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BRUISING AND FREEZING OF APPLES IN STORAGE AND TRANSIT

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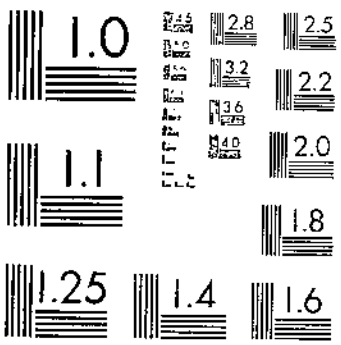

MICROCOPY RESOLUTION TEST CHART
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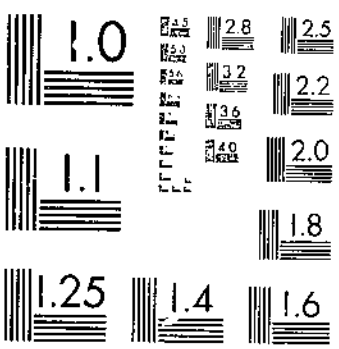

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NATIONAL BUREAU OF STANDARDS 1963 A

TECHNICAL BULLETIN No. 370 September 1933

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

BRUISING AND FREEZING OF APPLES IN STORAGE AND TRANSIT

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INTRODUCTION

Rather heavy losses are experienced every year with shipments of boxed apples because of a peculiar type of injury that occurs in transit. The injury is most common in apples from the Pacific Northwest but has been found in those from Eastern States. It is more frequently seen and is sometimes more severe during the winter months than in the fall and spring. However, it has been observed on boxed apples shipped in the fall before freezing weather had occurred either in the producing regions or anywhere along the route taken by the shipment. It has also been seen so late in the spring that there was no possibility of the fruit having been exposed to freezing weather in transit.

In shipments of boxed apples the injury is usually found only in the fruit at the lower side of the bottom layer of boxes in the railway car, and for this reason is frequently thought to have been caused by freezing. Its occurrence in shipments arriving on the market during the period from December to March, inclusive, leads receivers to suspect freezing damage in the whole bottom layer of

[1] The writers are indebted to R. L. Newton and M. J. Payne, of the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, U.S. Department of Agriculture, for the construction of the apparatus used to simulate transit conditions.

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boxes and generally results in the sale of those boxes at a price substantially lower than that brought by the rest of the load. So common is it at times on eastern markets that it becomes an important factor in complicating the freight-claim situation among railroads, shippers, and receivers.

A condition similar to that found in boxes has also been observed just under the lids of bushel baskets and at various levels downward from the tail end of barrels. In general, in the latter case, the tighter the pack the farther down the injury is found in the barrel.

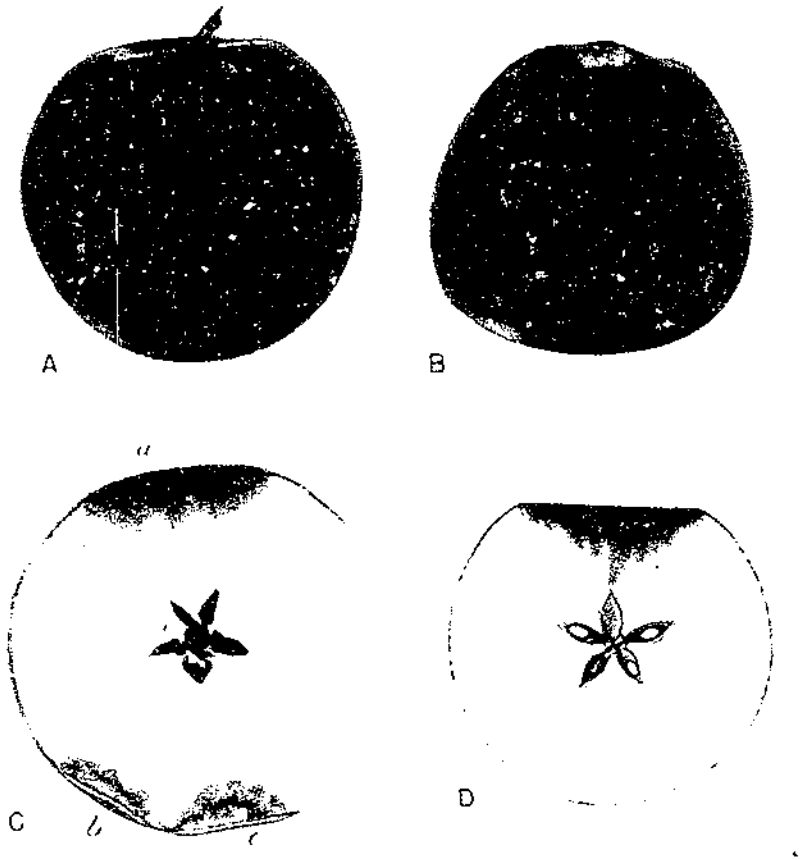
The form of the injury which is characteristic for barreled lots has been found (1) in York Imperial apples at the packing house 2 days after the barrels had been headed, and before even a light frost had occurred; (2) in Jonathan and King David apples, in New York City, after being unloaded from cars which moved from Virginia in September without transit refrigeration.

The following are the outstanding characteristics of the injury:

In boxed apples a flat bruised area is present on the side of the apple that was in contact with the lower side of the box as the latter lay in the car. The bruised spots have a water-soaked, darkened appearance, are generally quite firm, and may be an inch or more in diameter. Occasionally the skin covering them is discolored in spots or streaks, as shown in plate 1, B, or over practically all of the bruised area, as in plate 1, A. In cross section there is usually a water-soaked, glassy, wedge-shaped area which extends from the skin toward the center of the apple. This may be shallow or it may extend quite to the core. In some instances the inner edge of this area appears as a fairly smooth curve, concave toward the core; in others it is broken by strands or rays having the water-soaked appearance just mentioned and extending radially for as much as three fourths of an inch beyond the main affected area (pl. 1, C *a*, and D). Sometimes small water-soaked patches or streaks are also seen underneath bruises produced by the pressure of one apple against another, as shown in plate 1, C, *b* and *c*. Large bruised areas such as that shown in plate 1, A, are usually sunken, grayish or slate colored, and the flesh underneath them is rather soft.

In bruised apples from barrels and baskets, the bruised areas seen in cross section show a light-brown zone of fractured flesh underneath which there is frequently a more or less complete cone of glassy, water-soaked flesh almost identical in appearance with that described for boxed apples (pl. 2, A). It should be noted that the apple shown in plate 2, A, had not been exposed to freezing temperatures.

