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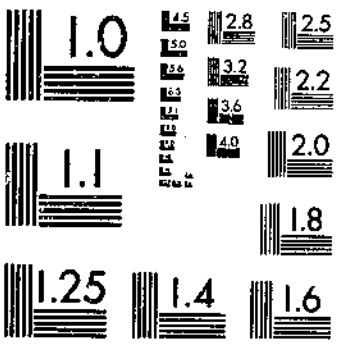
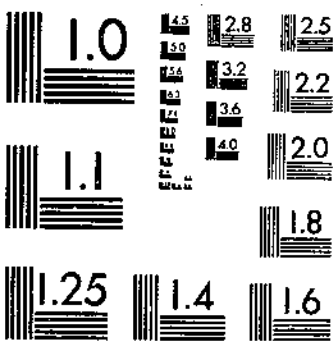


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



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Bruising, Freezing, and Chemical Injury of Potatoes in Transit[1]

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INTRODUCTION

Claims are frequently made by produce dealers of damage to potatoes next to the floor or floor racks of the railroad cars and trucks in which they are shipped. During the winter the injury often is attributed to freezing; at other times it may be attributed to the action of salt, fertilizer, or other chemicals present on floors or walls of carriers. It has been determined that in most cases such damage is caused by bruising when the potatoes are pressed or jolted, by weight of the load and movement of the car, against the floor and walls of the carriers in which they are shipped.

All such injured potatoes that have been examined have shown unmistakable signs of bruising, which varied from unbroken but flattened areas plainly showing the imprint of the bag to badly bruised areas. Injury of this type occurs only in potatoes loaded in sacks or in bulk. In some growing sections, bushel boxes or crates have recently come into rather general use as shipping containers. However, no transit injuries such as described herein have been reported in shipments made in these containers.

[1] Submitted for publication August 13, 1938. Revision submitted July 10, 1951.

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DISCUSSION OF PROBLEM

Transit Bruising

A common method of loading sacked potatoes in cars is to pile the bags five or six stacks high on their sides. Another method is to stand the first layer of bags on end and then place two or three layers of bags on their sides over the first layer. The pressure thus exerted on the potatoes next to the floor may range from 200 to 300 pounds per square foot.

As shown hereafter the amount of bruising injury caused by this pressure depends not only on the jolting the tubers receive in transit but also on their condition as influenced by treatment after harvest and before shipment. Thus the amount of bruising may vary from season to season or between growing sections. Much bruising occurs in transit in newly dug, early potatoes. Most of the early and mid-season potatoes are more or less immature when dug; the tissues are therefore quite turgid and fragile and the skins very tender and easily broken. These potatoes are usually sacked and loaded into cars within a few hours after being dug. When they arrive at destination, following ordinary commercial handling, they are generally found to be more or less skinned or "feathered" (fig. 1) and those in contact with the floor or the floor racks in the bottom sacks show definite bruising injury as well (fig. 2). Bruising in transit, caused by contact with the car floors, also occurs in old or well-matured potatoes (p. 7).

Floor bruising can be identified by a flattening and softening of the areas in contact with the floor or floor racks and by the fact that such areas usually show the imprint of the bag and generally are moist after being unloaded (fig. 3). Ruptured tissues may also

FIGURE 1.—Badly feathered, newly dug, White Rose potatoes on arrival at market. Most of the skin has been rubbed off or loosened and the potatoes are wilted and "rubbery."

FIGURE 2.—Newly dug White Rose potatoes showing both feathering and floor bruising on arrival at the market. The potatoes were taken from the bottom layer of sacks from the side next to the floor. The flattened areas show where the potatoes rested on the floor.

be found extending well into the tuber, and when these wounds are cracked open sufficiently to admit air, discoloration of the tissues may result. The rupturing of the tissues incident to bruising permits the evaporation of cell sap, leaving behind an accumulation of starch that may be seen as a tough, compact, whitish layer below the wounded surface (fig. 1).

The bruised tissues are subject to decay, particularly bacterial soft rot and fusarium rot, which may develop to such an extent as to mask the primary cause of injury (fig. 5). Bacterial soft rot (often called slimy soft rot) causes a softening of the infected tissue, which usually becomes moist and slimy, or sticky, and has a characteristically foul odor. This rot might be mistaken for freezing or chemical injury because of the softening and discoloration of the affected tissues and because of the likelihood of its following freezing or chemical injury, neither of which, however, will cause sliminess or foul odor. Furthermore, when such infected tubers are dried off there is usually left a whitish residue which resembles a chemical deposit in appearance. When not complicated by other forms of injury this rot is characterized by a sharp line of demarcation between healthy and infected tissues. Fusarium rot somewhat resembles freezing injury in the discoloration of underlying tissue which it produces, but it is usually characterized by a visible mold growth, which differentiates it from freezing injury.

