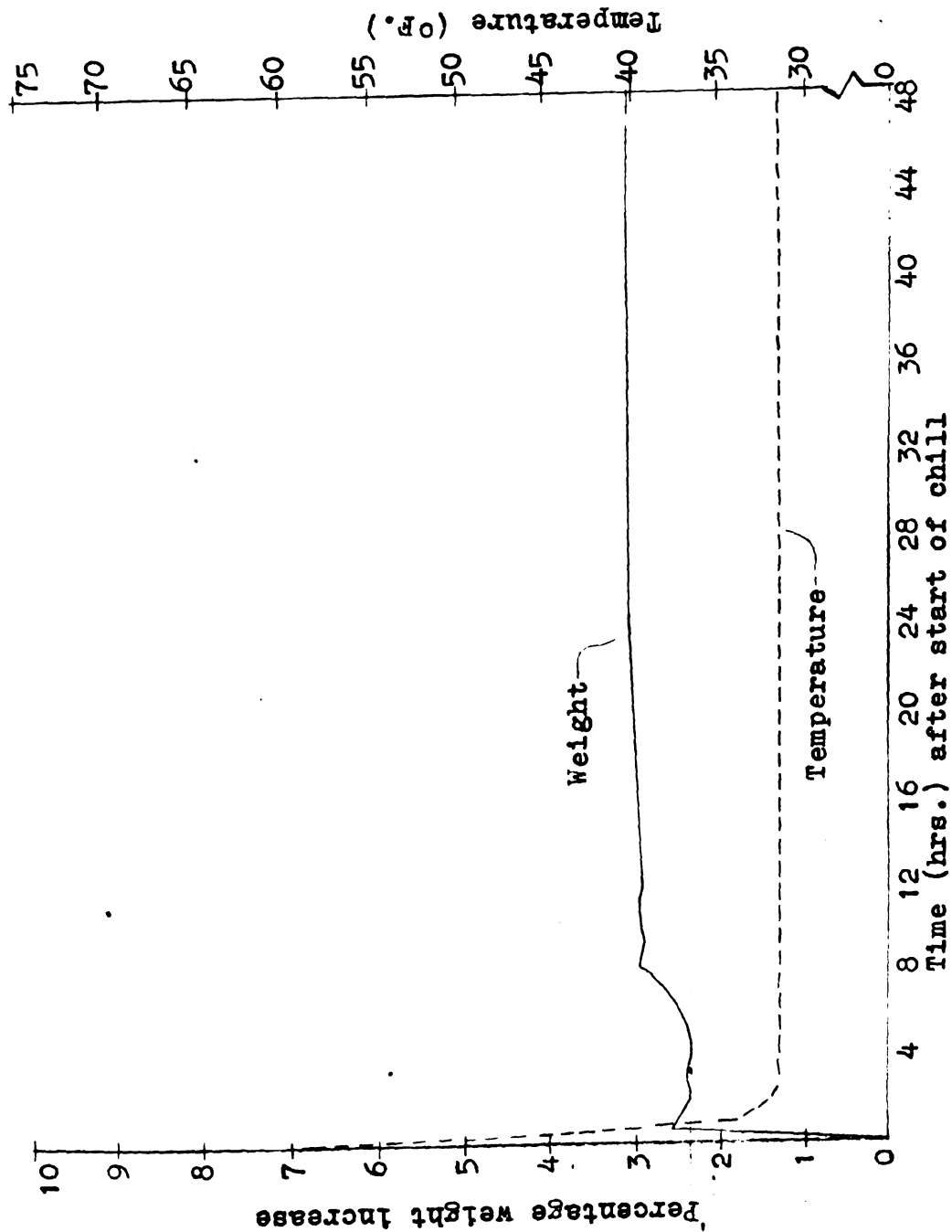


Figure 9: Weight change and average carcass temperature of fryers chilled in slush ice for 30 minutes and held in ice-pack at 35 F., to 48 hours. (Experiment 9).

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Experiment 10:

In this experiment carcasses were chilled as in Experiment 9, but were held in ice-pack at 40° F. rather than 35° F. The Average weight of the carcasses was 3.07 pounds. The carcasses increased in weight during the 30-minute chill period by 2.29 percent (Figure 10), then declined to 1.97 percent by the third hour of the experiment. From this point the carcass weights increased rapidly through the twelfth hour to 2.86 percent of their initial weight. A gradual weight increase was observed through the duration of the experiment when the net increases in carcass weights were 2.91 and 3.12 percent at 24 and 48 hours, respectively.

The average internal carcass temperature declined from 80.0° F. to 45.9° F. during the 30-minute chill period and reached a low of 35.1° F. by the 24th hour of the experiment. During the next 24 hours there was a very slight increase in average carcass temperature to 35.2° F.

Experiment 11:

The fryer carcasses in this experiment had an average weight of 2.32 pounds and were chilled in the same manner as those in Experiments 9 and 10, and after being placed in ice-pack were held in a refrigerator maintained at 60° F. A 3.04 percent increase in carcass weights was observed after 30 minutes of slush ice chilling (Figure 11). Carcass weights increased by 3.61 percent through the 12th hour, after which there was a slight decrease to 3.56 percent through the 24th hour of the experiment. There was a gradual increase in carcass weights to the 48th hour when the net increase in

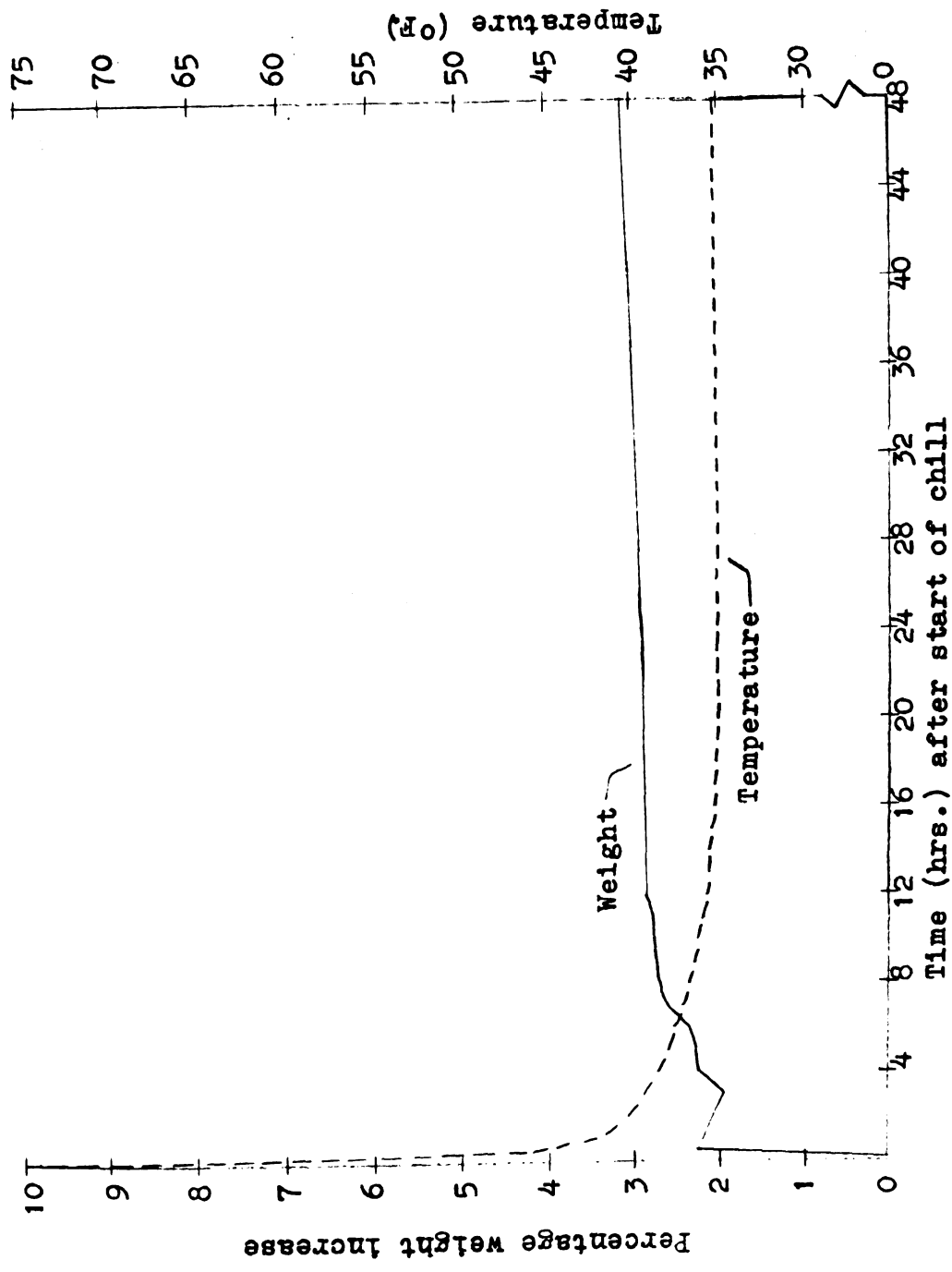


Figure 10: Weight changes and average carcass temperature of fryers chilled in slush ice for 30 minutes, and held in ice-pack at 40 F., to 48 hours. (Experiment 10).

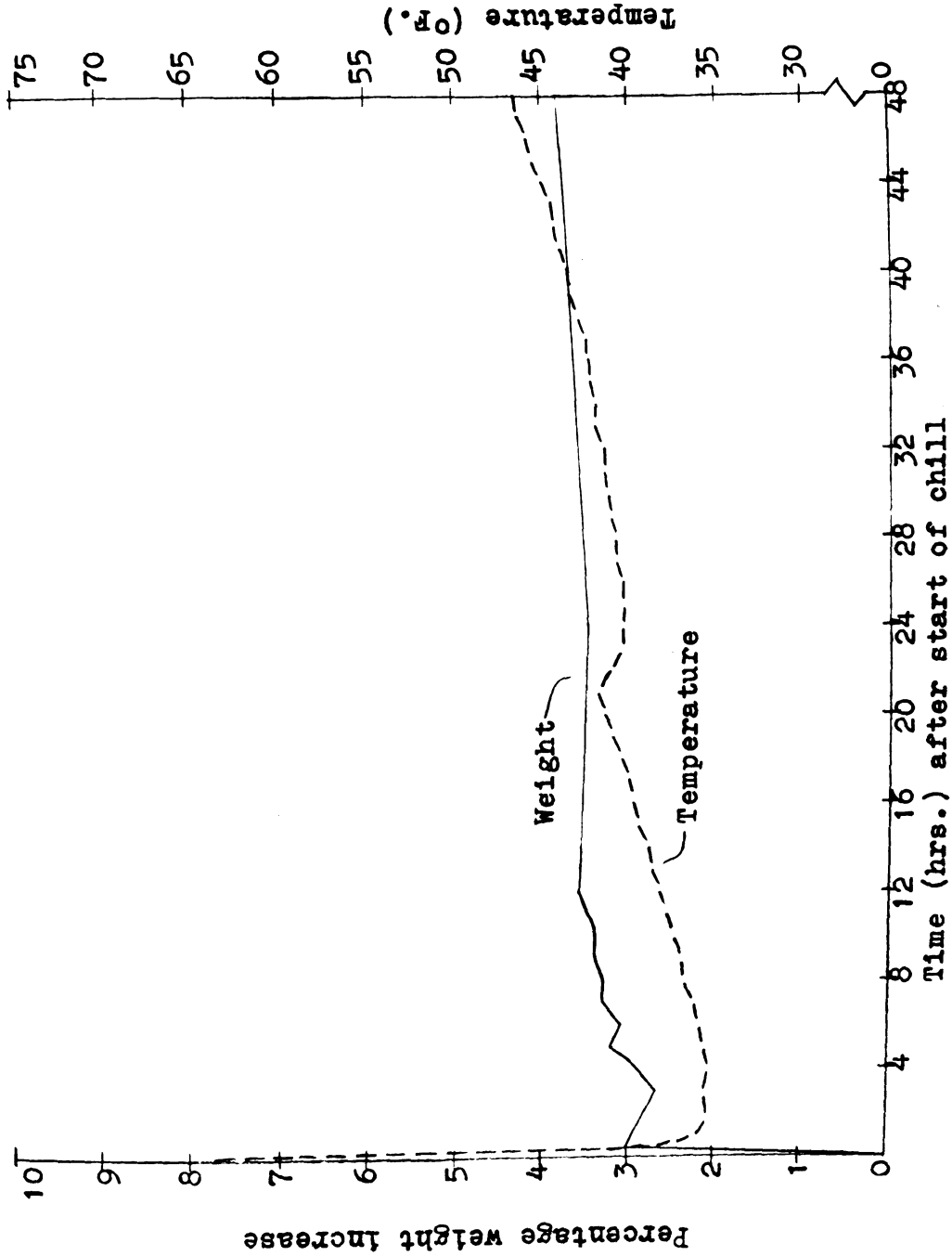


Figure 11: Weight change and average carcass temperature of fryers chilled in slush ice for 30 minutes, and held in ice-pack at 60 F., to 48 hours. (Experiment 11).

carcass weights was 3.84 percent of the initial weight.

The average internal carcass temperature declined from 72.3° F. to 36.9° F. after the carcasses were chilled for 30 minutes. A low of 35.5° F. was obtained by the second hour, after which the average internal temperature increased to 41.8° F. by the 21st hour of the experiment. The carcasses were re-iced and the average carcass temperature declined to 40.5° F. in three hours, then increased to 46.6° F. by the termination of the experiment.

Experiment 12:

Fryer carcasses were chilled for 45 minutes in slush ice and placed in ice-pack before storage in a refrigerator maintained at 35° F. The average carcass weight was 1.91 pounds for the two lots of birds used separately to evaluate the effect of the above conditions on carcass weight and internal temperature changes. Those carcasses used to determine weight changes had a 2.96 percent increase in weight during the chill period (Figure 12). Carcasses decreased in weight to 2.45 percent by the third hour and then increased gradually to 2.79 percent by the 48th hour, at which time the experiment was terminated.