In barreled lots, the apples next to the lid at the tail end show the flat bruises, whereas those farther down show concave areas where one fruit has been squeezed against or into another. Both kinds are produced of course when the head is forced into place in closing the barrel. In all three kinds of packages—boxes, barrels, and baskets—fruits can practically always be found which show only the light-brown, shallow, so-called packing bruises in which the flesh is crushed or fractured (pl. 2, B and C), the lines of fracture running roughly parallel to the bruised surface, or concave away from it and parallel to each other.



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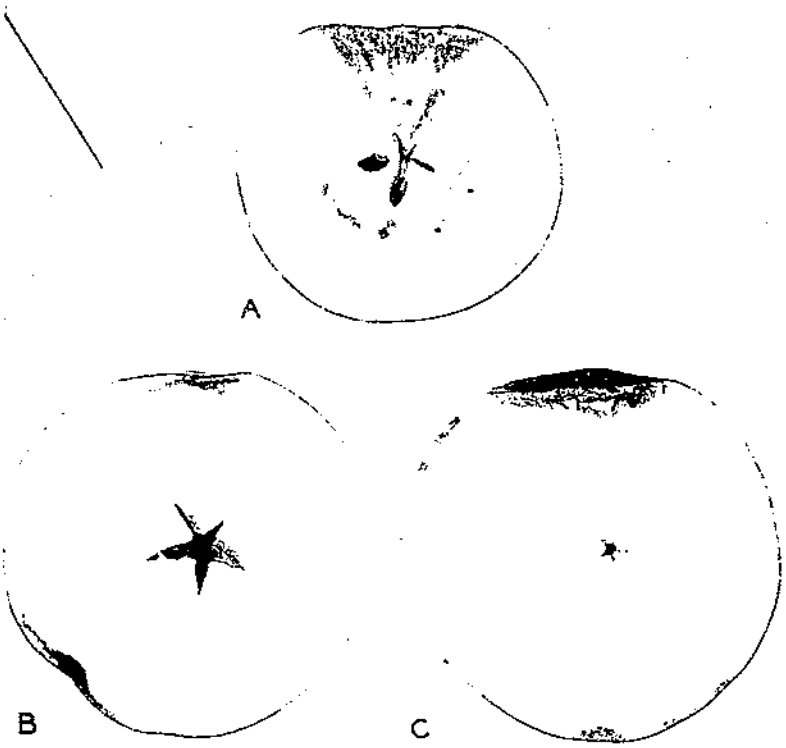
TYPICAL TRANSIT INJURY FOUND IN APPLE SHIPMENTS FROM THE PACIFIC NORTHWEST OR PRODUCED EXPERIMENTALLY.

A.—Exterior view of a Rome Beauty apple, showing severe transit injury in the form of a large, flattened, discolored, and water-soaked area. This apple was taken (in January) from the bottom layer of fruit in a commercially packed box which had lain on the false floor of a railway car during the transit period. There was no corrugated paper liner in the box.

B.—Exterior view of a Winesap apple, showing the same kind of injury as in A but in less pronounced form. The apple was taken from a commercial shipment in January. Note discolored streaks in the skin. No corrugated liner.

C.—Cross section of a Rome Beauty apple, from a commercial shipment in January, showing the transit type of injury *a* produced by pressure against the side of the box and two bruises *b* and *c* produced by pressure against other apples. No corrugated liner.

D.—Cross section of a Delicious apple, showing injury produced by jolting under pressure for four days at 70° F. No corrugated liner.



A, Cross section of a King David apple, showing a much flattened, bruised area in which a zone of browned flesh is present just under the skin, and below this is a conical water-soaked area extending to the core. This apple was taken from the tail end of a barrel which was unloaded in Jersey City, N.J., on September 17 after a 2-day journey from Front Royal, Va. The car was moved without refrigeration. B and C, Ordinary packing or handling bruises on Bonne Beauty apples, showing lines of fracture in the flesh, most of which are roughly parallel to the surface of the bruised area.

The glassy, water-soaked condition is commonly attributed to freezing in transit or in storage and has been the cause of much controversy among shippers, carriers, and receivers. Whether produced experimentally or observed in shipments of apples in railroad cars, it will be referred to in this bulletin as transit injury or the transit type of injury. The investigations herein reported were made in an effort to determine the cause of this condition and practical means by which it can be prevented.

HISTORICAL DATA

The effects of freezing on apples have been investigated by Carrick [2] and by Diehl and Wright,[3] but only under such conditions that while the fruit was freezing it was motionless and subjected to pressure. During both investigations, apples which had ice in their tissues were bruised, held for various lengths of time, and then allowed to thaw. They were then examined to determine the nature and extent of the injury produced.

Carrick [4] refers to a "darker triangular region shown in no. 4 [pl. III] and the three similar ones in no. 5" which were produced "by quickly applying a slight external force at these points while the fruit was still frozen." He also refers to a more severe form of the injury in which the triangular brown area extends to the core (his pl. VI, 1). He says;[5]

> The distinctive appearance of apples when sufficiently frozen and thawed, here assumed to be a manifestation of death, has been repeatedly designated by the terms *browning* and *discoloration*. In reality, the latter term often refers to some shade of brown or gray. The specific shade of color depends on the variety of apple, the severity of the injury, and the age of the lesion. These darkened areas, in whatever region they are observed, are usually water-soaked, and in less severe injury they appear somewhat translucent, as when ice is still present. When a large amount of tissue has been killed, the general effect is very suggestive of an overmature fruit which has become discolored in the absence of microorganisms.

Mention also is made of the frequent localization of browning in the fibrovascular bundles.

Diehl and Wright describe and illustrate much the same symptoms of freezing injury in apples as those described by Carrick, with a comment [6] that "bruises in hard frozen apples have a greater depth and are conical in shape with the apex reaching nearer to the middle of the fruit than on apples similarly bruised while unfrozen." They also note the condition in ordinary bruises mentioned earlier in this bulletin where lines of fracture appear approximately parallel to the surface.

In neither of the reports just discussed is there any description of an injury associated with freezing similar to the transit injury dealt with in this publication. The apple shown in plate 5, B, in the report by Diehl and Wright [7] has discolored areas in which there

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[2] CARRICK, D. B. SOME EFFECTS OF FREEZING ON MATURE FRUITS OF THE APPLE. N.Y. (Cornell) Agr. Expt. Sta. Mem. 81, 54 p., illus. 1924.