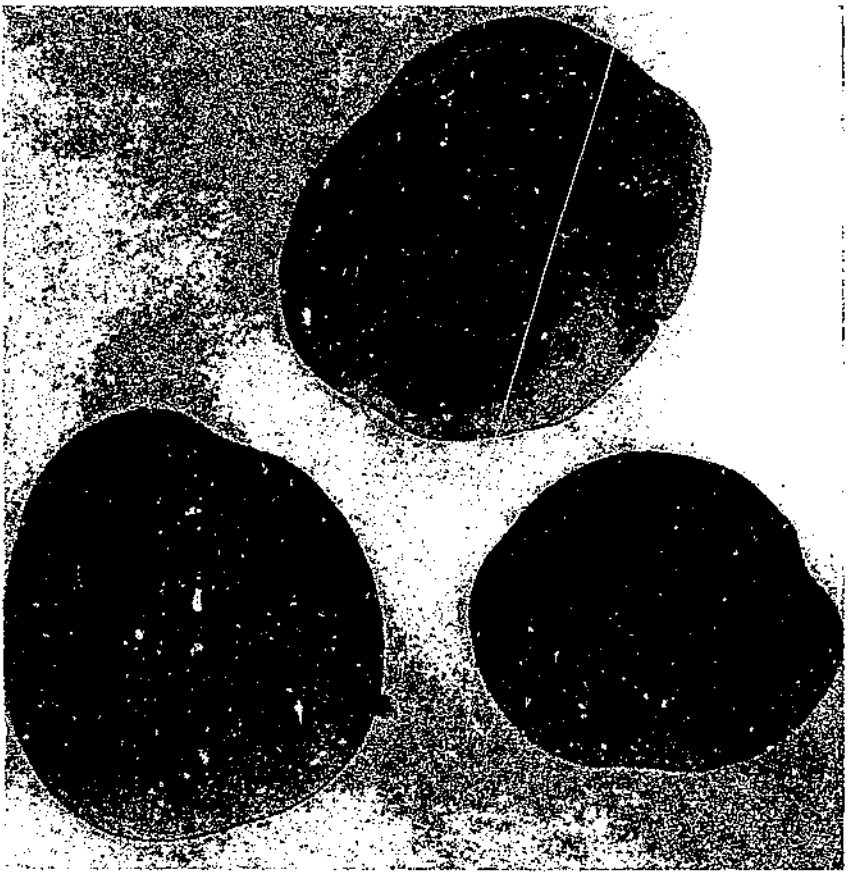


FIGURE 3.—Flattened, bruised areas on potatoes from the under side of the sack showing where they rested on the floor of the car. These potatoes had been dug for some time and were, therefore, not turgid or brittle. Although the bag imprint is unusually clear, very little injury resulted since the wounded area was shallow and soon healed over.

FIGURE 4.—*Left*, severe floor bruising in a potato from a commercial carlot. *Right*, the same potato with a portion of surface of the healed-over area removed, showing the feathery and compact whitish layer caused by the deposit of starch left when the wounded tissue dries out.

FIGURE 5.—Floor bruising that has been followed by secondary decay, which is just becoming apparent.

BRUISING OF EARLY CROP POTATOES

The ordinary handling of newly dug early crop potatoes in sacks always results in more or less skinning or feathering. The more immature the potatoes are the worse this condition will be. Shipments have been seen in which most of the potatoes in each bag have been found almost entirely skinned on arrival at the market (fig. 1). Because of loss of water due to evaporation from the unprotected sur-

faces such potatoes soon become wilted and soft. Where they press against each other discolored dents or depressions usually are produced in the tubers at or near the floor (fig. 6). When the tubers also show floor bruising those in the bottom layer of the sacks present