The average carcass temperature declined from 74.3° F. to 34.8° F. during the chill period and reached a low of 32.8° F. by the tenth hour. This temperature was maintained through the 15th hour and then increased to 33.0° F. by the 19th hour, where it remained for the duration of the experiment.

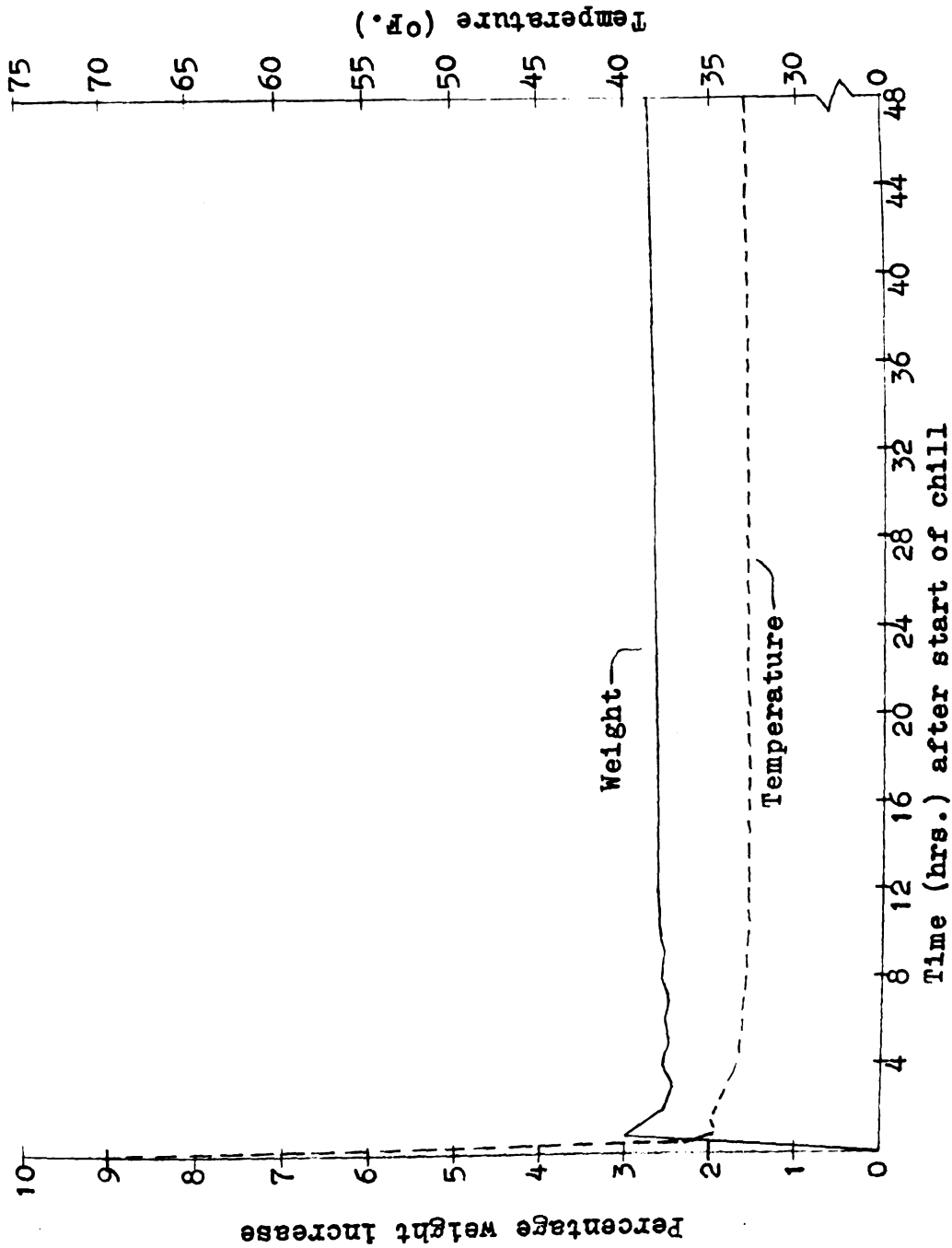


Figure 12: Weight change and average carcass temperature of fryers chilled in slush ice for 45 minutes, and held in ice-pack at 35 F., to 48 hours. (Experiment 12).

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Experiment 13:

This experiment was conducted using carcasses with an average weight of 1.81 pounds and chilling them in the same manner as those in Experiment 12. The chilled carcasses were placed in ice-pack and held in a refrigerator maintained at 40° F. The average carcass temperature decreased from 76.6° F. to 34.2° F. during the 45-minute chill period (Figure 13), and reached a low of 32.9° F. by the 13th hour. The carcass temperature then increased gradually to 33.7° F. at the conclusion of the experiment.

Carcass weights increased by 2.79 percent during chilling after which they decreased to 2.37 percent by the sixth hour. They remained relatively steady through the ninth hour then increased to 2.50 percent by the tenth hour. From the 24th hour through the 48th hour, carcass weights increased to 2.92 percent of their warm eviscerated weight.

Experiment 14:

Carcasses averaging 2.09 pounds were used for both carcass weight and temperature change evaluations in this experiment. Carcasses were chilled for 45 minutes in slush ice, placed in ice-pack and held in a refrigerator maintained at 35° F. During the 45-minute chill period, the average internal carcass temperature declined from 73.4° F. to 34.8° F. (Figure 14), and reached a low of 32.8° F. by the tenth hour. The average carcass temperature increased gradually to 33.00° F. by the 19th hour, where it remained to the termination of the experiment at 48 hours.

There was a 2.89 percent increase in carcass weights

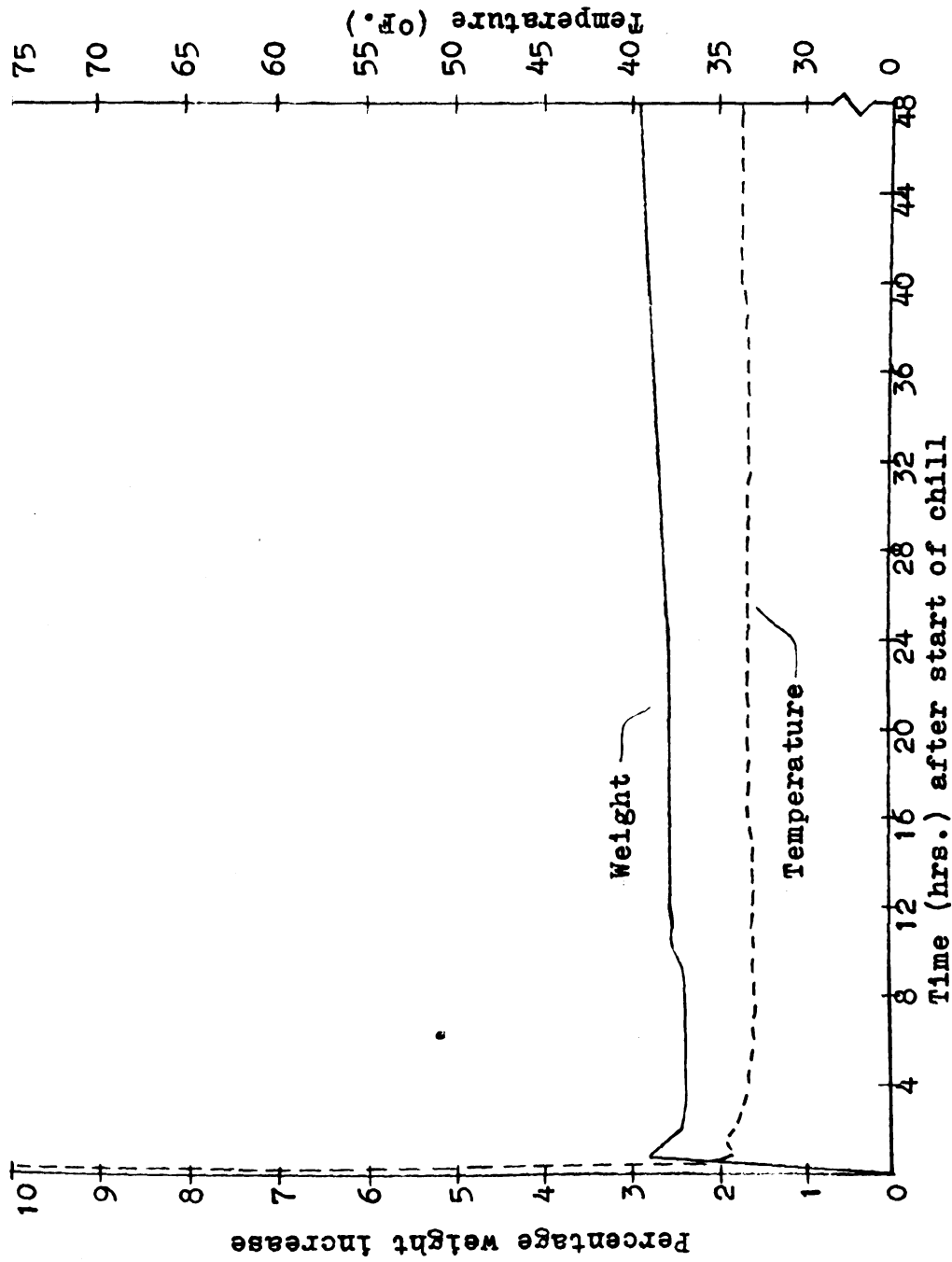


Figure 13: Weight change and average carcass temperature of fryers chilled in slush ice for 45 minutes and held in ice-pack at 40 F., to 48 hours. (Experiment 13).

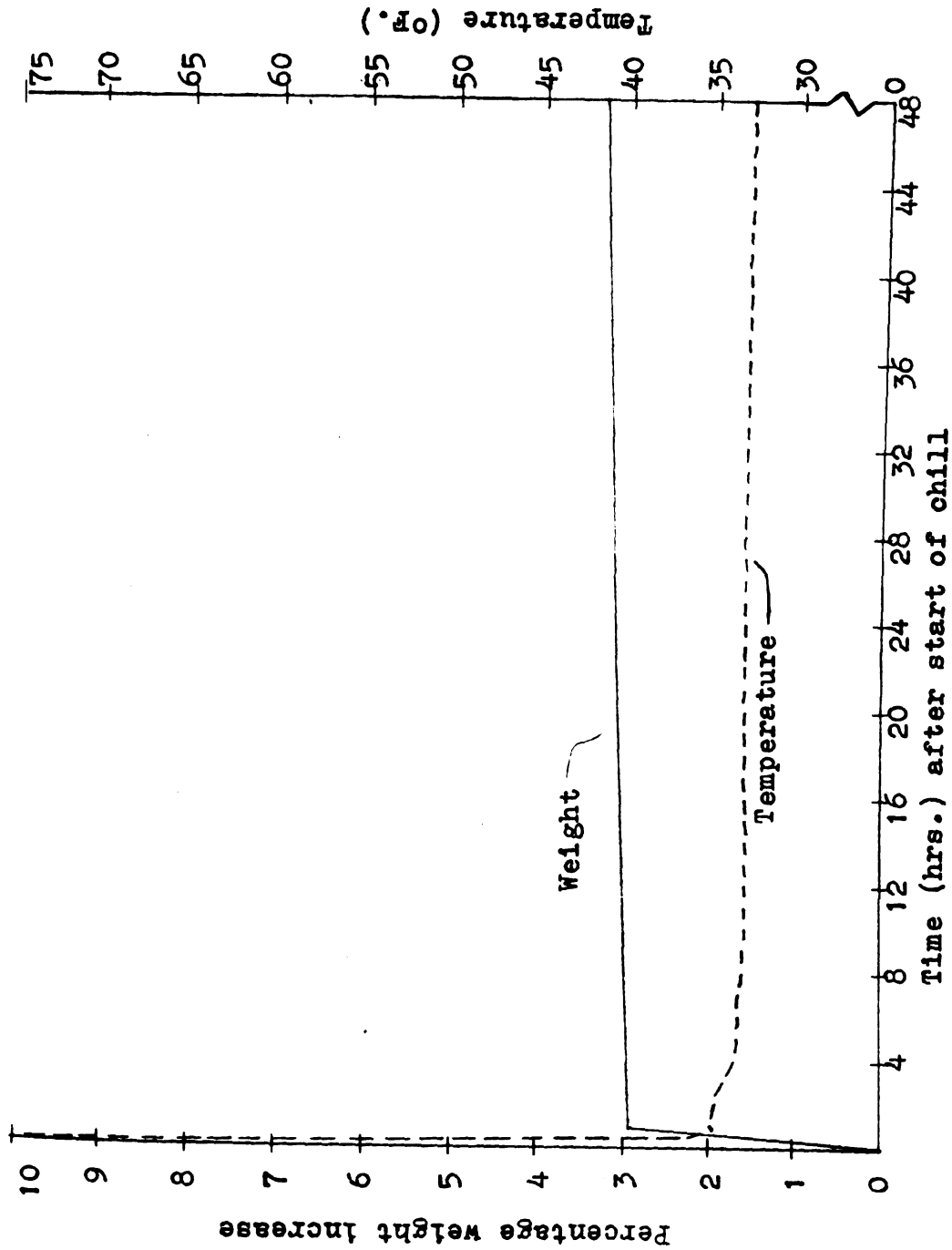


Figure 14: Weight change and average carcass temperature of fryers chilled in slush ice for 45 minutes, and held in ice-pack at 35 F., to 48 hours. (Experiment 14).

during the chill period, with a net percent increase of 3.31 percent at the termination of the experiment.

Experiment 15:

The carcasses in Experiment 15 had an average weight of 2.02 pounds and were chilled in the same manner as those for Experiment 14 and were held in ice-pack in a refrigerator maintained at 40° F. Carcass weights increased by 2.04 percent (Figure 15) when they were chilled in slush ice for 45 minutes. The net percent increase in carcass weights was 3.08 percent at the termination of the 48-hour experiment.