[3] DIEHL, H. C., and WRIGHT, R. C. FREEZING INJURY OF APPLES. Jour. Agr. Research. 29: 99–127, illus. 1924.

[4] CARRICK, D. B. Op. cit., p. 40.

[5] ——— Op. cit., p. 30.

[6] DIEHL, H. C., and WRIGHT, R. C. Op. cit., pp. 104–105.

[7] ——— and WRIGHT, R. C. Op. cit.

are bands or streaks extending inward toward the center of the fruit. These streaks do not have the water-soaked appearance, however, that is described on pages 2 and 6 of this bulletin and shown in plates 1 and 2.

Zimmerman[8] described the transit injury seen in bottom-layer boxes of apple shipments arriving in New York and, so far as the writers are aware, was the first to call attention to the value of paper pads in preventing it. His description is as follows:

> The bruises are large, flat, in many cases discolored, and extend into the flesh of the apple for some distance. * * * If the fruit actually has been frozen, the bruises are deep, glassy, discolored, and the discoloration extends into the flesh in a pyramidal shape, whereas the bruises on apples which have not been subjected to freezing temperatures in transit may be badly discolored (especially on large ripe Romes or Delicious), but discoloration does not extend into the flesh to as great a depth.

Results reported later in this bulletin show, however, that glassy, discolored bruises extending deep into the flesh can be produced in apples at temperatures well above freezing and therefore are not necessarily a sign of freezing injury.

EXPERIMENTAL WORK

The apples used in this investigation were grown in the Pacific Northwest. They were secured in November and December 1930 and in January 1931 and 1932 from commercial lots that were in cold storage at the time or had just been removed from such storage. Immediately after being purchased they were placed at 32° F. and held there until needed for the tests. The fruit was carefully sorted before being used, and bruised specimens removed. In any one season it probably was somewhat riper and therefore softer in the later tests than in the earlier ones, and for that reason was fairly comparable to commercial lots inspected at various times in New York City during the season (winter of 1930–31) in which most of the tests were conducted (p. 12). Temperature readings were obtained by means of single-junction copper-constantan thermocouples, of the kind described by Taylor,[9] used in connection with a galvanometer and a potentiometer.

FREEZING POINTS OF BRUISED AND UNBRUISED PORTIONS OF APPLES

Early in the investigation it was thought possible that the pressure exerted on the bottom layer of apples in transit might have forced some of the cell sap into the intercellular spaces of the fruit and that the temperatures encountered were low enough to freeze the cell sap but not the pulp. Accordingly, freezing-point determinations were made on bruised and unbruised portions of apples. The results are shown in table 1. Although the average freezing point of the bruised portion was slightly higher than that of the unbruised portion, it hardly seemed possible that the small difference in freezing points (0.15° to 0.44° F.) was sufficient to cause one portion of the apple to freeze while the remainder did not. Furthermore, in some instances the unbruised portion of one apple froze at a higher temperature than the bruised portion of another apple.

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[8] ZIMMERMAN, F. PAPER PADS IN FRUIT PACKAGES. Better Fruit 24 (11) : 10–11. 1930.

[9] TAYLOR, G. F. SOME IMPROVEMENTS OF THE NEEDLE-TYPE THERMOCOUPLE FOR LOW TEMPERATURE WORK. Jour. Indus. and Engin. Chem. 12 : 797–799, illus. 1920.

TABLE 1.—*Freezing points of bruised and unbruised portions of apples*

Variety	Average freezing point of bruised portions	Average freezing point of unbruised portions
	°F.	°F.
Rome Beauty	28.35	27.91
Stayman Winesap	28.93	28.60
Delicious	28.05	27.90

RATE OF COOLING OF APPLES IN THE BOTTOM LAYER OF A PACKED BOX

The rate of cooling in the upper and lower parts of individual apples in the bottom layer of a packed box of fruit was determined in order to find out whether it is possible for the lower part of the individual fruits to freeze while the upper part of the same fruits remains above the freezing point. The determinations were made after a box of fruit which had been held at 40° F. for a period of 6 days had been placed in a room held at 25°. This box was placed on a platform similar to the false floor used in a standard refrigerator car and was surrounded on the sides, ends, and top by other boxes of apples that had the same temperature. Just before freezing occurred the temperature of the bottom portion of the lowermost apples was 1° to 2.5° below that in the top portion of the same fruits, but freezing took place in all parts of an individual fruit at about the same time.

EFFECT OF FREEZING ON BRUISED AND UNBRUISED APPLES

Rome Beauty, Delicious, and Stayman Winesap apples, some of which had been purposely bruised, were subjected to a temperature of 21° F. for various periods up to 11 days in order to determine the relative effect of freezing on bruised and unbruised apples. In most cases a water-soaked area appeared under the bruises even after slight freezing. This injury apparently was not the same as the transit injury described earlier in this bulletin because the bruises characteristic of the transit injury are firm and darkened, whereas those produced in this experiment were soft and the only discoloration was a slight browning after freezing. Unbruised apples did not show injury until after prolonged freezing. In the Delicious only slight injury was noticeable on unbruised fruits after they had been frozen 3 days; Rome Beauty apples were very susceptible to freezing injury and the Stayman Winesaps were even more so.

EFFECT OF PRESSURE DURING AND AFTER FREEZING IN STATIONARY TESTS

In an attempt to determine the effect of pressure in producing the transit injury some stationary tests were conducted in which pressure equivalent to 10 pounds per apple was applied by weights. This is probably greatly in excess of the pressure sustained by an apple in a packed box. Pressure was applied to the apples (1) while they were freezing at 22° F., (2) while they were thawing, (3) while they were freezing and again while they were thawing, and (4) to unfrozen fruit held at 32°. The test included apples that were not bruised,

as well as bruised apples with the weight resting on the bruise. The varieties used in these tests were Delicious, Winesap, and Yellow Newtown.

In no case was the typical transit injury produced. Pressure while the fruit was thawing resulted in more severe injury and more of the water-soaked appearance than was found under any of the other three test conditions. Although some of the bruises produced by pressure while the fruit was thawing became dark colored they were always soft, whereas those characteristic of transit injury were firm. The bruises were hardly visible in the fruit which was subjected to pressure but not frozen. Pressure applied only while the fruit was freezing produced very slight injury; bruising before pressure was applied increased the total injury slightly.