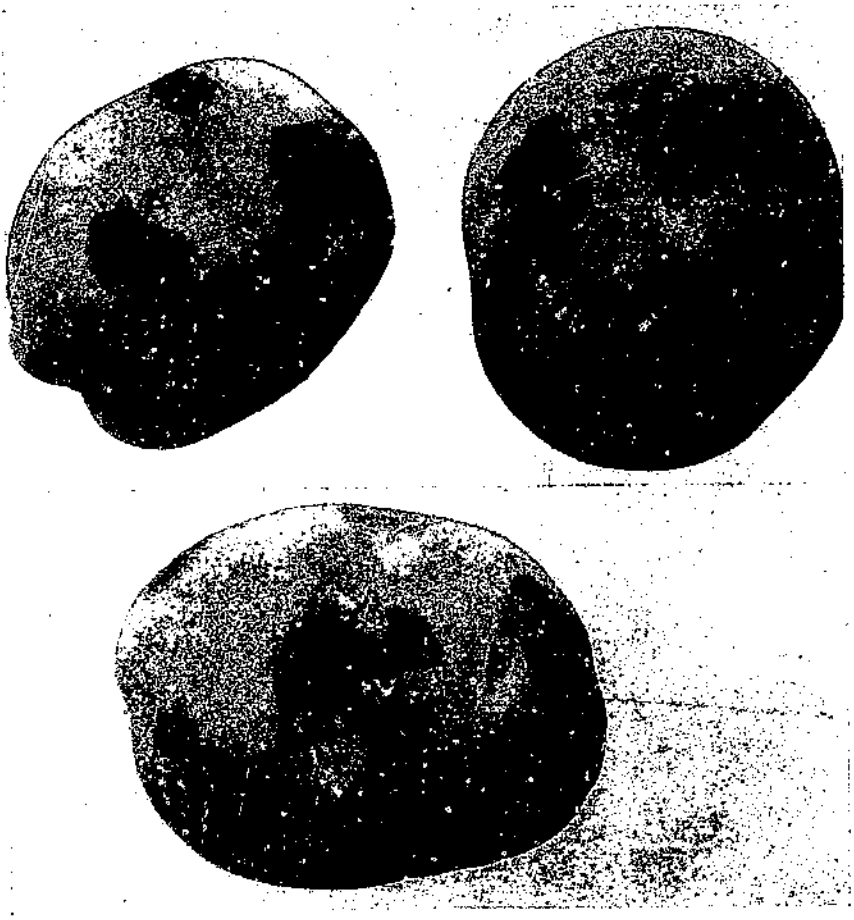


FIGURE 6.—Bruises on sacked potatoes from the bottom of a commercial carlot. The bruises were caused by contact of the potatoes with each other. This is not floor bruising.

such an unattractive appearance that their market value is materially reduced. Pads are sometimes used to prevent floor bruising. The padding material may be loose shredded paper, manufactured pads consisting of shredded paper between two layers of paper glued together along the edges, or excelsior in paper sleeves.[2]

[2] BARGER, W. R., SHEAR, E. V., and MORRIS, L. L. THE PREVENTION OF MECHANICAL INJURY DURING TRANSIT OF NEW-CROP POTATOES. Calif. Agr. Expt. Sta. [Unnumb. Pub.], 7 pp., illus. 1945. [Processed.]

ROSE, D. H. HANDLING AND SHIPPING EARLY POTATOES. U. S. Dept. Agr. Cir. 744, 44 pp., illus. 1946.

UNION PACIFIC RAILROAD. DEPARTMENT OF TRAFFIC, AGRICULTURAL DEVELOPMENT. HANDLING POTATOES. 63 pp., illus. Omaha, Nebr. [1950.]

BRUISING OF OLD POTATOES

Under ordinary handling the bruising damage occurring to old potatoes coming from storage is not generally so great as that to early crop potatoes because the skins have become "set" or toughened, and through loss of water the potatoes are less turgid than at harvest. However, more or less bruising occurs even to old potatoes, because they are usually shipped during the winter in refrigerator cars that have slatted floors or floor racks. It is a common practice to cover the floor racks with building paper to minimize any bruising damage that might occur from these slats. Pads are sometimes used.

It has been demonstrated by Edgar [3] that the temperature of the potato greatly influences its susceptibility to mechanical injury. He found that commercial lots of potatoes that had been warmed in the bin from about 35° to 50° F. just previous to being graded remained dry and free from cracks and skin abrasions. When passed over the same grader, those that had not been warmed up showed at least 50 percent with fresh cracks or bruises, and were damp because of the escape of sap.

FREEZING INJURY

The symptoms of freezing injury to potatoes have been extensively studied and described.[4] Potatoes may be frozen so severely that all their tissues are killed; less severe freezing results in the killing of only a part of the tissues. Frozen potatoes are usually found scattered among uninjured ones. Those that are frozen to death will upon thawing begin to ooze water through the skin. These are commonly known as leakers and are of course unsalable and must be sorted out very soon to prevent their wetting and staining the surrounding uninjured tubers. If sorting is delayed these potatoes will soon decay and collapse since they furnish a very favorable medium for the organism causing bacterial soft rot. The decaying fragments from one such potato will sometimes contaminate and ruin the salability of many of the surrounding ones.