During the chill period the average carcass temperature declined from 76.6° F. to 34.3° F. and a low of 32.9° F. was observed at the 13th hour. The carcass temperature then increased gradually to 33.7° F. at the termination of the experiment.

Experiment 16:

This experiment was conducted using chilling conditions similar to those used for Experiment 14. The average carcass weight was 2.33 pounds. A 1.87 percent increase in carcass weights occurred during the 45-minute chill period (Figure 16). At the conclusion of the 48-hour experiment, carcass weights had increased by 2.09 percent.

After the 45-minute chill period, the average carcass temperature had declined from 74.5° F. to 35.4° F. The carcass temperature reached a low of 32.9° F. by the 22nd hour, then fluctuated between 32.9° F. and 33.0° F. for the remainder of the experiment.

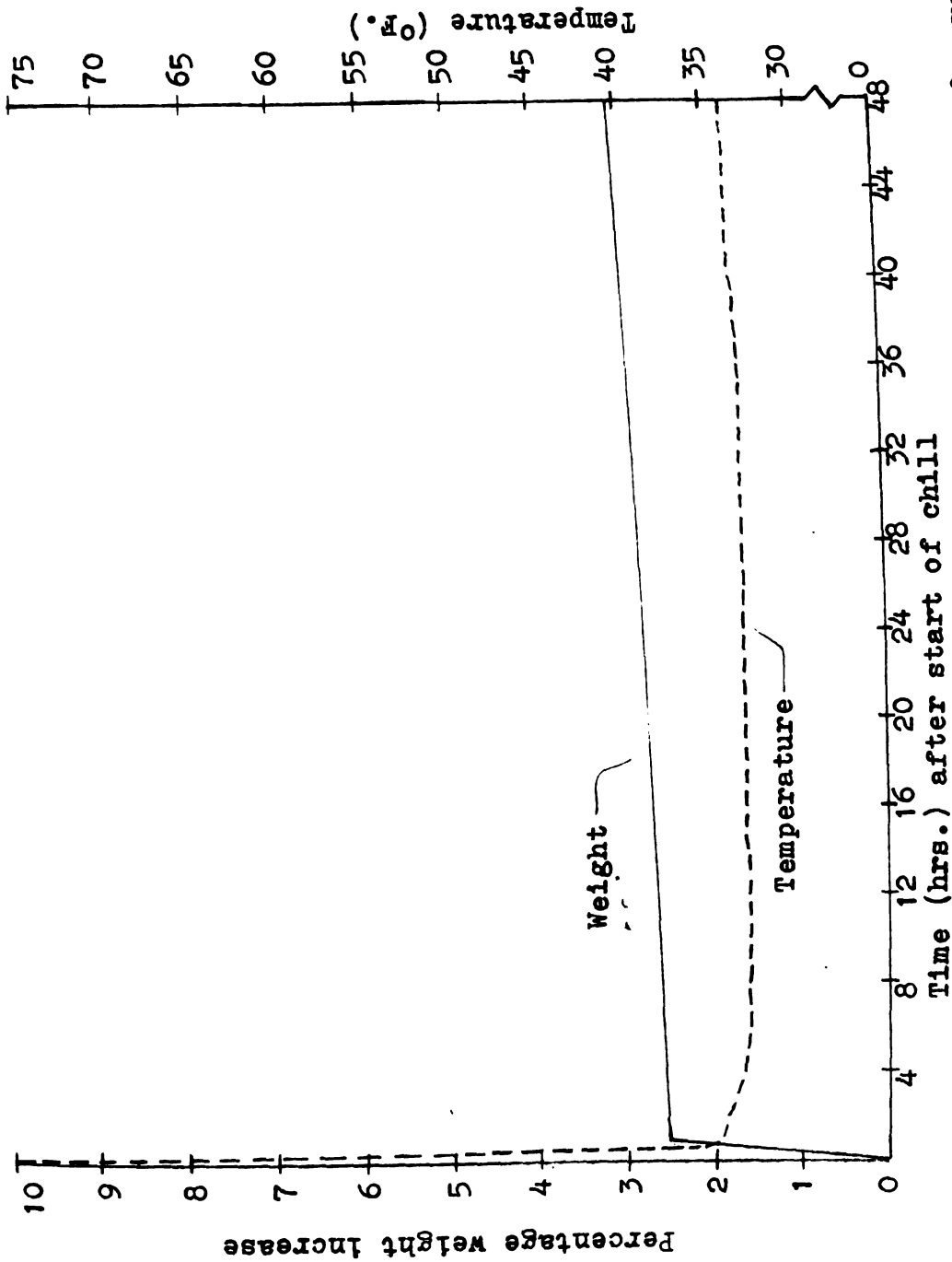


Figure 15: Weight change and average carcass temperature of fryers chilled in slush ice for 45 minutes, and held in ice-pack at 40 F., to 48 hours. (Experiment 15).

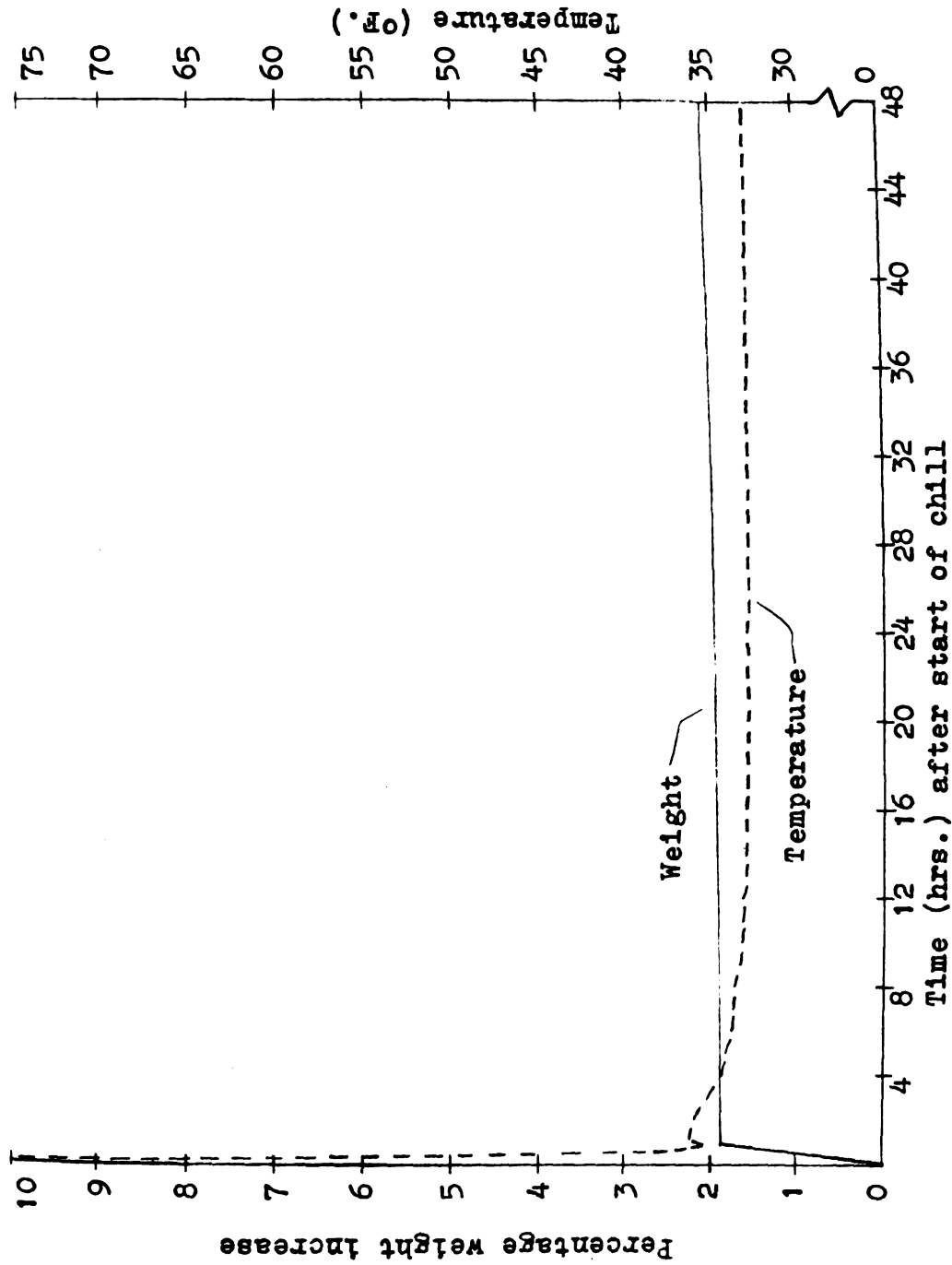


Figure 16: Weight change and average carcass temperature of fryers chilled in slush ice for 45 minutes, and held in ice-pack at 35 F., to 48 hours. (Experiment 16).

Experiment 17:

Carcasses with an average weight of 2.30 pounds were used to determine the weight and temperature changes of fryers chilled for 45 minutes in slush ice, placed in ice-pack and stored in a refrigerator maintained at 40° F. The carcasses increased in weight by 2.31 percent during the chill period, (Figure 17) and had a net percent increase in weight of 2.81 percent by the close of the 48-hour experiment. The average carcass temperature decreased from 74.5° F. to 36.9° F. during the chill period and reached a low of 34.0° F. by the 13th hour. By the termination of the experiment, the average carcass temperature had increased to 35.4° F.

Experiment 18:

Carcasses were chilled for one hour in slush ice and then transferred to ice-pack and stored in a refrigerator maintained at 35° F. They had an average weight of 2.85 pounds. Figure 18 shows that the carcasses increased in weight, during the chill period, by 2.46 percent. The net increase in weight was 2.58 percent at the conclusion of the 48-hour experiment. During the chill period, the average carcass temperature decreased from 83.8° F. to 35.4° F., a low temperature of 33.5° F. was observed at the 12th hour and this temperature was maintained throughout the remainder of the experiment.

Experiment 19:

This experiment was conducted to determine the maximum level of water absorption for carcasses held for a prolonged period of time in slush ice. Twenty carcasses, 10 with the

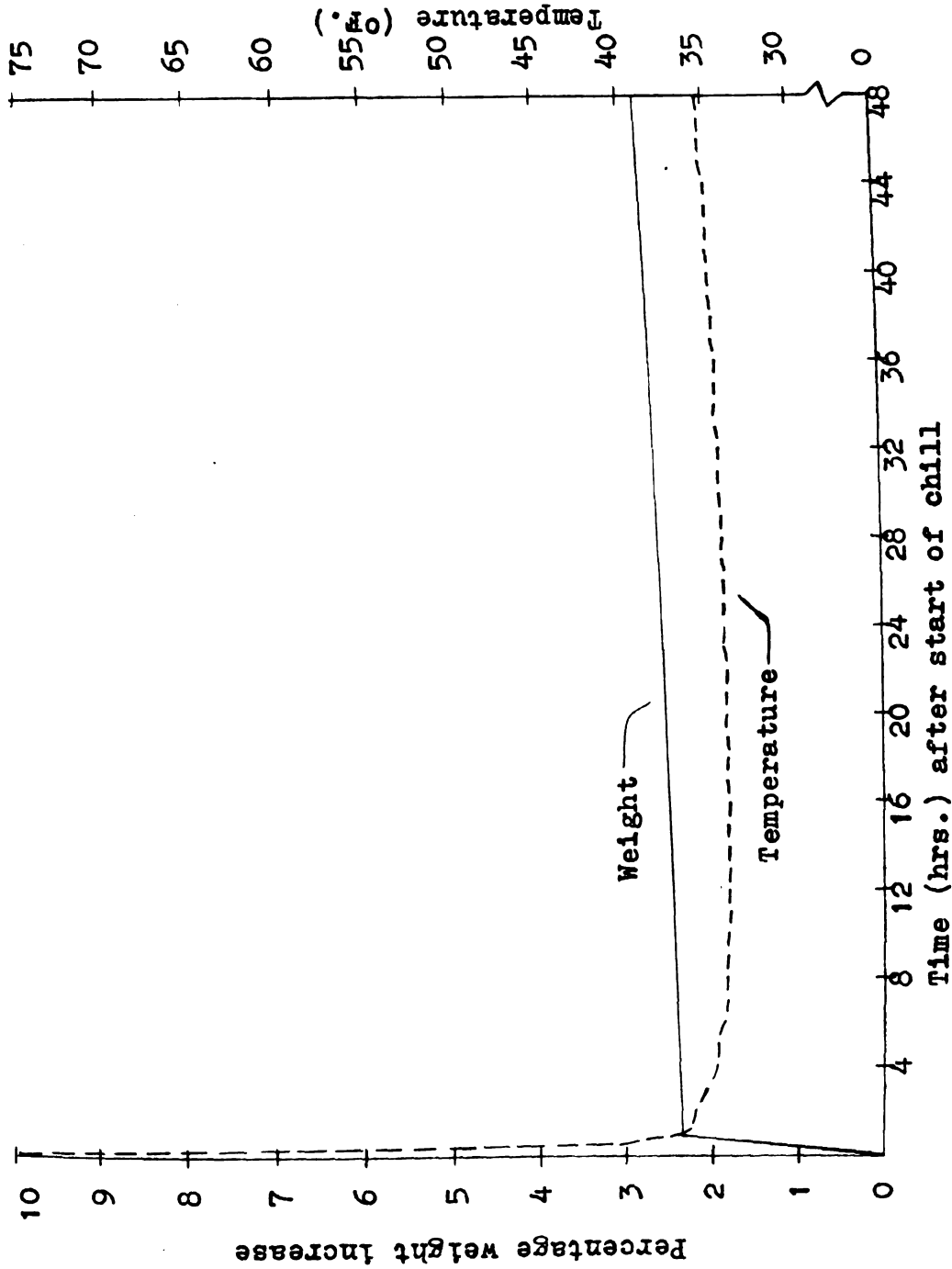


Figure 17: Weight change and average carcass temperature of fryers chilled in slush ice for 45 minutes, and held in ice-pack at 40 F., to 48 hours. (Experiment 17).