SIMULATING TRANSIT CONDITIONS IN THE LABORATORY

In an effort to simulate transit conditions, particularly the jolting to which shipments are subjected while being carried to market by rail, an apparatus was constructed, consisting of a small wagon that ran on a metal track and passed over wooden cleats five eighths of an inch high, 38 times a minute. The box held about 15 pounds of apples if the fruit was packed so that the lid when fastened in place had a pronounced bulge. Rome Beauty, Stayman Winesap, Delicious, Winesap, and Yellow Newtown apples were jolted in this apparatus for 48 to 72 hours at 22° F.; Winesap, Delicious, Stayman Winesap, and Yellow Newtown were run at 26° for 96 hours. Tests were also run with Delicious, Yellow Newtown, and Winesap at 35° and 65° for 3 days. In each test some of the fruit was wrapped, and some was not. A box of fruit similarly packed was held at each temperature—not jolted—as a check. About half of the fruit was bruised before being subjected to these conditions. All the fruit was examined for injury immediately upon removal from the apparatus and after being held at room temperature for 2 to 3 days.

In none of these tests was the typical transit type of injury produced. A water-soaked area extending from the bruise radially towards the core appeared in most of the bruised apples that were jolted and frozen and in some of the bruised apples that were frozen but not jolted. The water-soaked condition was more extensive where the bruise was in contact with the top or the bottom of the box. The bruised places, however, unlike those characteristic of typical transit injury, were somewhat soft and usually not discolored on the outside. Only a trace of the water-soaked condition appeared in Yellow Newtowns.

Some of the water-soaked condition was found in bruised apples that were jolted but not frozen; however, there was less of it in the nonfrozen fruit than in that which froze during the experiment.

Because of the failure of the apparatus described heretofore to reproduce the transit injury, a larger truck was constructed (fig. 1), which was capable of carrying 3 bushel boxes of apples with a 200-pound weight on each box.[10] This truck ran on a steel track

[10] Tests of this apparatus by means of an impact recorder kindly lent by the Fruit Growers' Express Co., of Alexandria, Va., showed that the jolting it produces is about the same as that to which shipments are subjected in the ordinary type of refrigerator car.

and passed 38 times a minute over bolt heads projecting one fourth of an inch above the track. When the boxes with their weights were in place on the truck the whole load was wired down securely, to keep the shifting to a minimum. An extra board from the side of another apple box was placed between the weight and the top of each test box in order to distribute the applied weight as evenly as possible.

Northwestern-grown Delicious, Winesap, Esopus Spitzenburg, and Rome Beauty apples of medium size, commercially packed in standard bushel boxes, were used. The boxes were laid on their sides during these tests as they are when loaded into railroad cars. Unless otherwise specified there was no corrugated pad between the apples and the side of the box. The length of each test was approximately 92 hours. At 25° F., freezing started about 12 to 36 hours after the fruit was placed in this temperature.

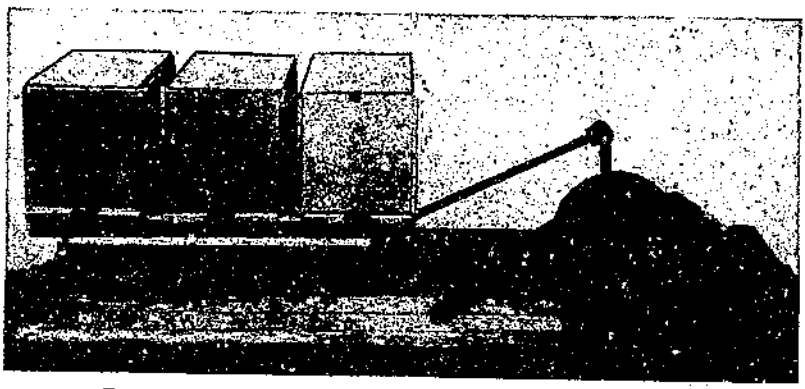


FIGURE 1.—Large apparatus used to simulate transit conditions.

The firmness of the fruit at the beginning of this series of tests, as determined by the pressure tester described by Magness and Taylor,[11] was as follows:

	Pounds
Rome Beauty	11.2
Esopus Spitzenburg	8.7
Delicious	9.0
Winesap	13.2

EFFECT OF JOLTING WITH AND WITHOUT PRESSURE AT FREEZING AND NONFREEZING TEMPERATURES

One box of each of the four varieties of apples was subjected to each of the following treatments:

Frozen; jolted; pressure.
Frozen; jolted; no pressure.
Frozen; not jolted; pressure.
Frozen; not jolted; no pressure.
Not frozen; jolted; pressure.
Not frozen; jolted; no pressure.
Not frozen; not jolted; pressure.
Not frozen; not jolted; no pressure.

[11] MAGNESS, J. R., and TAYLOR, G. F. AN IMPROVED TYPE OF PRESSURE TESTER FOR THE DETERMINATION OF FRUIT MATURITY. U.S. Dept. Agr. Cir. 350, 8 p., illus. 1925.

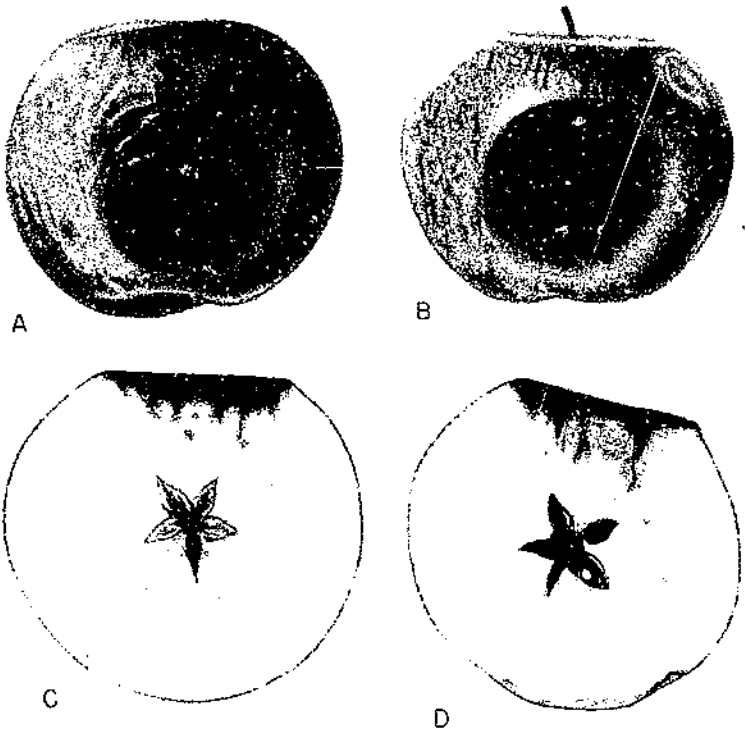
"Pressure" means that a 200-pound weight was placed on the box, and wired down as already noted. The apples that were to be frozen were kept in a room held at 25° F. Those to be tested without freezing were subjected to a constant temperature of either 40° or 70°.