Potatoes not so severely frozen as to become leakers can usually be discovered and identified only by cutting into tubers 6 to 12 hours after thawing. At this time the vascular tissues will usually be discolored to a blue gray or black. This discoloration will occur in different patterns depending on the length and severity of exposure to freezing temperatures. A portion of the vascular ring that is located about a quarter of an inch in from the surface of the potato may be discolored, or may show a generally darkened netting, dotting, or blotching of the cut surface (fig. 7). The net and ring types of freezing injury are not to be confused with ring necrosis and net

[3] EDGAR, A. D. STUDIES OF POTATO STORAGE HOUSES IN MAINE. U. S. Dept. Agr. Tech. Bul. 615, 47 pp., illus. 1938. Out of print; may be consulted in libraries.

[4] JONES, L. R., MILLER, M., and BAILEY, E. FROST NECROSIS OF POTATO TUBERS. Wis. Agr. Expt. Sta. Res. Bul. 46, 46 pp., illus. 1919.

WRIGHT, R. C., and DIEHL, H. C. FREEZING INJURY TO POTATOES. U. S. Dept. Agr. Tech. Bul. 27, 24 pp., illus. 1927. Out of print; may be consulted in libraries.

RAMSEY, G. B., WIANT, J. S., and SMITH, M. A. MARKET DISEASES OF FRUITS AND VEGETABLES—POTATOES. U. S. Dept. Agr. Misc. Pub. 87, 60 pp., illus. 1949. (Revised.)

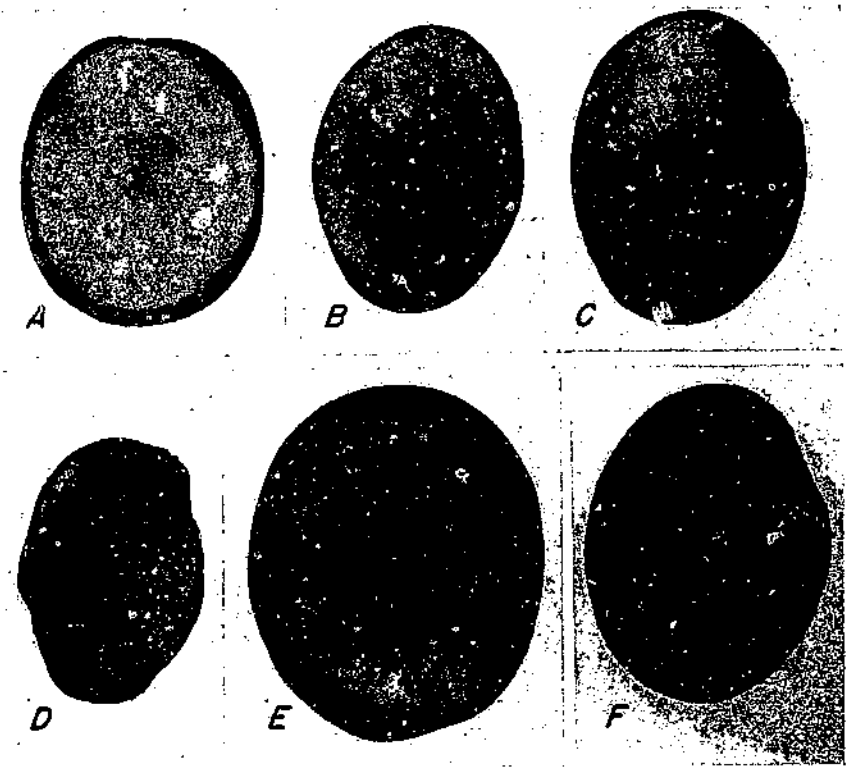


FIGURE 7.—Freezing injury without evidence of floor bruising in potatoes from a commercial carlot: *A*, Slight injury, marked by a trace of ring-type necrosis; *B*, *C*, and *D*, blotch type together with the ring and net types. *B* is beginning to decay at the center and *D* has been entirely frozen to death, showing a general breaking down with decay; *E* and *F*, combinations of ring and net type of injury.

necrosis, both of which originate in the field.[5] Ring necrosis is attributed to *Fusarium* invasion and is differentiated from the ring type of freezing injury by having a reddish-brown rather than black discoloration and by being more strictly localized in the vascular ring. The ring type of freezing injury is often accompanied by net and blotch types. Net necrosis is a manifestation of the virus leaf roll disease. The discoloration by this disease is also generally reddish brown as opposed to the bluish gray of the net type of freezing injury. Except for color, both of these diseases can be easily mistaken for freezing injury. Where freezing has occurred, various types and degrees of injury will usually be found in individual potatoes, whereas in a lot affected with ring necrosis or net necrosis nearly all the affected potatoes will show the one characteristic type of injury.