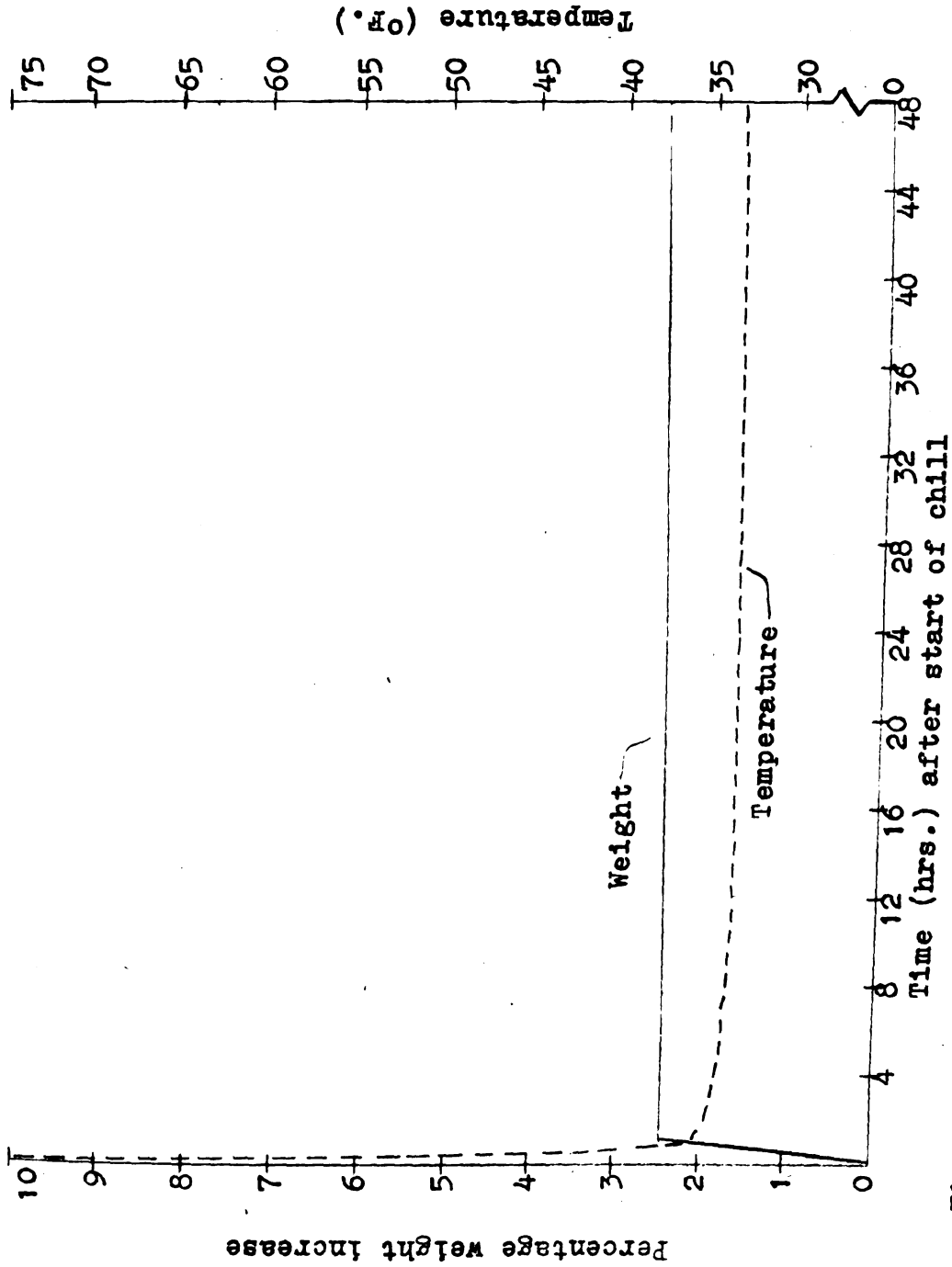


Figure 18: Weight change and average carcass temperature of fryers chilled in slush ice for 1 hour, and held in ice-pack at 35 F., to 48 hours. (Experiment 18).

giblets in the body cavity, Treatment A, and 10 without giblets, Treatment B, were subjected to 120 hours of slush ice chilling. Hourly weights were taken for the first 12 hours, then at 24, 48, 72 and 120 hours during the experiment.

The rate at which water was taken up was very rapid during the first 12 hours in both treatments. During this portion of the experiment, carcass weights had increased by 16.0 and 13.75 percent for Treatments A and B, respectively (Figure 19). From the 12th to the 72nd hour the rate of weight increase was reduced, with net increases of 30.90 and 26.80 percent obtained after 72 hours for the respective Treatments A and B. A slight decrease in carcass weights occurred in fryers for Treatment A between the 72nd and 120th hours, resulting in a net increase in carcass weights of 29.9 percent. However, during this period of time, the carcasses in Treatment B increased slightly in weight, resulting in a net increase in weight of 27.8 percent after 120 hours of slush ice chilling.

Water Transfer

Three experiments were conducted in an attempt to associate the change in carcass weights with a change in moisture content of various carcass tissues as follows:

Experiment 20:

In Experiment 20, carcasses were slush ice chilled for 12 hours, Treatment A, or held in ice-pack at 60° F., Treatment B. As shown in Figure 20, the average moisture content of the skin of carcasses in Treatment A increased from 46.54

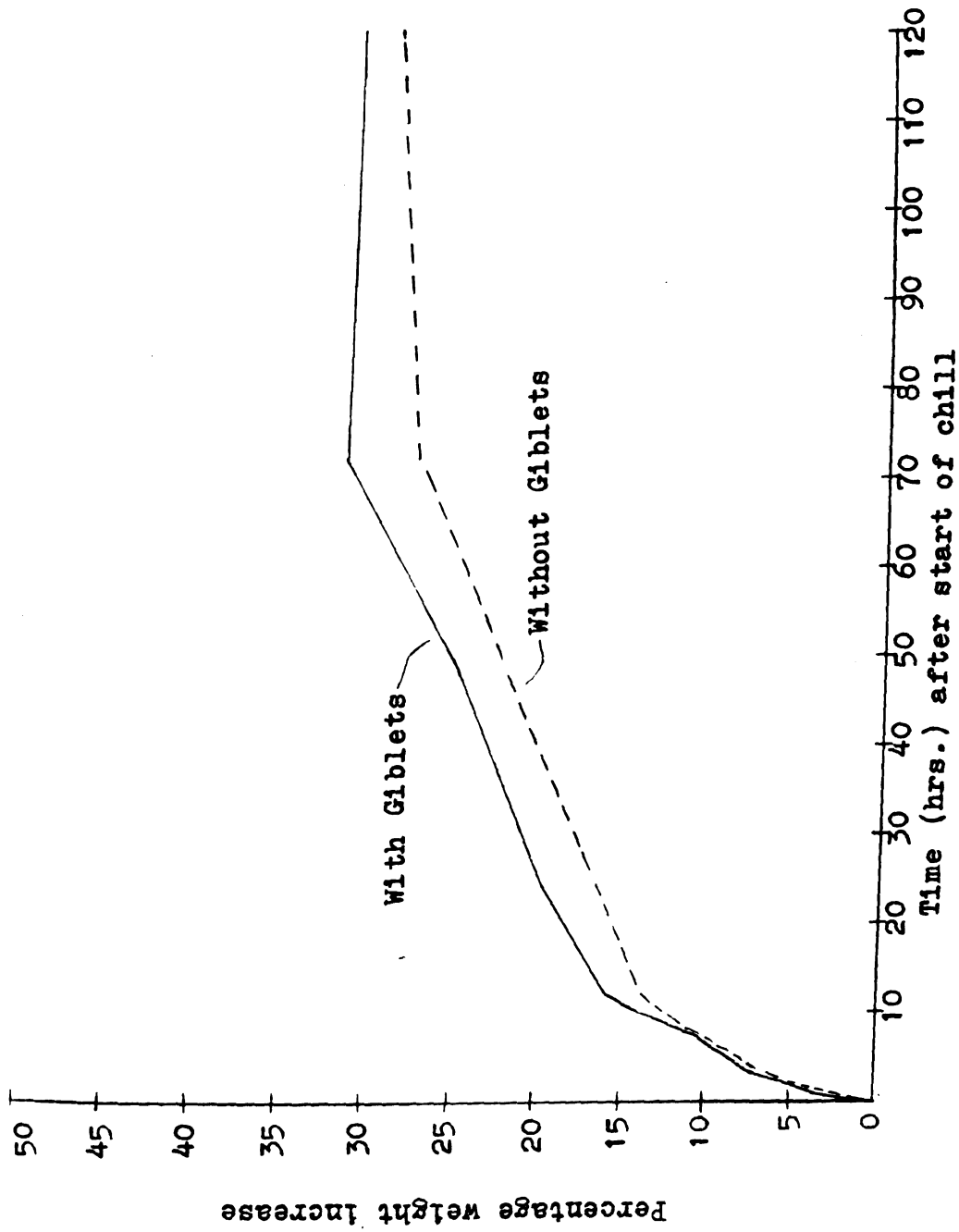


Figure 19: Weight change of fryers chilled in slush ice, with and without giblets, to 120 hours. (Experiment 19).

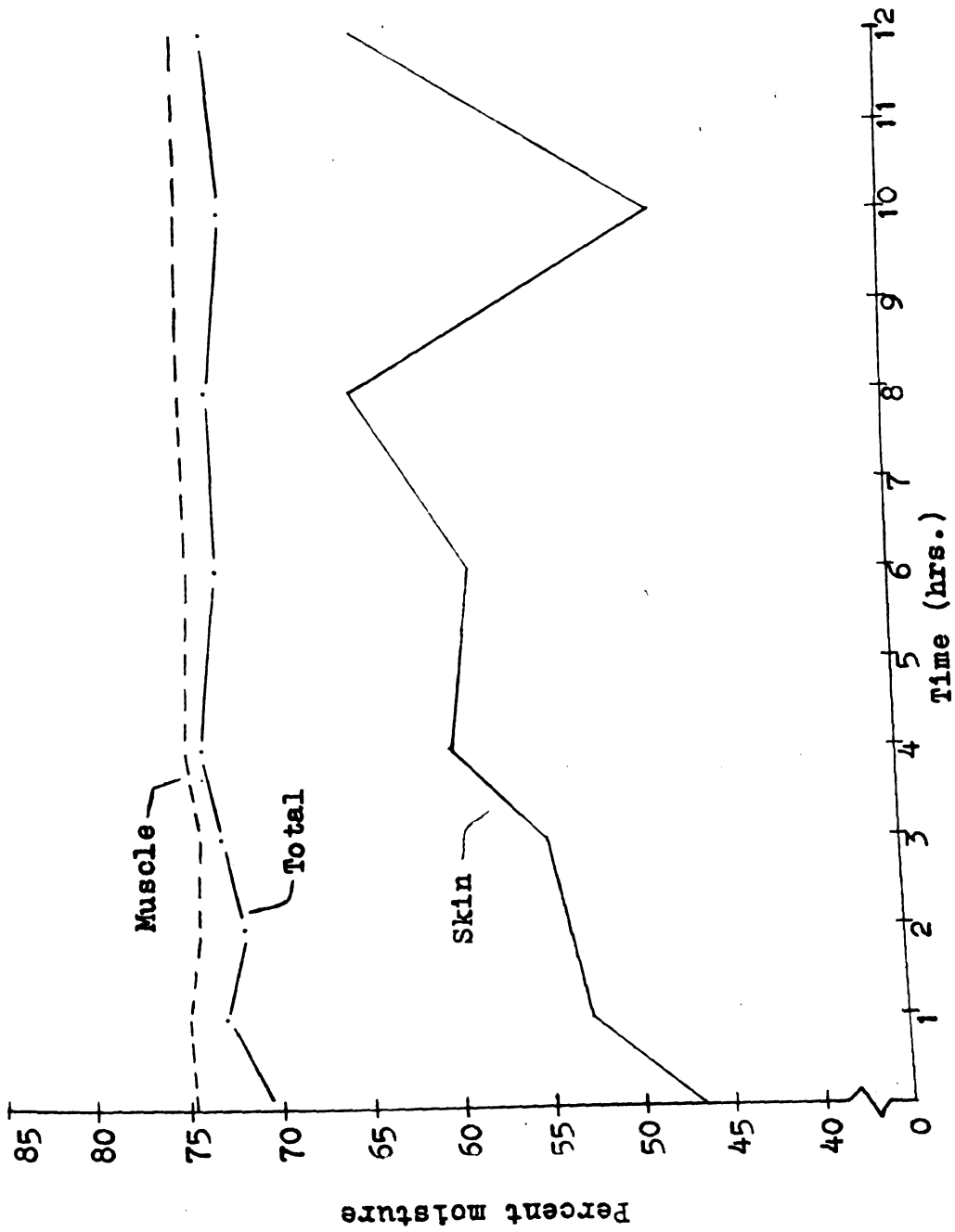


Figure 20: Moisture content of skin, muscle, and total tissue of fryers held in slush ice for 12 hours. (Experiment 20, Treatment A).

percent to 65.01 percent during the 12-hour period. However, the average moisture content of the muscle tissue remained relatively constant at about 75.0 percent. The average total moisture content increased only slightly from 70.24 percent to 73.36 percent during the 12-hour chill period.

When carcasses were held in ice-pack, the average moisture content of the skin increased from 46.54 percent to 59.67 percent (Figure 21). The average moisture content of the muscle tissue varied from one sampling point to another but remained relatively constant throughout the experiment. An increase from 70.24 percent to 73.36 percent moisture was observed in the combined muscle and skin tissue.

Experiment 21:

The carcasses in treatments A, B and C of Experiment 21 were slush ice chilled for 30 minutes, 2 hours, and 6 hours, respectively. After they were chilled, the carcasses were ice-packed and held in a refrigerator maintained at 35° F. through 24 hours from the time they were placed in ice-pack.