The typical transit injury described earlier in this bulletin, with the exception of the type of injury shown in plate 1, A, was produced in most of the bottom layer of apples in boxes that were jolted at 25° F., both with and without pressure. It was also produced in apples in the same position which had been given the same treatment except that they were held at 40° during the test; that is, under conditions where freezing could not occur. The injury was slightly augmented by freezing as well as by the application of a 200-pound pressure on the box.

The bruising produced by the jolting apparatus on Rome Beauty apples at freezing and nonfreezing temperatures is shown in plate 3. That produced on Esopus Spitzenburg under these conditions is shown in plate 4. The transit injury was not produced by freezing alone or by pressure on the boxes when the boxes were kept motionless during the test. In a subsequent experiment the typical injury was produced in all four varieties at 70° F., which is further evidence that low temperature is not a factor in producing it. The wrinkling of the skin noted on some of the apples that froze during the test (shown in pl. 3, A) was also seen on apples jolted at nonfreezing temperatures.

The results of these tests indicate that the transit injury is not necessarily due to freezing. When fruits from the various tests just described were compared, it was found impossible to distinguish the injury produced by jolting at nonfreezing temperatures from that produced by jolting at 25° F., except in a few cases where the bruised spots in apples that had frozen were noticeably soft.

The finding of transit injury in boxes of apples that were jolted at 25° and at 40° F. without pressure from the outside shows that the weight of the apples in a packed box furnishes enough pressure to cause the injury. As a matter of fact, the pressure on the bottom layer of apples in a packed box at the bottom of the load in a refrigerator car is probably not much greater than that produced by the weight of the apples in the same box, above the bottom layer, as compared with the actual weight of the boxes above. Information on this point was obtained by partly supporting a box of apples at the ends, the portion between being allowed to rest on the platform of a set of scales and the weight registered on the beam being noted, and then setting five packed boxes of apples on top of this box, and again noting the weight. All of the boxes were laid on the side, as is done when they are loaded into railroad cars. The pressure exerted on the scales by a single box whose ends were supported was 15 pounds; placing five additional boxes on top of this box resulted in 26 pounds of pressure on the scales, an increase of only 11 pounds, which is very much less than the weight of the added boxes. Rocking the boxes back and forth increased this pressure only slightly and of course only momentarily.



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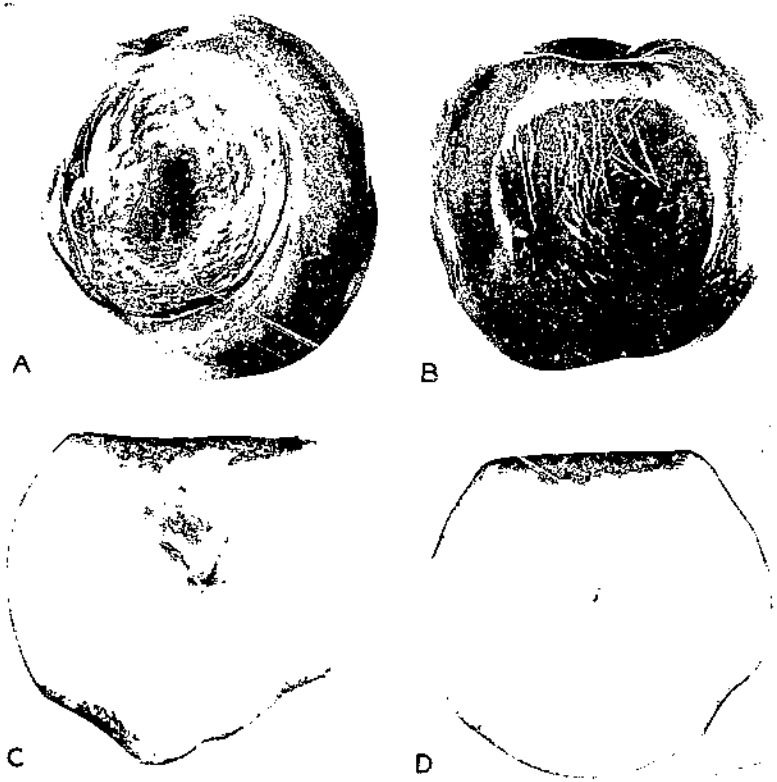
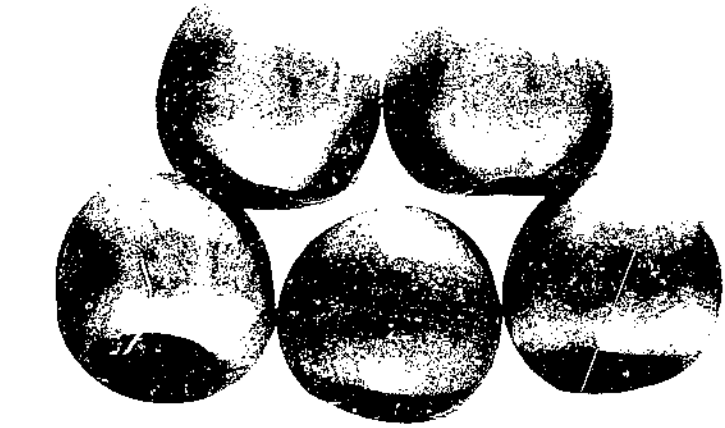
TYPICAL TRANSIT INJURY IN ROME BEAUTY APPLES, PRODUCED IN THE LABORATORY BY JOLTING FOR FOUR DAYS UNDER PRESSURE IN A COMMERCIALLY PACKED BOX.

A and C.—Frozen. Temperature during the experiment, 25° F.
B and D.—Not frozen. Temperature during the experiment, 40° F.
No corrugated liners.