Although mild to moderate freezing injury is not apparent on the outside of tubers, the internal discoloration renders the potatoes undesirable for use as table stock. The most convenient method of determining the presence of such freezing injury is to slice off a por-

[5] See first and third references, footnote 4.

tion of the stem end of a suspected tuber, as this is where symptoms of such injury are usually first apparent. The viability of seed stock that has been frozen is likely to be impaired. Secondary decay is not likely to follow mild freezing injury; the decay may follow, however, when the injury is more severe but not enough to entirely kill the tissues. The interior then becomes blotched over extensive areas.

As a rule, most of the potatoes frozen in transit are so severely injured that they are badly blotched or become leakers. Fewer specimens show the milder forms of injury, such as are marked by the ring or net type of necrosis. Doubt often exists as to whether freezing injury found in a given carlot occurred during transit or during previous storage. In such cases it is helpful to know that freezing injury that occurred in storage before shipment is likely to be found scattered throughout the load, whereas that due to freezing in transit will be found mostly localized along the floor and walls and around the doorway of the car. Since freezing in transit occurs largely along the floor of the car, this injury is often found in conjunction with floor bruising. Careful observations of commercial shipments, however, have shown that, in the same carlots, freezing injury and floor bruising may occur independently or together in the same specimens (fig. 8).

Chemical Injury

Chemical debris left on the floors or walls of railway cars, motortrucks, or ships' holds, or chemicals impregnated in the woodwork of such carriers, have frequently been reported as the cause of injury to potatoes in transit. Ramsey and coworkers[6] state that potatoes are sometimes damaged by contact with various chemical salts, asphalt, coal tar, and oil products. They also state, however, that mere contact with these substances is not sufficient to produce injury, but that if the substances are pressed or rubbed into the tissue, the characteristic symptoms will develop. The symptoms are marked especially by a soft, flabby, semiwatery condition adjacent to the point of contact. This condition is caused by exosmosis, or the loss of water from the cells of the tuber, brought about by the action of the chemicals. After several hours' exposure, the affected tissue sometimes becomes discolored to a gray or black.

The shipment of fertilizers or other chemical materials in refrigerator cars is not authorized. Chemical injury in potatoes from one of these cars may be caused by the use of picking bags previously used for fertilizer or by contact of the potatoes with injurious materials while being transported to the car. Under normal handling the skins of tubers will be broken enough to allow entry of the injurious materials. Such injury can also result when bags of potatoes are temporarily stacked on dirty storage floors or platforms. During emergencies potatoes may be carried in ordinary boxcars; often bulk lots are so transported. Large amounts of potatoes are now being taken to market in motortrucks. Both motortrucks and boxcars are used for the transportation of industrial chemicals and fertilizers, such as common salt, sodium nitrate, ammonium sulfate,

[6] See third reference, footnote 4.