The moisture content of the carcasses in Treatment A decreased during the chill period. The average moisture content of the skin declined from 45.75 percent to 42.83 percent (Figure 22) while the moisture content of the muscle tissue and total carcass decreased from 67.17 percent to 65.54 percent, and 64.85 percent to 62.29 percent, respectively. After being ice-packed for four hours, the average moisture content of the skin had decreased to 41.69 percent, then increased to 48.92 percent by the sixth hour. The average moisture content of the skin decreased to 47.77

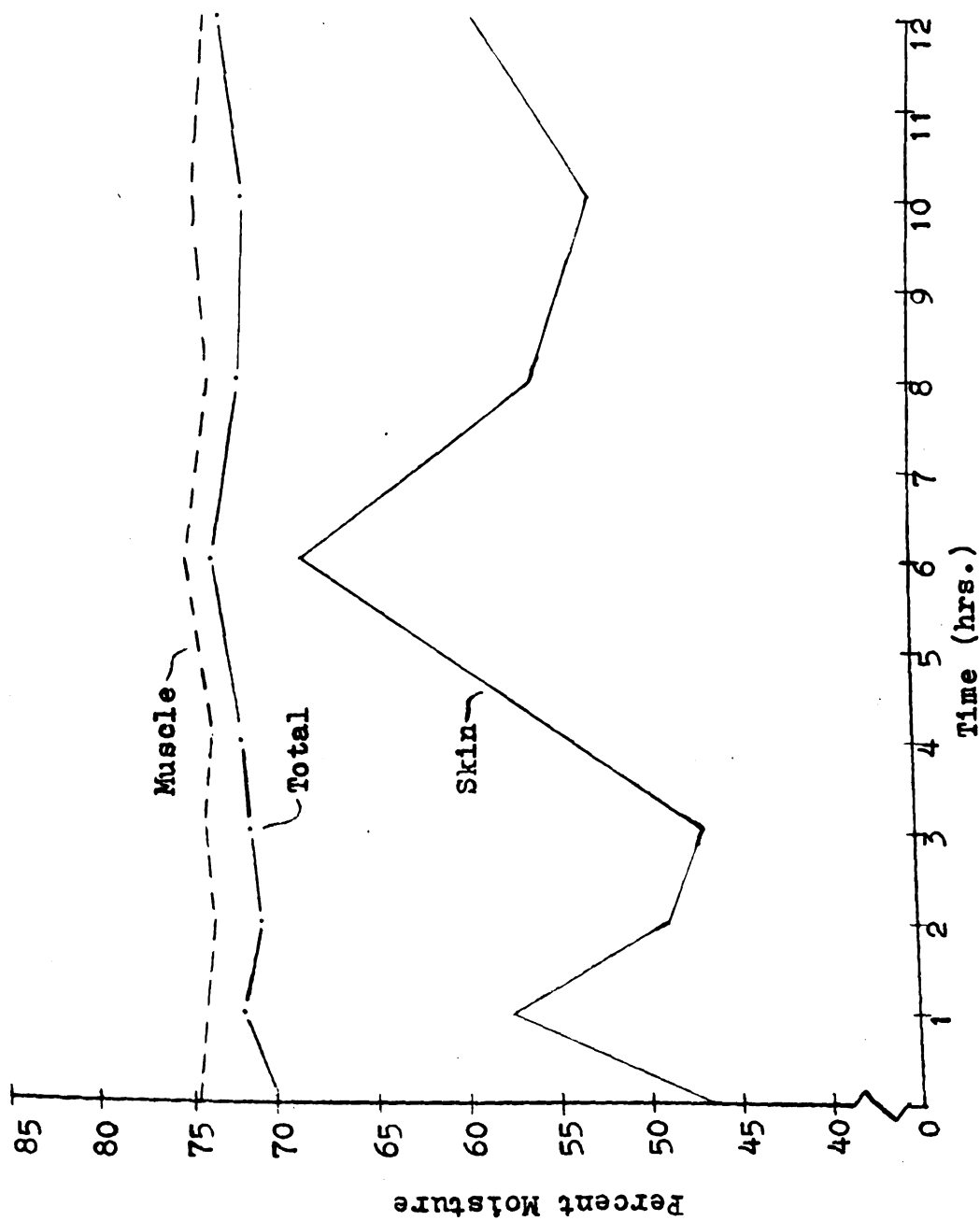


Figure 21: Moisture content of skin, muscle and total tissue of fryers chilled in ice-pack for 12 hours at 60 F. (Experiment 20, Treatment B).

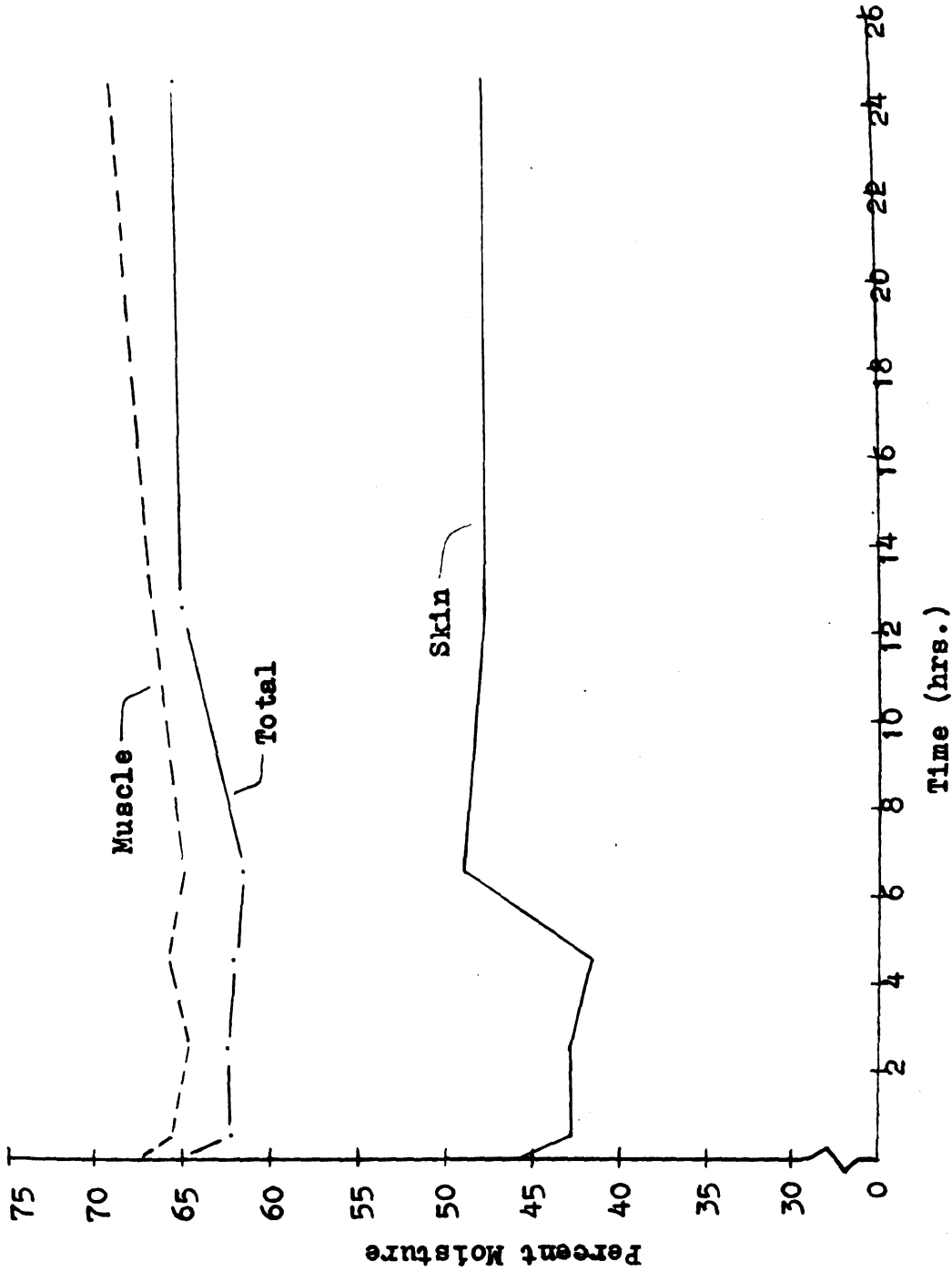


Figure 22: Moisture content of skin, muscle, and total tissue of fryers chilled for 30 minutes, and held in ice-pack at 35°F. to 24 hours of storage. (Experiment 21, Treatment A)

percent after 12 hours of holding in ice-pack and 47.61 percent by the 24th hour. The average moisture content of the muscle tissue had decreased to 64.64 percent by the second hour of storage in ice-pack, then increased gradually through the 24th hour to 69.10 percent. The total average moisture content of the carcasses declined to 61.43 percent by the sixth hour of holding in ice-pack, then increased to 65.24 percent after 24 hours of ice-pack storage at 35° F.

In Treatment B, the average moisture content of the skin increased from 45.73 percent to 50.25 percent during the two-hour chill period (Figure 23). It decreased to 41.50 percent by the sixth hour of storage followed by an increase to 44.81 percent by the 24th hour. The average moisture content of the muscle tissue increased to 69.41 percent from 67.17 percent during the two-hour chill period. This was followed by a decrease to 63.65 percent after two hours of storage in ice-pack. The average moisture content of the muscle increased gradually through the remainder of the experiment to 66.88 percent. During the chill period, the average total moisture content increased from 64.85 percent to 68.30 percent. It declined to 60.52 percent after six hours of ice-pack storage at 35° F. and between the sixth and 24th hour the average total moisture content of the carcasses increased to 65.40 percent.

The skin of the carcasses in Treatment C had an initial average moisture content of 45.73 percent. This declined to 45.05 percent during six hours of chill in slush ice and increased to 49.42 percent after four hours of storage in

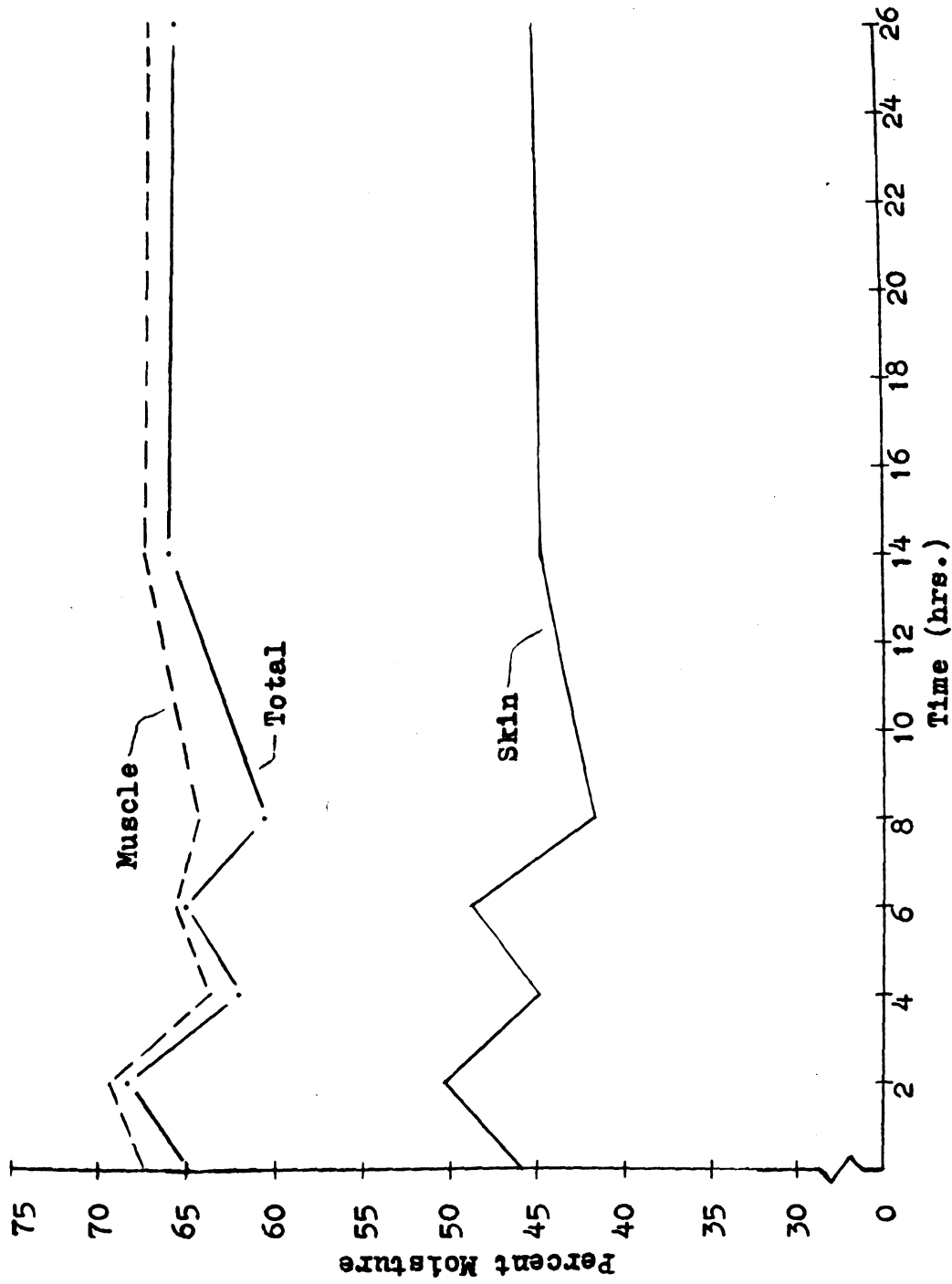


Figure 23: Moisture content of skin, muscle and total tissue of fryers chilled in slush ice for 2 hours, and held in ice-pack at 35 F., to 24 hours of storage. (Experiment 21, Treatment B).

ice-pack (Figure 24). The average moisture content of the skin decreased to 42.77 percent between the fourth and sixth hours and increased to 47.82 percent after 24 hours of storage. The average moisture content of the muscle tissue declined during the chill period from 67.17 percent to 65.03 percent. It increased to 68.22 percent after four hours of storage in ice-pack, followed by a decrease to 64.64 percent by the sixth hour. The muscle tissue average moisture content then increased to 67.32 percent after 24 hours of storage in ice-pack. After six hours of slush ice chill, the average total carcass moisture content had declined from 64.85 percent to 63.18 percent. There followed a general increase in moisture content to 65.02 percent after four hours of ice-pack storage. The total average moisture content decreased to 62.83 percent by the sixth hour, only to increase to 65.20 percent by the conclusion of the experiment.