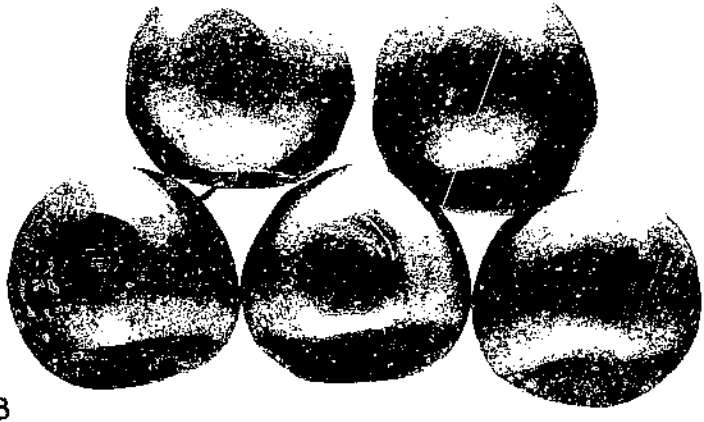


ESOPUS SPITZENBURG APPLES. SHOWING TRANSIT INJURY PRODUCED BY JOLTING FOR 4 DAYS

A and C, Frozen; temperature, 25° F. B and D, Not frozen; temperature, 70° F.



A



B

ROME BEAUTY APPLES SHOWING THE EFFECT OF JOLTING TWO COMMERCIALLY PACKED BOXES

One box was placed directly on top of another for 4 days. [illegible] apples were taken from the bottom layers of the respective boxes. There was no protection from the outside on the top box. A, From upper box; B, from lower box.

Boxes of apples in a railroad car are subjected to more or less jolting while en route from shipping point to market, the severity depending on the speed of the train, the type of springs under the car, the smoothness or roughness of the track, the manner in which the cars are handled in starting or stopping the train and in switching operations, and on the length of the rail journey. It seems highly probable that the jolting received by the bottom layer of apples in the bottom boxes in a railroad car is sufficient to cause the transit injury here under discussion, without the fruit having been in a frozen condition at any time during the transit period. In this connection, it is worthy of particular note that in barreled apples (p. 2) the typical transit injury can be caused by pressure alone. In this case the pressure to which the fruit at the tail end of the barrel is subjected is undoubtedly much greater than that existing at any time in boxes of apples packed and handled in the ordinary commercial manner. In barrels a single heavy application of pressure produces practically the same injury as that produced in boxes by a long-continued application of a small amount of pressure.

COMPARISON OF FROZEN AND UNFROZEN APPLES IN THE SAME BOX

Apples when subjected to freezing temperatures remain undercooled below their freezing point for various lengths of time before freezing occurs, even when jolted.[12] This fact was made use of in an effort to determine definitely whether there is a difference in the appearance of apples that freeze while being jolted and of those that do not freeze under such conditions. Standard boxes of each of the four varieties were run on the jolting apparatus at 25° F., with thermocouples placed in the bottom portion of each of the apples in the bottom layer. Winesap and Esopus Spitzenburg were run without pressure on the box; a 200-pound weight was placed on each of the boxes of Rome Beauty and Delicious. These apples were jolted on the apparatus until about half of them were frozen; the remaining ones were still undercooled but had not frozen. At the end of the jolting period all of the fruit was removed and held for 2 to 3 days at 40°, in order to defrost the frozen apples, and was then examined.

Typical transit injury was found in both the frozen and the unfrozen fruit, but, with the exception of a few of the frozen apples in which the bruised area was somewhat soft, there was no apparent significant difference between the apples that had actually been frozen and those that had undercooled but did not freeze. In other words, the results are further evidence that freezing is not necessary for the production of the injury. An interesting point in this connection is illustrated in plate 5, B, which shows the water-soaked, glassy condition alongside the hole made in a Rome Beauty apple by inserting a thermocouple. Slight movement of the thermocouple in the flesh of the apple while the box was being shaken was apparently sufficient to produce the condition shown. In this instance the pressure against the flesh must have been very slight.

[12] LUTZ, J. M., and WRIGHT, R. C. STUDIES ON THE UNDERCOOLING OF CERTAIN FRUITS AND VEGETABLES UNDER EXPERIMENTAL TRANSIT CONDITIONS. Unpublished manuscript.

EFFECT OF JOLTING ONE BOX DIRECTLY ON TOP OF ANOTHER

During this investigation the question was frequently raised, why apples in the lowermost layer of the bottom boxes in the car show the transit injury while apples in the same layer in boxes on top of these are injured less severely, if at all. If the injury were due to freezing it could be attributed to a temperature difference at various levels in the car sufficient to result in a localization of the injury near the floorboards, since it is a well-established fact that the temperature at the bottom of the load in a refrigerator car in transit is nearly always several degrees lower than that in other parts of the load.

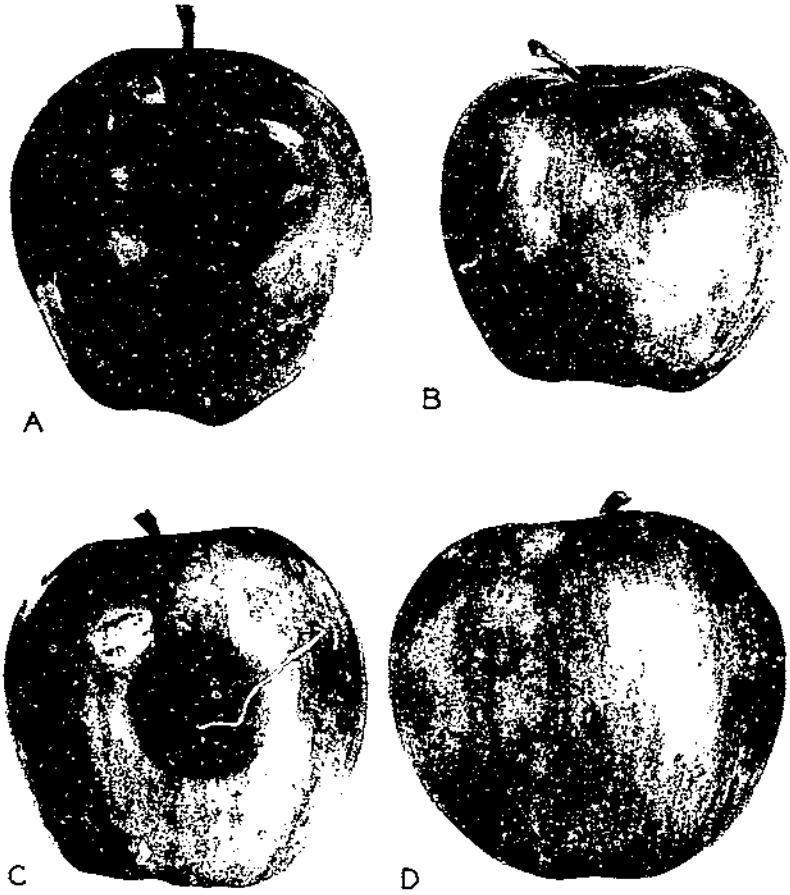
In order to secure information on this point, one box of apples was placed directly on top of another on the platform of the jolting apparatus and wired in place. This test was run with all four varieties at 40° F. and with Rome Beauty, Delicious, and Winesap at 25°. The typical transit injury was produced at both temperatures in most of the apples in the bottom layer of the bottom boxes (pl. 6, B), whereas only a trace of it was found in apples similarly placed in the top box (pl. 6, A). The most plausible explanation for the difference is that the bottom box of apples absorbed the shock which produced the transit type of injury and did not transmit it to the upper box. If this is the true explanation it probably accounts for the prevalence of the transit injury in the bottom layer of boxes in a railroad car, even when some of the apples at that location do actually freeze, since the evidence already presented indicates that freezing alone does not produce the injury. It might be argued that injury appeared in the lower box and not in the upper one because of the extra weight on the apples in the lower box. Against this it is only necessary to refer to the evidence already presented (p. 8), that the injury can and does occur in jolted boxes which have no weight on top of them.