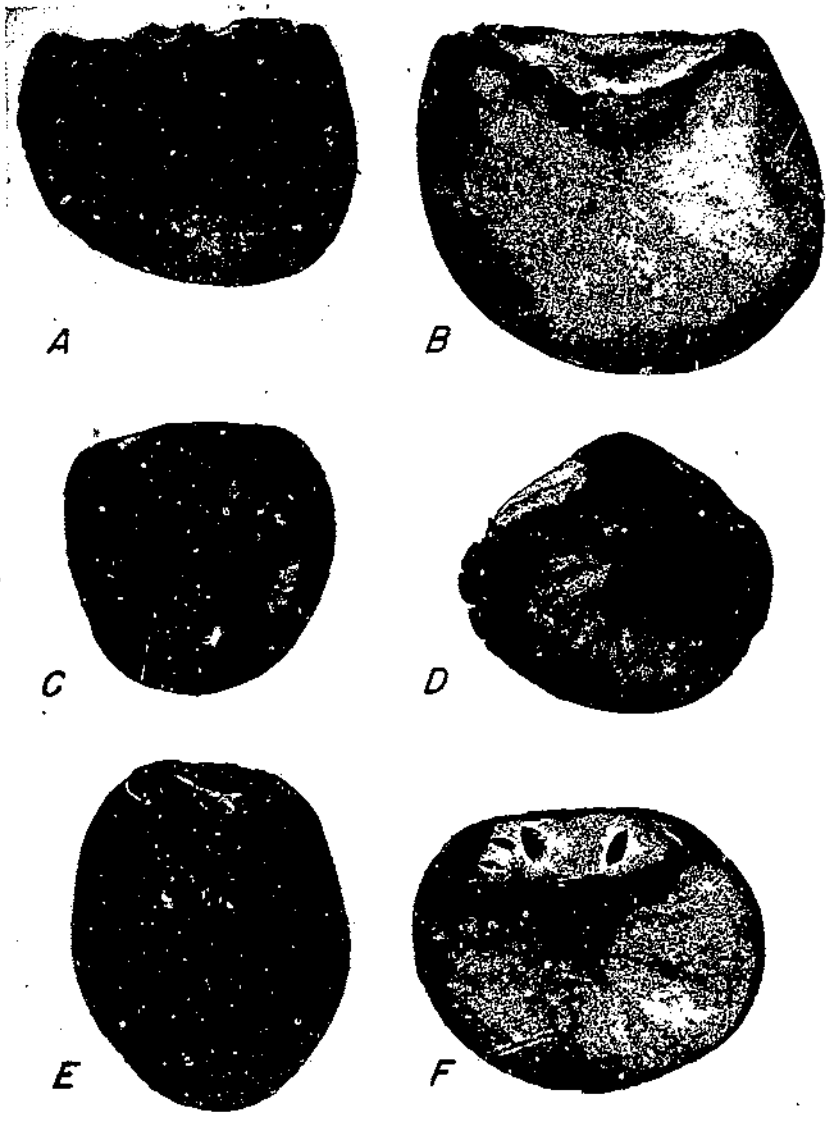


FIGURE 8.—Freezing injury and floor bruising in potatoes from a commercial carlot. The potatoes were taken from the same car as the specimens shown in figure 7: *A*, Small blotchlike frozen area on one side of the tuber that apparently is not related to the bruised area; *B*, typical vascular-ring-type freezing injury with soft decay shown developing below the bruise that may be due to freezing; *C* and *E*, freezing necrosis of the vascular ring; *D* and *F*, severe freezing injury followed by decay adjacent to and involving the bruised areas.

superphosphate, ground limestone, hydrated lime, gypsum, and various commercial fertilizer mixtures. Salt, sodium nitrate, ammonium sulfate, and many other substances are readily soluble in water and are therefore active plasmolyzing agents; that is, under certain conditions they will withdraw water from plant tissue (fig. 9). Superphosphate and the usual types of commercial mixed fertilizers have only a relatively small percentage of water-soluble material. Ground limestone, hydrated lime, and gypsum are quite conspicuous when present but because of their insolubility are relatively noninjurious.

Through the courtesy of the fruit and vegetable inspection service of the Production and Marketing Administration, the writer has had opportunity to examine samples of potatoes from a number of carlots about which receivers had complained of chemical injury. In most of the cases investigated the injury was actually caused by floor bruising. In rare instances where evidence of chemical injury was present it was associated with floor or wall bruising, indicated by the usual flattening of one side of the tubers, with the bag prints plainly evident.

Sunscald, as the name implies, is a form of heat injury to newly dug potatoes, which is caused by exposure to the rays of the sun during hot weather. Because of the similarity of results, sunscald is sometimes mistaken for chemical injury. In both cases the tissues break down, become soft, and decay. The organism causing this breakdown and decay is the same as that causing bacterial soft rot (p. 3). In this case, however, it causes a slimy "puffy" condition beneath the epidermis and produces a foul odor which is not found in connection with chemical injury.