These data indicate that the skin may be the primary carcass tissue involved with changes in carcass weights resulting from water uptake during slush ice chilling. However, there was a wide variation in water content between carcasses within any one treatment at any given sampling period. Thus the evidence obtained was not sufficient to support any conclusion as to a relationship between changes in moisture content of any given carcass tissue or tissues and changes in weight of the total carcass.

Experiment 22:

Sections of skin were taken from both sides of the breast, so that equal portions of the pectoral feather tract

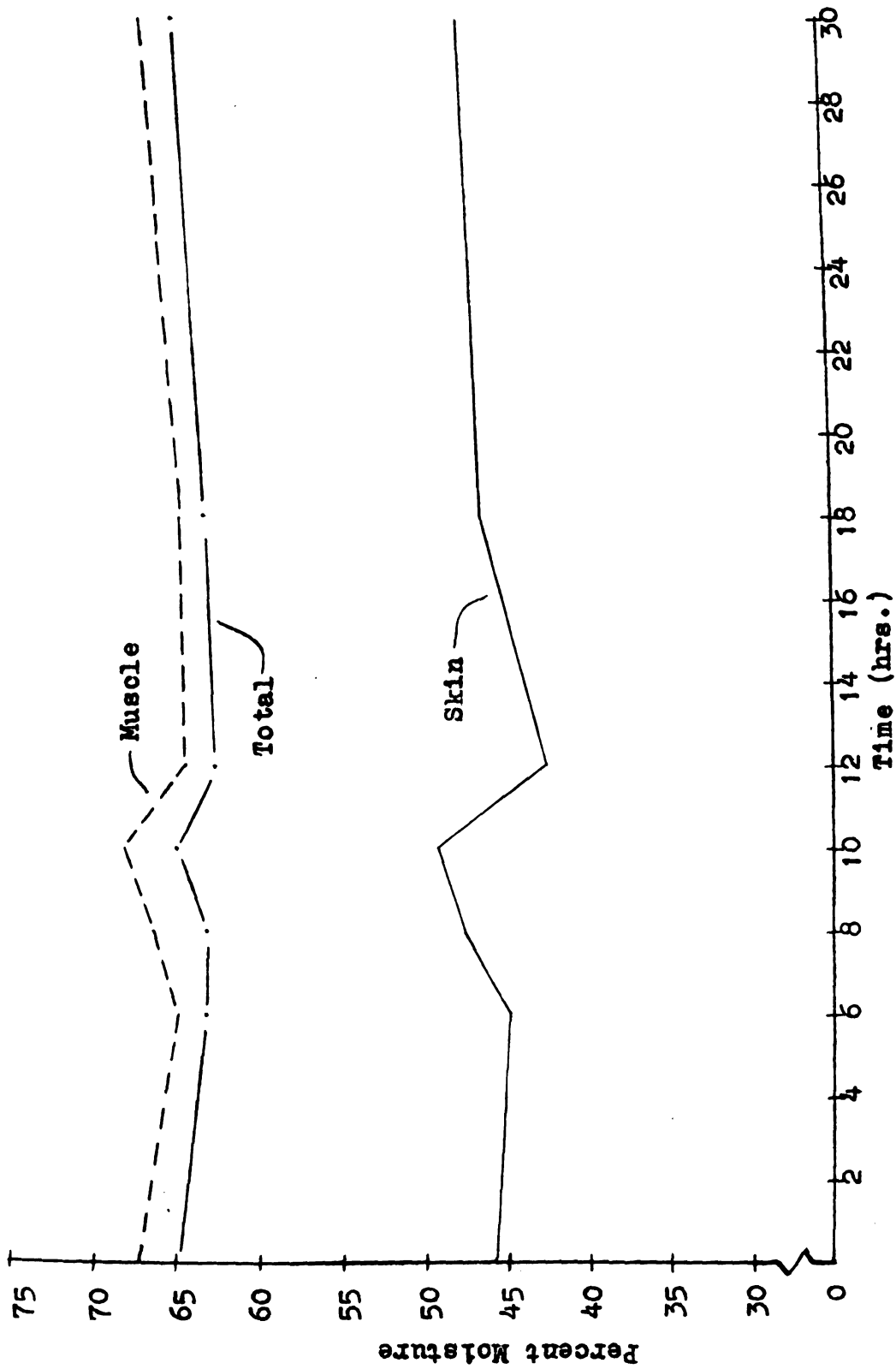


Figure 24: Moisture content of skin, muscle and total tissue of fryers chilled in slush ice for 6 hours, and held in ice pack at 35 F. to 24 hours of storage. (Experiment 21, Treatment 0).

and lateral trunk space were included, attached to specially prepared 303 tin cans and immersed in slush ice. In Treatment A, the subcutaneous fat layer and associated membranes were removed from the respective skin section. In Treatment B, the respective skin section was left intact. Two trials were conducted for each of the two treatments.

Experiment 22 was conducted to determine the water permeability of the skin. The results are summarized in Table 2. It was observed under the conditions of the experiment that water passed through the skin in approximately one hour when the subcutaneous fat layer and associated membranes were removed (Treatment A). When the skin was left intact (Treatment B), evidence of water passage through the skin was not observed until the fourth or sixth hour of exposure to slush ice, in Trials 1 and 2, respectively. In both trials, a one-gram increase in the weight of the skin was associated with the passage of water through the skin in Treatment A. For Treatment B, an increase in the weight of the skin was detected prior to the observation of water passing through the skin in Trial 2, however, the reverse was observed in Trial 1.

General Results

It was observed that the percentage increase during the chill period in the weight of carcasses varied considerably from one group of carcasses to another for any given length of chill time. This variation apparently was due to the respective differences in initial carcass weights. Tarver et al.

Table 2. The water permeability of chicken broiler skin when immersed in slush ice

Length of exposure (hrs.)	Subcutaneous fat removed		Intact	
	Trial 1	Trial 2	Trial 1	Trial 2
	Weight (gms.)	Appearance of water	Weight (gms.)	Appearance of water
0	144.0	-	144.0	-
1/2	144.0	-	144.0	-
1	144.5	x	144.0	-
2	145.0	xx	144.0	-
3			No. wt.	-
4			144.0	-
5			144.5	-
6			145.0	x
7			145.0	xx

- No evidence of water passage through the skin

x Evidence of water passage through the skin

xx Positive evidence of water passage through the skin

(1956) and Thomson et al. (1961) found that smaller carcasses tend to have greater percentage increases in weight due to water uptake than do larger carcasses chilled for the same period of time. However, correlation analysis of the present data indicates that larger carcasses had greater actual increases in weight due to water absorption than did smaller carcasses. The data from all experiments were subjected to correlation analysis. Highly significant positive correlations were obtained between initial carcass weight and weight increase within each chill period (Table 3). Thus, the weight increase during chilling was directly proportional to the initial weight of the carcass.

Table 3. The Correlation Coefficients* between initial carcass weight and increase in weight after chilling in slush ice for 1/2, 3/4, 1 and 2 hours

<u>1/2 hour</u>	<u>3/4 hour</u>	<u>1 hour</u>	<u>2 hours</u>
0.97	0.95	0.98	0.95

* Snedecor, G. W., 1956. Statistical Methods, 5th ed. Iowa State College Press. 162.

A correlation analysis of the initial carcass weights and the respective carcass weight loss after being placed in ice-pack was made to determine if there was any correlation between carcass weight and weight decrease during ice-pack. This was done by calculating the correlation coefficients for the respective factors for Experiments 6 through 13. The correlation coefficients are presented in Table 4. There appears to be a highly significant positive correlation between initial carcass weight and weight lost during the

initial stages of storage in ice-pack. Thus, the larger the carcass weight, the greater was the absolute loss in weight after initial storage in ice-pack.

Table 4. The Correlation Coefficients* between initial carcass weight and loss in weight after ice-packing for Experiments 6-13.

Experiment	6	7	8	9	10	11	12	13
Coefficient	0.93	0.83	0.79	0.74	0.83	0.76	0.91	0.86

* Snedecor, G. W., 1956. Statistical Methods, 5th ed. Iowa State College Press. 162.

The data were analyzed to determine the effect of the remaining carcass heat, after chilling, on the amount of water that could be available for absorption during ice-pack storage. This was calculated by use of the following formula:

$$Q = m s t \times 24 \times 0.317$$

Where

Q = grams of ice melted

m = average initial carcass weight

s = specific heat of the carcass (0.76)

t = degrees F. change in carcass temperature

24 = number of carcasses per treatment

0.317 = BTU's required to melt 1 gram of ice

An estimate of the theoretical amount of ice that could have been melted during a given period of time within each experiment was determined. The results of this analysis for Experiment 9 are reported in Table 5. Similar results were obtained for Experiments 6 - 8 and 10 - 13 and are reported in Tables 6 - 12 of the Appendix. From the second to the fourth hour

Table 5. The accumulated theoretical heat loss, amount of ice melted by that heat, and change in weight of 24 fryer carcasses chilled for 30 minutes in slush ice and held in ice-pack at 35° F. (Experiment 9)

Time (hrs)	B.T.U.	Ice Melted (grams)	Wt. Change (grams)
1	--	--	--
2	547.05	1,725	- 70
3	573.35	1,808	- 52
4	578.61	1,825	- 71
5	"	"	- 51
6	"	"	- 19
7	"	"	+ 34
8	"	"	+116
9	"	"	+ 88
10	"	"	+104
11	"	"	+ 99
12	"	"	+104
24	"	"	+111
48	"	"	+154

3
2
1



of the experiment, the carcasses theoretically lost 578.61 BTU's of heat that could have melted 1,825 grams of ice. However, as shown in Table 5, during this same period of time, the carcasses lost 71 grams of weight. Between the fourth and 48th hour of the experiment there was no measurable change in the average carcass temperature that would result in the melting of the surrounding ice. Even so, carcass weights increased by 154 grams.

DISCUSSION

The results from Experiments 1 and 2 indicated that the increase in weights during chilling and the subsequent weight loss during storage in ice-pack were proportional to the length of the chill period. This concurs with the findings of Fromm and Monroe (1958). It was found from Experiments 3 to 5 that carcasses held in ice-packs at room temperature, or initially placed in ice-packs and held at 35° F. continued to increase in weight rather than lose weight during their respective storage periods. These results indicated that changes in carcass weights were related to length of chill period, holding temperature and changes in average carcass temperature. A reduction in chill time resulted in less moisture uptake and subsequently a lower weight to be maintained. The reduced chill time resulted in more heat remaining in the carcass, which could be used to melt the surrounding ice to provide water for weight maintenance. Therefore, it appeared that at a given chill time there was a definite amount of water required to maintain carcass weights. Thus, maintenance of carcass weights would depend on the relationship between average carcass temperature and refrigerator temperature due to their influence on the amount and rate of ice melted.

When weight changes were evaluated at hourly intervals after carcasses were chilled for 1/2 and 2 hours, it was found, however, that they lost weight during the first 4 to 6 hours of storage in ice-pack. The carcass weights then

stabilized or increased under certain chilling and temperature conditions. Carcasses chilled for 2 hours and held in ice-pack at 35° F. lost weight during the initial period of ice-pack storage, after which their weights were relatively stable. On the other hand, when they were held at 40° F. or 60° F. the carcasses had regained a major portion or more of the initial weight decrease by the twelfth hour in Experiments 6 and 7. Similar results were obtained for carcasses chilled for 1/2 hour in that they lost weight during the first hours of storage in ice-pack and began to increase rapidly in weight through the twelfth hour when held at 35° F., 40° F. or 60° F. In all experiments where ice-pack conditions were conducive to weight increases, weights were relatively stable from the twelfth through the 48th hour when the experiments were terminated. Thus, it appears that this relationship did not prevent a major change in carcass weights, but did bring about a positive adjustment in carcass weights.

These results suggested the postulation that the decrease in weight immediately after the birds were ice-packed was due to the time required for the temperature of the carcass and the cooler to begin to melt the ice at a rate fast enough to offset the loss of carcass moisture due to drainage and/or evaporation. However, when the average carcass temperature data were analyzed to estimate the amount of ice that could be melted by the remaining carcass heat (i.e. Experiment 9, Table 4), it was found that more ice could have been melted than the amount of weight lost by the carcasses during the first 3½ hours of storage. This indicates

that changes in average carcass temperature tend to influence the amount of weight decrease during the initial period in ice-pack. Apparently an excess of water from ice was required to bring about any change in carcass weights. This was due to the proximity of the birds to the ice, and ice water lost by drainage.

It could be theorized that the decrease in carcass weights after birds were ice packed could be associated with relationships within or between the water holding mechanisms of the carcass. Lentz and Rooke (1958) pointed out that 75 percent of the absorbed water was loosely held in lenses or pockets between the thighs and body, muscles and tissues under the skin of the back and neck of birds chilled for 24 hours. In Experiment 22, it was found that approximately one hour of chilling was required before any measurable amount of water was absorbed by the skin of the carcass. Therefore, it would appear that the major portion of the water taken up by the carcasses during 1/2 and 2-hour chill periods was trapped under the skin of the back and neck as reported by Lentz and Rooke (1958). Thus, a large part of the trapped water drained during storage in ice-pack and the amount of water reabsorbed was not sufficient to off-set the drainage, which resulted in a decrease in carcass weights during the initial period of storage in ice-pack.