EFFECT OF PLACING STRIPS UNDER THE ENDS OF TEST BOXES

It was thought that resting the ends of the boxes on a wooden strip might be of some value in preventing the bruising injury. Accordingly, standard boxes of apples, the ends of which were supported by 1- by 2-inch lumber, were jolted on the apparatus at 25° and 40° F. with and without pressure applied from the outside. Under these conditions typical transit injury was produced in all four varieties, similar to that found in boxes not resting on strips. Plate 7 shows the condition of apples from boxes in which a corrugated paper liner was used and of apples from other boxes whose ends were supported by strips.

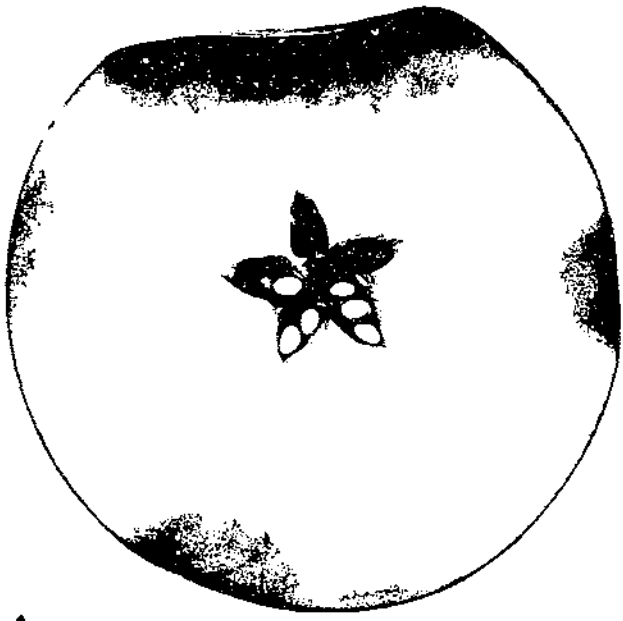
EFFECT OF STRIPS IN COMMERCIAL SHIPMENTS

During the winters of 1929–30 and 1930–31, about 20 shipments of apples in which the ends of the bottom layer of boxes were supported by strips were inspected in New York. Some of these had been prepared for test by the United States Department of Agriculture, and the others constituted part of an extensive series of tests inaugurated by one of the private car companies. It was found that the strips were of no value in preventing the transit injury.



DELICIOUS APPLES JOLTED FOR 4 DAYS APPLES TAKEN FROM THE BOTTOM LAYER IN THE BOX

A, Ends of boxes supported by strips but no corrugated paper used, 25° F. B, Corrugated paper placed between the fruit and the side of the box, no strips under the ends of the boxes; 25° F. C, Same as A, at 40° F. D, Same as B, at 40° F.



A

B

A, Rome Beauty apple, taken from a car unloaded in New York City on April 19, 1931, showing slight vascular browning in the deeper lying, browned portions of the injuries. Spots similar to these were found in ripe Rome Beauty apples subjected to jolting for 4 days at a temperature of 70° F. B, Longitudinal section of a Rome Beauty apple, showing a glossy, or translucent, water-soaked condition alongside of the hole made by thrusting a thermocouple into the flesh.

In fact, when a box slipped endwise, as frequently happened, so that one end rested on the false floor instead of on the strip and the other end rested on a strip at an angle, worse bruising resulted than if the strips had not been used.

EFFECT OF PLACING CORK, LITH, AND CELOTEX UNDER THE BOXES

Sheets of cork, lith, and Celotex were placed on the platform, and boxes of fruit were placed directly on each of these materials to determine their effectiveness in absorbing shock sufficiently to prevent bruising injury. The cork and lith were 2 inches thick, and the Celotex was one half inch thick. Typical transit injury was found in apples in the bottom layer of all the test boxes placed on these materials.

EFFECT OF PLACING LITH UNDER THE SHAKING APPARATUS

In order to test the effect of a yielding roadbed, 2-inch sheets of lith were built up into a block 12 inches high, 2½ feet wide, and 7 feet long in a room maintained at a temperature of 40° F. The shaking apparatus was set on this block and a 4-day test was run with commercially packed boxes of Rome Beauty, Delicious, and Esopus Spitzenburg apples, the boxes being laid on their sides on the carriage of the apparatus. No corrugated-paper liners were used. After the completion of the test the lith was removed, the apparatus was placed on a concrete floor, and a second test was run with apples from the same lot as those used in the first test. An examination of the two lots showed that more of the transit type of bruising had been produced when the shaking apparatus rested on the concrete floor than when it rested on lith.

EFFECT OF A FROZEN AND AN UNFROZEN BASE UNDER THE SHAKING APPARATUS

About the middle of January 1932 two other tests were run, with the same varieties as in those just described. In the first test the shaking apparatus rested on a relatively dry, unfrozen mixture of soil and gravel about a foot thick, confined by a wooden form; during the second test the gravel and soil mixture was kept frozen by means of brine coils connected with a refrigerating system. The brine coils were not installed until after the first test.

The boxes were jolted under pressure for approximately 96 hours. Examination at the end of that time showed typical transit bruising on the lower side of the bottom layer of apples in all boxes of both tests. In other words, the condition of the experimental roadbed seemed to have little or no effect on the amount of bruising produced in the fruit. Whether this holds under actual transit conditions during the shipment of apples by rail is a matter for further investigation.