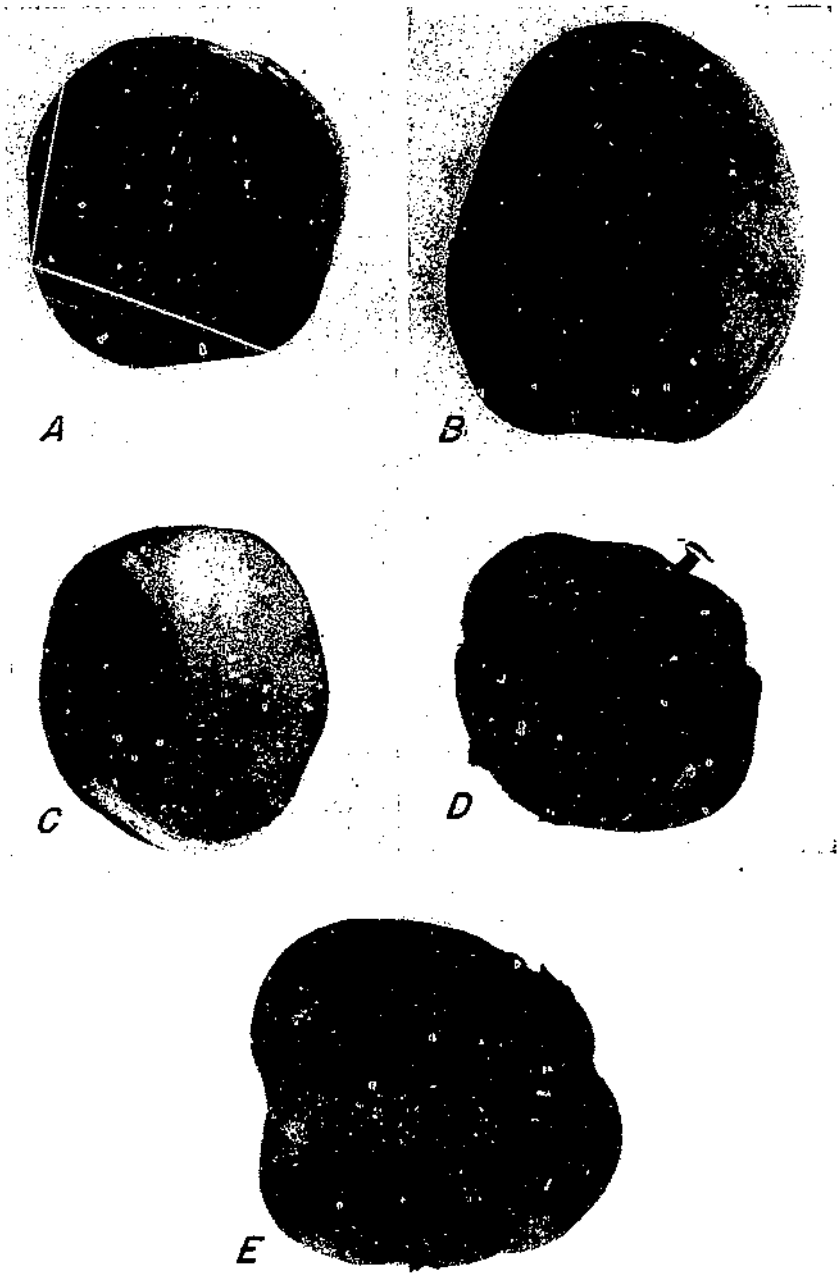
METHODS AND RESULTS OF EXPERIMENTAL TESTS

The similarity of the injury caused by floor bruising, shown in many lots of potatoes on arrival at the market, to the injury caused by chemical and freezing damage, resulted in a study to determine the distinguishing symptoms of these three types of injury. The scope of this study embraced (1) the effect of tissue temperature on susceptibility to bruising; (2) the relation of floor bruising to freezing injury; and (3) the relation of floor bruising to chemical injury. Much of this work consisted of a series of laboratory tests made with the apparatus described by Rose and Lutz[7] in order to simulate actual transit conditions. Briefly, this apparatus consisted of a small car, which was operated back and forth over steel tracks. Bolt heads projected just above the rails so that when the wheels passed over them, the car was jolted and swayed somewhat like a railroad car in transit.

Tissue Temperature and Bruising

The first of a series of tests to study the relation of tissue temperature to bruising in transit was made with mature Maine-grown Green Mountain potatoes purchased on the Washington, D. C., market. When received, the potatoes were divided into three portions, two of

[7] Rose, Dean H., and Lutz, J. M. Bruising and freezing of apples in storage and transit. U. S. Dept. Agr. Tech. Bul. 370, 15 pp., illus. 1933. Out of print; may be consulted in libraries.


A
B
C
D
E

which were stored at constant temperatures of 32° and 50° F., respectively; the third was kept in a storage cellar where the temperature varied between 36° and 60° but averaged about 50°.

In these tests two burlap bags, each holding about 1 peck, were filled with potatoes and placed on the car. A wooden platform carrying 450 pounds of weights was placed atop the potatoes. In each test the apparatus was installed in a storage room at the temperature indicated in table 1 and was operated for 7 hours on 2 successive days and for 4 hours on the third day. The potatoes were inspected 4 days after the termination of each test, and the number of tubers showing bruises accompanied by skin breaks was determined. Most of the injury occurred next to the floor; but in some cases the potatoes on the top side of the bags were bruised by the overhead weight, whereas a few specimens were bruised and cracked where they came in contact with each other. Some of those classed as sound were somewhat flattened where they rested on the floor and showed the imprint of the bag at these places, but the skins were unbroken. The results of these tests are shown in table 1. The injuries resulting from floor bruising thus experimentally produced were always similar in appearance to those commercially produced where it was certain that other complicating factors were not present.