The stabilization or increase in carcass weights that occurred after four to six hours of storage could be due to a minimization of the drainage and the gradual absorption of water by the skin. The results of Experiment 20 tend to

indicate that the moisture content of the skin increased during ice-pack storage.

It was found that a holding temperature of 40° F. or above would melt sufficient ice to provide a quantity of water which would allow an increase in carcass weights in excess of the chilled weight, regardless of length of chill, during ice-pack storage. When birds were chilled for two hours and held at 35° F. only enough water was provided to stabilize weights after the weight loss which occurred during the initial stages of ice-pack holding. On the other hand, birds chilled for 1/2 hour increased in weight after the fourth to sixth hour of storage at 35° F. This would support the theory that changes in weight of ready-to-cook poultry could be controlled by adjusting the length of the chill period so that the loss in weight after the birds were ice-packed would be equal to the amount of water reabsorbed during the remaining period of ice-pack storage. Also, adjustments in the cooler temperature might be used to give the same result by adjusting the amount of water for reabsorption to the amount of weight lost due to water loss during the first hours of ice-pack storage. However, it appears that refrigerator temperatures above 35° F. would not be conducive to satisfactory shelf-life of the poultry. Therefore, it would seem that adjustment of the length of the chill period to the amount of water made available at 35° F. would be the most satisfactory solution to the problem of controlling changes in carcass weights.

It was found that carcasses chilled for two hours and

held at 35° F. lost weight during ice-pack storage. Carcasses chilled for 30 minutes and held at 35° F. lost weight and then increased in weight to an amount in excess of the chilled weight. It was postulated that these results were due to non-equalization of the amount of moisture lost by drainage and the amount made available for absorption by the skin during ice-pack storage at 35° F. Thus, birds chilled for two hours lost more moisture than the carcass heat and 35° F. temperature could melt from ice and make available for absorption. However, the amount of water available at that temperature was sufficient to bring about a stabilization of weights after the fourth or sixth hour of storage. When carcasses were chilled for 30 minutes the amount of water made available from melted ice was greater than the amount lost and resulted in a net increase in carcass weights in excess of the chilled weight.

Based on the previous results birds were chilled for 45 minutes in an attempt to adjust the amount of moisture lost to the amount that could be absorbed at 35° F. and 40° F. As was expected, the birds held at 40° F. increased in weight during the latter portion of the holding period by an amount in excess of the weight lost during the first 3 to 4 hours of storage in ice-pack. However, when carcasses were held at 35° F. the increase in weight during the latter portion of the holding period was less than that lost during the initial period of ice-pack storage. At first, it was assumed that 45 minutes of chilling was too long, due to the small size of the carcasses resulting in too much carcass heat

being removed during the chill period. Thus, two additional experiments were conducted under the same conditions, using larger birds. Results similar to those from the earlier experiment were obtained when carcasses were held at 40° F. However, carcasses held at 35° F. gained more weight during the latter portion of the holding period than they lost during the initial period of storage in ice-pack. This was contrary to the results obtained in the first experiment conducted under similar conditions. This led to the conclusion that an additional factor was influencing changes in carcass weights. Further evaluation of the data indicated that the only difference between the three experiments was the average weight of the carcasses used. The data indicated that with each increase in average carcass weight the amount of weight increase more closely approached that of the weight lost during the first 4 to 6 hours of ice-pack storage at 35° F. The reverse of this phenomenon was observed for birds held at 40° F. Based on these findings, another experiment was conducted in which carcasses of high average weight were chilled for one hour and held in ice-pack at 35° F. It was found that the increase in weight more nearly approached that which was lost during the first 4 to 6 hours of holding in ice-pack than was obtained from smaller carcasses chilled for 45 minutes.

These results did not concur with previous results which indicated that an increase in average carcass weight had a negative rather than a positive influence on controlling changes in carcass weights. A direct relationship was found

between carcass weights and changes in carcass weights due to slush ice chilling and storage in ice-pack. Assuming that only so much water would be made available from ice for absorption at any given temperature, it would appear that any increase in the weight loss would result in a reduced recovery of weight during the remaining ice-pack holding period. It could then be assumed that the average carcass weight had some indirect as well as direct influence on changes in weight of ready-to-cook poultry.

In the following theorization, a constant temperature of 35° F. will be used due to its positive influence on the shelf-life of ready-to-cook poultry. The proposed theory is that the average carcass weight indirectly influences the changes in carcass weights by controlling the amount of ice in which the birds are packed. In this study, 24 birds per experiment were packed in wire-bound boxes with a layer of ice on the bottom of the box and another layer on the top layer of birds. In this manner, as the weight of the birds increased the amount of ice per pack decreased. A smaller mass of ice would melt more rapidly than would a larger mass of ice. Thus, the smaller mass of ice surrounding the larger birds would melt faster supplying a greater amount of water for absorption by the carcasses in a given period of time. A greater mass of ice surrounding the smaller carcasses would not melt as rapidly, which would result in less water available for absorption.

This might explain why the birds chilled for 45 minutes and held at 35° F. more nearly maintained their chilled

weight as the average carcass weight increased. The smaller carcasses had smaller weight increases and smaller weight decreases but the mass of ice surrounding them was too large for the carcass heat and 35° F. temperature to melt at a rate sufficient to provide enough water for absorption to offset the weight loss that occurred during the initial period of storage in ice-pack. As the carcass weight increased the mass of ice was reduced to an amount where the carcass heat and 35° F. temperature could melt it at a rate sufficient to produce enough water so that an increase in weight in excess of the chilled weight was obtained. When birds of greater average weight were chilled for one hour and held at 35° F. the mass of ice was further reduced and the increase in weight more nearly equaled that lost during the initial stages of ice-pack holding.

It appears then that the original hypothesis that "changes in weight of ready-to-cook poultry could be minimized by a relationship between length of chill period, average carcass temperature and holding temperature" was correct. However, it was not complete in its scope. The results now indicate that the hypothesis should be expanded, and indications are the changes in weight of ready-to-cook poultry can be minimized by a relationship between length of chill, average carcass weight, the mass of the surrounding ice, changes in average carcass temperature, and the holding temperature.

These results indicate that further investigations of the relationships between the controlling factors already

proposed would be justified. Due to the apparent influence of the mass of the surrounding ice in ice-pack, an evaluation of the size of the ice particle (i.e. flake or crushed) in relation to carcass and holding temperature should be made. Additional information is needed concerning the mechanism and/or mechanisms by which the carcass holds water taken up during the chill period. The method by which the carcass loses moisture and regains it during holding in ice-pack should also be determined.

SUMMARY

This study was conducted to test the hypothesis that the changes in carcass weights due to slush ice chilling are associated with and can be controlled by a relationship between the length of chill period, changes in the average internal carcass temperature, and holding temperature. Fryers, 8 to 10 weeks of age were slaughtered, eviscerated (roaster style) and the giblets and neck sealed in plastic bags and replaced in the body cavity. The processed fryers were subjected to various chilling periods and ice-pack holding conditions. The changes in carcass weight and temperature were obtained by weighing the carcasses at various time intervals and by placing thermocouples in the carcasses and recording their temperature with a recording potentiometer. The moisture content of various carcass tissues, as affected by different chilling and holding conditions was determined, and the water permeability was determined for chicken broiler skin held in slush ice.

The results indicate that the weight increase during chilling and the weight decrease during storage in ice-pack was directly proportional to the length of the chill period. There was also a direct relationship between the size of the carcass and the weight increase and decrease during slush ice chilling and holding in ice-pack. Holding temperatures of 40° F. or above were conducive to carcass weight increases in excess of the chilled weight of the carcass. Similar results were obtained, however, when carcasses were chilled

for 1/2 hour and held in ice-pack at 35° F. Indications were that loss of the remaining carcass heat during the first 3½ hours of storage in ice-pack influenced the weight decrease that occurred during that time. An additional factor which appeared to influence changes in carcass weights was the size of the carcass in relation to the mass of ice surrounding the carcasses in ice-pack. On the basis of these findings, it may be theorized that changes in carcass weights were due to and controlled by a relationship between length of chill period, carcass weight, amount of ice in ice-pack, carcass temperature and holding temperature.

Experiments were conducted to determine the effect of various chilling and ice-pack conditions on the moisture content of different carcass tissues. Although the data were not conclusive, the indications were that the moisture content of the skin was changed in a positive direction during ice-pack storage at 35° F., regardless of the length of chill.

In one experiment, intact skin and skin with the subcutaneous fat and membranes removed were exposed to slush ice to determine the water permeability of the skin. Water passed through the lateral trunk space in approximately one hour when the fat layer was removed. This evidence of water penetration was accompanied by an increase in the weight of the skin section. However, when the skin was left intact the results were variable. Evidence of water penetration was observed after four to six hours of exposure in each of two trials. In the first trial, water penetration was observed prior to an increase in the weight of the skin

section, while the reverse was found in the second trial. As in the case of the moisture analysis data, these results indicate that the skin may be the primary carcass tissue involved with changes in carcass weights.

Fryer carcasses reached a maximum level of water absorption between 72 and 120 hours when held in agitated slush ice. Carcasses with giblets in the body cavity took up slightly more water than those without giblets in the body cavity. During the 120 hour chill period carcasses with giblets increased in weight by 29.9 percent, while those without giblets increased in weight by 27.8 percent of their initial eviscerated weight.

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APPENDIX

Table 1. The percentage change in weight of fryers chilled and held to 96 hours under various conditions, based on their warm eviscerated weight (Experiments 1-3)

Exp. No.	Chill treatment	Holding temp. (F°)	Time (hours)						
			2	4	6	12	24	48	72
			Percentage weight increase						
1	A - Ice pack	35						1.69	2.22
	B - 2 Hrs. slush ice	"	4.75					4.13	4.09
	C - 4 Hrs. slush ice	"		5.19				3.78	3.66
	D - 24 Hrs. slush ice	"				8.31	6.11		5.50
2	A - Ice pack	35							
	B - 2 Hrs. slush ice	"	5.70						
	C - 4 Hrs. slush ice	"		6.12					
	D - 24 Hrs. slush ice	"							
3	A - Ice pack	Room	0.73	1.37	1.77	2.10	2.39	3.25	4.75
	B - 2 Hrs. slush ice	"	3.48				4.06	4.66	5.73
	C - 4 Hrs. slush ice	"		3.94			4.10	4.73	5.53
	D - 6 Hrs. slush ice	"			4.75		4.62	4.81	5.63
	E - 12 Hrs. slush ice	"				5.45	5.57	4.62	5.88

Table 2. The percentage change in weight of fryers chilled and held to 48 hours under various conditions, based on their warm eviscerated weight (Experiments 4-18)

		Experiment No.																	
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			
Time	2/	Treatment 1/																	
(Hrs.)	IP-35	IP-60	2-35	2-40	2-60	2-60	2-35	2-40	2-60	2-60	3/4-35	3/4-40	3/4-35	3/4-40	3/4-35	3/4-40	1-35	1-35	
Percentage weight increase																			
1/2							2.60	2.29	3.04	2.96	2.79	2.89	2.50	1.87	2.31				
3/4																			
1	0.81	3.66																2.46	
2		1.11	5.15	2.91	3.25	2.34	2.08	2.83	2.54	2.46									
3		1.48	5.10	2.62	2.98	2.40	1.97	2.75	2.45	2.39									
4		1.75	4.50	2.60	2.98	2.34	2.34	2.95	2.54	2.38									
5		1.97	4.27	2.54	2.86	2.41	2.39	3.26	2.49	2.38									
6		2.18	4.17	2.62	2.92	2.51	2.44	3.15	2.52	2.37									
7		2.50	4.25	2.57	3.06	2.58	2.63	3.30	2.49	2.38									
8		2.57	4.20	2.63	3.27	2.95	2.73	3.32	2.58	2.38									
9		2.99	4.34	2.70	3.42	2.86	2.75	3.39	2.55	2.39									
10		3.06	4.36	2.67	3.53	2.91	2.78	3.45	2.59	2.50									
11		3.13	4.29	2.79	3.60	2.94	2.78	3.54	2.63	2.53									
12		2.99	4.34	2.70	3.42	2.86	2.75	3.39	2.55	2.39									
13		3.06	4.36	2.67	3.53	2.91	2.78	3.45	2.59	2.50									
14		3.13	4.29	2.79	3.60	2.94	2.78	3.54	2.62	2.53									
15		3.40	4.36	2.77	3.64	2.90	2.86	3.61	2.65	2.54									
24	1.09	3.52	4.32	2.76	3.72	3.04	2.91	3.56	2.67	2.55									
48	1.60	4.00	3.88	2.95	4.14	3.08	3.12	3.84	2.79	2.92	3.31	3.08	2.09	2.81	2.58				
1/	The first designation represents the length of chill in slush ice and the second designation the temperature of the refrigerator during storage in ice-pack.																		
2/	Initially placed in ice-pack.																		