EFFECT OF CORRUGATED-PAPER LINERS IN TEST BOXES

In an attempt to find a means of reducing or eliminating the transit injury, various boxes of fruit were prepared for test by placing a single corrugated-paper liner between the fruit and the side of the box which was to lie on the platform of the jolting apparatus. The boxes thus packed were jolted for 92 hours at 25°

and 40° F., with and without pressure. All four varieties were used. Inspection at the end of each test showed that there was much less of the bruising injury in the boxes containing corrugated liners than in those in which no liners were used. A slight amount of bruising appeared in some of the apples in boxes containing liners, especially when the fruit froze or had been subjected to the pressure of a 200-pound weight during the test, but it was far less serious than that occurring where the corrugated liners were not present. These results indicate that such liners would be an effective means of preventing bruising injury to apples under commercial conditions in transit, because of the protection they furnished against the injury under the extreme conditions to which the fruit was subjected on the jolting apparatus.

EFFECT OF CORRUGATED-PAPER LINERS IN COMMERCIAL SHIPMENTS

During the winters of 1929–30 and 1930–31, at least 50 shipments of apples in which the boxes either had been completely lined with corrugated paper or had corrugated paper next to the sides were inspected on the New York market. Some of these shipments were prepared for test by the United States Department of Agriculture, but most of them were ordinary commercial shipments. The transit injury was not found in any of the fruit in these cars but did appear, apparently in the form observed by Zimmerman [13] in 1930 and earlier, in fruit in the bottom layer of boxes from commercial shipments in which the corrugated paper liners had not been used. A few cars of apples were observed (prepared for test by the U.S. Department of Agriculture) in which the corrugated-paper liners were used in only part of the boxes in the car. Under such conditions the injury was not present in the bottom-layer boxes that had the corrugated-paper liners between the fruit and the side of the box, but did occur in the bottom-layer boxes that did not have such liners.

These observations and the results obtained with the jolting apparatus show the advisability of lining the sides of apple boxes with corrugated-paper liners if the bruising injury is to be avoided.

EFFECT OF CORRUGATED-PAPER PADS IN BARRELS

The failure of the pad to protect apples in barrels is undoubtedly due to the heavy pressure required to force the head into position. There is ample evidence at least that the fuller the barrel (and consequently the greater the pressure required in heading it), the greater is the damage from bruising.

Investigations made at a packing house at Hancock, Md., showed that when barrels are filled so that the apples stand an inch and a half above the top of the staves, about four times as much bruising is produced by the heading operation as when the apples come only to the top of the staves. In either case most of the severe bruises, if examined 2 or 3 days after the barrels are filled, show the water-soaked condition already described. After the fruit has been in headed barrels for a month, bruised spots on being cut no longer show the water-soaked condition but are dry and corky.

[13] ZIMMERMAN, F. Op. cit.

EFFECT OF MATURITY OF THE FRUIT

During the latter part of the shipping seasons of 1929 and 1930 some of the transit bruises were rather soft in fruit in the more advanced stages of maturity. A similar condition was observed during the laboratory tests. It should be noted also that in tests with Rome Beauty apples which were eating ripe and were jolted with and without pressure, at temperatures of 40° and 70° F., a few bruises were found in which the flesh was brown throughout but not fractured; in the same lots of apples there were other bruises which had a quarter-inch layer of water-soaked flesh next to the skin, and underneath this was a brown zone of unfractured flesh one fourth to one half an inch deep. The latter is illustrated in plate 5, A. In both types of injury there was slight but distinct browning of the smaller vascular bundles. Both types are generally considered definite indications of freezing injury, but both were found in apples which could not have frozen during the experiment and were known to have been free of bruises at the beginning of the experiment. The bruises in which there was browning of the small vascular bundles were not restricted to the side of the apple which lay against the lower side of the box.

The wholly brown bruises with vascular browning just described had very much the appearance of those figured by Carrick on his plate III, 4 and 5.[14] When considered with the other results of this investigation, they justify the statement that the jolting of commercially packed boxes of apples at nonfreezing temperatures with or without pressure applied from the outside is able to cause all of the visible symptoms commonly recognized as characteristic of freezing injury, except the browning of the large vascular bundles near the core, the extensive killing of tissue mentioned by Carrick (see p. 3 of this bulletin), and the very large bruised areas similar to the one shown in plate 1, A. Such areas are gray or slate colored over nearly the whole surface; they are also noticeably sunken; and the flesh underneath them is rather soft. The injury, as already noted, usually occurs on the under side of the lowermost layer of apples in the box.

SUMMARY

A peculiar type of transit injury of apples is described which is found most commonly at the bottom of loads of boxed apples in railroad cars.

A description is also given of a somewhat similar type of injury found in barrels and baskets of apples when considerable pressure has been used to force the head or the cover into place.

The occurrence of the injury cannot be ascribed to the small difference in freezing point of bruised and unbruised portions of the apples or to the difference in the rate of cooling of the upper and lower portions of individual apples.

Attempts to produce the injury in stationary tests were unsuccessful.

The typical transit injury was produced at freezing and nonfreezing temperatures by simulating transit conditions; that is, by jolting apples in commercially packed boxes, with and without pressure

[14] CARRICK, D. B. Op. cit.

from the outside. The only visible symptoms of true freezing injury which have not been produced by this treatment are the browning of the large vascular bundles, usually 10 in number, around the core, the extensive killing of tissue found in severely frozen apples, and the large gray or slate-colored sunken areas similar to the one shown in plate 1, A.

It is impossible to distinguish the transit injury produced at freezing temperatures from that produced at nonfreezing temperatures except in occasional fruits in which the bruised area becomes somewhat soft after having been frozen. However, this softening is sometimes found in bruises on fairly ripe fruit which has been bruised while not frozen.

Corrugated-paper liners placed next to the sides in boxes of apples eliminated practically all of the bruising or transit injury both in the laboratory and under actual transit conditions. Wooden strips placed under the ends of the boxes were of no value in preventing the injury in the laboratory tests or under actual transit conditions. In barrels, the placing of a corrugated-paper pad on the fruit after the barrel is filled but before it is headed up seems to have no effect in preventing bruising and the transit type of injury.

Cork, lith, or Celotex placed under the bottom layer of boxes were of no value in laboratory tests in preventing the transit type of bruising.

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