Table 3. The average internal carcass temperature of fryers chilled and held to 48 hours under various conditions (Experiments 4-18)

Time (Hrs)	Experiment No.																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
	Treatments-1/ Temperature - degrees F.																
IP-60	2-35	2-40	2-60	1-35	1-40	1-60	3/4-35	3/4-40	3/4-35	3/4-40	3/4-35	3/4-40	3/4-35	3/4-40	1-35	1-40	
0	63.5	73.9	72.3	66.4	73.9	63.5	86.0	72.3	74.3	76.6	74.3	76.6	74.5	74.8	83.8		
1/2	50.5		36.2	37.9		42.5	45.9	36.9	36.8	36.0	36.8	36.0	34.3	40.8	42.6		
3/4	47.6		34.2			35.8		35.9	34.8	34.3	34.8	34.3	35.4	36.8	37.1		
1	45.2	48.2	33.4	34.3	33.2	34.1	42.2	35.8	34.9	34.6	34.9	34.6	36.3	35.4	35.4		
2	40.1	43.1	33.3	34.1	32.0	32.1	40.3	35.5	34.6	34.3	34.6	34.3	36.0	36.0	34.7		
3	37.3	40.5	32.3	33.8	32.8	31.6	39.4	35.6	34.1	33.7	34.1	33.7	35.2	35.3	34.4		
4	35.6	39.1	32.0	33.6	32.5	31.5	38.6	35.5	33.6	33.3	33.6	33.3	34.5	34.7	34.1		
5	34.5	38.7	32.0	"	32.4	38.0	35.7	33.3	33.1	33.3	33.3	33.1	34.2	34.6	34.0		
6	33.7	38.3	31.8	33.7	"	"	37.7	35.9	33.2	"	33.2	"	33.8	34.3	33.9		
7	33.3	38.2	31.7	"	"	"	37.2	36.3	"	"	"	"	33.6	34.1	33.8		
8	32.8	37.8	"	"	32.5	"	36.9	36.7	33.0	"	33.0	"	"	34.2	33.6		
9	32.5	38.3	"	33.8	"	"	36.5	37.0	"	33.0	"	33.0	33.4	34.1	33.5		
10	32.3	38.9	"	"	32.6	"	36.3	37.5	32.8	33.1	32.8	33.1	33.3	34.0	"		
11	32.2	39.4	31.5	"	"	"	36.0	37.9	"	33.0	"	33.0	"	34.1	"		
12	32.1	39.9	"	"	32.9	"	35.8	38.3	"	33.1	"	33.1	"	"	"		

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Table 3. (Continued)

Time (Hrs)	Experiment Number																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
	Treatments																
	IP-35	IP-60	2-35	2-40	2-60	$\frac{1}{2}$ -35	$\frac{1}{2}$ -40	$\frac{1}{2}$ -60	3/4-35 3/4-40 3/4-40 3/4-35 3/4-40 3/4-35 3/4-40 1-35								
	Temperature - degrees F.																
13	32.0	40.4	31.5	33.9	32.9	31.5	35.7	38.6	32.8	32.9	32.8	32.9	33.1	33.1	34.0	33.5	
14	32.0	40.9	"	34.1	33.1	"	"	39.0	"	33.1	"	33.1	"	34.1	"	"	
15	31.8	41.7	"	34.0	33.4	"	35.5	39.5	"	"	"	"	"	"	"	"	
16	31.9	42.3	"	"	33.5	"	35.3	39.7	33.0	33.2	33.0	33.2	"	34.0	"	"	
17	31.7	42.9	"	34.1	33.6	"	"	40.0	"	"	"	"	"	34.2	"	"	
18	"	43.5	"	"	34.0	"	"	40.5	"	"	"	"	"	"	"	"	
19	"	44.1	"	34.2	34.3	"	35.2	40.9	"	"	"	"	33.0	"	"	"	
20	"	44.8	"	"	34.6	"	35.1	41.4	"	"	"	"	33.1	"	"	"	
21	"	45.5	"	"	34.9	"	"	41.8	"	"	"	"	33.0	34.1	"	"	
22	"	46.4	"	34.3	35.1	"	35.2	41.1	"	"	"	"	32.9	"	"	83	
23	"	47.2	"	"	35.6	"	35.1	40.6	"	"	"	"	33.0	34.3	"	"	
24	"	47.8	"	"	35.8	"	"	40.5	"	"	"	"	"	"	"	"	
25	"	39.9	"	"	36.3	"	"	40.6	"	"	"	"	"	"	"	"	
26	31.8	38.8	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
27	31.7	38.8	"	"	36.5	"	"	40.7	"	"	"	"	"	34.4	"	"	
28	"	38.0	"	"	36.6	"	"	40.8	"	"	"	"	32.9	"	"	"	
29	31.8	37.9	"	34.4	36.9	"	"	41.0	"	"	"	"	33.0	"	"	"	
30	"	38.0	"	"	37.4	"	"	41.2	"	"	"	"	"	"	"	"	

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Table 3. (Continued)

		Experiment Number															
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Time		Treatments															
(Hrs)		IP-35	IP-60	2-35	2-40	2-60	2-35	2-40	2-60	3-35	3-40	3-60	3/4-35	3/4-40	3/4-35	3/4-40	1-35
		Temperature - degrees F.															
31		31.7	38.1	31.5	34.4	37.5	31.5	35.1	41.5	33.0	33.2	33.0	33.2	33.0	33.2	33.0	33.5
32		"	38.3	"	"	37.8	"	"	"	"	"	"	"	"	"	"	34.6
33		31.8	"	"	"	37.9	"	"	41.9	"	"	"	"	"	"	"	34.7
34		"	"	"	"	38.1	"	"	42.0	"	"	"	"	"	32.9	"	"
35		"	38.5	"	"	38.5	"	"	42.2	"	"	"	"	"	"	"	"
36		"	38.6	"	"	38.6	"	"	42.4	"	"	"	"	"	33.0	"	"
37		"	39.0	"	"	39.0	"	"	42.6	"	"	"	"	"	32.9	34.8	"
38		"	39.4	"	"	39.3	"	"	42.9	"	33.4	"	33.4	"	"	"	"
39		32.0	39.8	31.6	"	39.5	"	"	43.2	"	"	"	"	"	33.0	34.9	"
40		"	40.3	"	"	39.6	"	"	43.5	"	33.6	"	33.6	"	35.0	"	"
41		"	40.8	31.8	"	40.0	"	"	43.9	"	"	"	"	32.9	"	"	"
42		"	41.4	"	"	40.3	"	"	44.2	"	"	"	"	"	"	"	"
43		32.1	41.8	"	"	40.4	"	"	44.6	"	"	"	"	"	35.1	"	"
44		32.0	42.5	"	"	40.8	"	"	44.9	"	"	"	"	"	"	"	"
45		"	42.8	"	"	41.0	"	"	45.4	"	"	"	"	33.0	35.3	"	"
46		32.1	43.3	"	"	41.1	"	"	45.8	"	33.7	"	33.7	"	"	"	"
47		"	43.7	31.9	34.5	41.5	"	35.2	46.3	"	"	"	"	32.9	"	"	"
48		"	44.0	"	"	41.9	"	"	46.6	"	"	"	"	33.0	35.4	"	"

1/ The first designation represents the length of chill in slush ice and the second designation, the temperature of the refrigerator during storage in ice-pack.

2/ Initially placed in ice-pack.

Table 4. Percentage moisture content of fryer carcass tissues chilled in slush ice or ice pack for different lengths of time and held in ice pack at 35°F. (Experiment 20)

Treatment	Tissue	Time interval (hrs.)									
		0	1	2	3	4	6	8	10	12	
Slush ice						Percent					
	Skin	46.54	52.71	53.78	54.97	60.17	58.99	65.38	48.14	65.01	
	Muscle	74.72	74.99	74.31	74.17	74.90	74.65	74.95	74.97	75.04	
	Total	70.24	72.92	71.73	73.05	74.05	72.99	73.45	72.53	73.36	
Ice pack											
	Skin	46.54	57.65	49.02	47.07	53.77	69.18	56.24	53.16	59.67	
	Muscle	74.72	74.36	73.95	74.43	74.04	75.50	74.47	75.26	74.73	
	Total	70.24	72.22	71.32	71.99	72.42	74.11	72.64	72.58	73.85	

Table 5. Percentage moisture content of fryer carcass tissues taken from carcasses chilled in slush ice for 1/2, 2 and 6 hours and held for 24 hours in ice pack at 35°F. Analysis was made at 2, 4, 6, 12 and 24 hours from the start of storage in ice pack (Experiment 21)

Treatment Tissue		Time interval (hrs.)												
		0	1/2	2	4	6	8	10	12	14	18	24	26	30
30-min chill		Percent												
	Skin	45.73	42.83	42.89	41.69	48.93	....	....	47.77	....	....	47.61	....	....
	Muscle	67.17	65.54	64.64	65.73	64.84	....	....	66.56	....	....	69.10	....	....
	Total	64.85	62.29	62.42	62.07	61.43	....	....	64.97	....	....	65.24	....	....
2-Hr. chill		Percent												
	Skin	45.73	....	50.25	44.82	48.73	41.50	....	....	44.75	....	....	47.81	....
	Muscle	67.17	....	69.41	63.65	65.55	64.25	....	....	67.23	....	....	66.88	....
	Total	64.85	....	68.30	62.05	64.97	60.52	....	....	65.80	....	....	65.40	....
6-Hr. chill		Percent												
	Skin	45.73	....	....	....	45.05	47.85	49.42	42.77	....	46.71	....	....	47.82
	Muscle	67.17	....	....	....	65.03	66.50	68.22	64.64	....	66.81	....	....	67.32
	Total	64.85	....	....	....	63.18	63.26	65.02	62.83	....	63.46	....	....	65.20

Table 6. The accumulated theoretical heat loss, amount of ice melted by that heat, and change in weight of 24 fryer carcasses chilled in slush ice for 2 hours and held in ice-pack at 35°F. (Experiment 6)

Time (hrs)	Heat loss (B. 'U. 's)	Ice melted (gms)	Weight change (gms)
3	42.30	133	- 5
4	54.99	173	- 66
5	"	"	- 90
6	63.45	200	- 101
7	67.88	213	- 93
8	"	"	- 97
9	"	"	- 83
10	"	"	- 81
11	76.14	240	- 88
12	"	"	- 81
24	"	"	- 85
48	"	"	- 130

Table 7. The accumulated theoretical heat loss, amount of ice melted by that heat and change in weight of 24 fryer carcasses chilled in slush ice for 2 hours and held in ice-pack at 40°F. (Experiment 7)

Time (hrs.)	Heat loss (B.T.U.'s)	Ice melted (gms.)	Weight change (gms.)
3	20.30	64	- 103
4	29.85	94	- 110
5	31.64	99	- 128
6	"	"	- 102
7	"	"	- 119
8	"	"	- 98
9	"	"	- 83
10	"	"	- 93
11	"	"	- 53
12	"	"	- 61
24	"	"	- 62
48	"	"	+ 2

Table 8. The accumulated theoretical heat loss, amount of ice melted by that heat and change in weight of 24 fryer carcasses chilled in slush ice for 2 hours and held in ice-pack at 60°F. (Experiment 8)

Time (hrs.)	Heat loss (B.T.U.'s)	Ice melted (gms.)	Weight change (gms.)
3	0	0	- 78
4	24.71	77.94	- 77
5	"	"	- 112
6	"	"	- 94
7	"	"	- 54
8	"	"	+ 7
9	"	"	+ 50
10	"	"	+ 82
11	"	"	+ 102
12	"	"	+ 113
24	"	"	+ 135
48	"	"	+ 256

Table 9. The accumulated theoretical heat loss, amount of ice melted by that heat and change in weight of 24 fryer carcasses chilled in slush ice for 30 minutes and held in ice-pack at 40°F. (Experiment 10)

Time (hrs.)	Heat loss (B.T.U. 's)	Ice melted (gms.)	Weight change (gms.)
1	- -	- -	- -
2	321.26	1,013	- 71
3	375.28	1,183	- 109
4	420.10	1,325	+ 15
5	454.01	1,432	+ 33
6	475.85	1,501	+ 48
7	502.86	1,586	+ 114
8	520.67	1,642	+ 145
9	540.21	1,704	+ 153
10	552.85	1,743	+ 163
11	570.66	1,800	+ 163
12	583.30	1,840	+ 191
24	621.23	1,959	+ 206
48	"	"	+ 278

Table 10. The accumulated theoretical heat loss, amount of ice melted by that heat and change in weight of 24 fryer carcasses chilled in slush ice for 30 minutes and held in ice-pack at 60°F. (Experiment 11)

Time (Hrs.)	Heat loss (B.T.U. 's)	Ice melted (gms.)	Weight change (gms.)
1			
2	60.80	191	- 53
3	56.46	"	- 72
4	60.80	205	- 21
5	"	"	+ 57
6	"	"	+ 27
7	"	"	+ 66
8	"	"	+ 71
9	"	"	+ 88
10	"	"	+ 103
11	"	"	+ 127
12	"	"	+ 145
24	"	"	+ 133
48	"	"	+ 202

Table 11. The accumulated theoretical heat loss, amount of ice melted by that heat, and change in weight of 24 fryer carcasses chilled in slush ice for 45 minutes and held in ice-pack at 35°F. (Experiment 12)

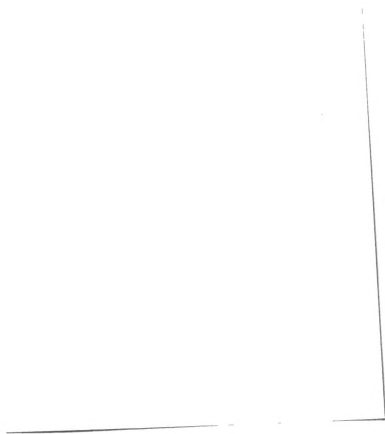
Time (hrs.)	Heat loss (B.T.U. 's)	Ice melted (gms.)	Weight change (gms.)
2	4.65	14	- 87
3	23.60	74	- 105
4	41.48	130	- 88
5	51.49	162	- 97
6	55.06	173	- 91
7	57.20	180	- 98
8	62.56	197	- 96
9	"	197	- 103
10	68.28	215	- 94
11	"	"	- 88
12	"	"	- 83
24	"	"	- 77
48	"	"	- 53

Table 12. The accumulated theoretical heat loss, amount of ice melted by that heat and change in weight of 24 fryer carcasses chilled in slush ice for 45 minutes and held in ice-pack at 40°F. (Experiment 13)

Time (Hrs.)	Heat loss (B.T.U. 's)	Ice melted (gms.)	Weight change (gms.)
2	1.35	4	- 64
3	22.02	69	- 79
4	35.23	111	- 80
5	39.97	126	- 80
6	42.34	133	- 83
7	41.32	"	- 81
8	42.34	136	- 80
9	43.89	141	- 79
10	42.34	"	- 56
11	43.89	145	- 51
12	"	"	- 49
24	"	"	- 46
48	"	"	+ 26

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