TABLE 1.—*The influence of tissue temperature on the amount of bruising sustained by potatoes subjected to experimental transit jolting*

Test No.	Previous treatment	Temperature of test room	Results	
			Sound potatoes	Bruised potatoes
		° *F*	*Percent* [1]	*Percent*
1	Stored at 32° F. for approximately 3 months	32	35	65
2	Stored at 50° F. for approximately 3 months	50	69	31
3	In cellar storage for approximately 3 months less 3 days in 32° F. previous to test	32	46	54
4	In cellar storage for approximately 3 months less 7 days in 50° F. previous to test	50	68	32

[1] Based on total number of potatoes in each bag.

FIGURE 9.—*A*, Bruised potato after standing in contact with nitrate of soda. Area adjacent to the bruised surface is soft and wrinkled to a depth of one-fourth to one-half inch. *B*, Bruised potato after standing in contact with 5–10–5 commercial fertilizer mixture. No injury present, wounded area firm and mostly healed over. *C*, Discoloration produced in a bruised potato by contact with nitrate of soda. *D* and *E*, Bliss Triumph potatoes taken from next to the floor of a commercial carlot. Sulfates predominated in the debris on the car floor, and the potatoes show unmistakable evidence of chemical injury.

When potatoes from tests 1 and 2 were compared, more than twice as much bruising was found in the lot from storage at 32° F. as in that from 50°. The type of injury that occurred in the potatoes from 32° storage was different from that in tubers from 50° in that rather severe cracking accompanied the usual flat bruising, probably because the potatoes were more turgid and brittle. Tests 3 and 4 were made with potatoes from the same lot that had been held in cellar storage for approximately 3 months. In test 3 a portion of this cellar-storage lot had been put into the 32° room for 3 days previous to the test in order to bring the tissue temperature to that of the room. This test was then run in the same manner as test 1 where the potatoes had been stored continuously at 32° for approximately 3 months. It is interesting to note that the amount of bruising in test 3 was not so great as that in test 1 but greater than that in test 2 where the run was made at 50° with potatoes from the same temperature. The results from test 4 where the potatoes from the cellar storage with its fluctuating temperature were held at 50° for 1 week immediately previous to the test are practically the same as in test 2.

These tests show that the temperature of potatoes at the time of bruising largely determines the amount and extent of injury resulting, although the previous storage temperature may have considerable influence.

Floor Bruising and Freezing Injury

During the winter shipping season, reports of damage claimed to be freezing injury in potatoes in the bottoms of sacks are sometimes made because of symptoms which are similar to such injury. These symptoms are: (1) The presence of moist, soft, flattened areas on tubers resting on the floor, (2) wet spots on the sacks suggesting the presence of leakers or frozen potatoes, (3) the discoloration within the bruised and cracked areas due to oxidation of exposed tissue as previously described, and (4) the recognized liability of potatoes next to the floor to freezing injury before those higher in the load.

Three experimental tests made with the jolting apparatus and under freezing conditions were conducted as follows: For all of these tests, peck-size lots of potatoes from 50° F. storage had previously been put into burlap sacks and held overnight at a temperature of 35° to facilitate their coming to freezing temperature after the simulated transit tests were begun. In the first test two lots of Maine-grown Irish Cobbler potatoes were put in place on the experimental car in a storage room held at 24°. A weight of about 175 pounds was equally distributed on top of the load. After standing for 2 hours at this temperature the car was run for 4½ hours and then left standing for 17 hours before the potatoes were removed. These potatoes were then stored at 70° for 5 days before inspection. The results of these tests are shown in table 2.

In the second test well-matured Virginia-grown Bliss Triumph potatoes were used. They were handled similarly to those in test 1 except that they were left standing at 24° F. for 3 hours instead of 2; then the car was run for 4 instead of 4½ hours, and the subsequent holding time at 70° was 2 days instead of 5. Since freezing injury to potatoes can usually be detected in 24 hours, the 2-day instead of 5-day holding period was ample for the purpose. The total time the potatoes in test 1 were in the freezing room was 23.5 hours, whereas

TABLE 2.—*Freezing and bruising in potatoes subjected to experimental transit tests at freezing temperature*

Test No.	Variety	Treatment	Sound (not bruised and not frozen)	Not bruised but frozen	Bruised but not frozen	Bruised and frozen
			Percent	*Percent*	*Percent*	*Percent*
1	Irish Cobbler	Potatoes were held quiet at 24° F. for 2 hours, then run 4½ hours, then quiet 17 hours, then stored at 70° for 5 days.	46	31	1	22
2	Bliss Triumph	Potatoes were held quiet at 24° F. for 3 hours, then run 4 hours, then quiet for 17 hours, then stored at 70° for 2 days.	33	24	15	28
3	Irish Cobbler	Potatoes were held quiet at 24° F. for 20 hours, then run 4 hours, then stored at 70° for 5 days.	0	68	0	32

in test 2 it was 24 hours. The damage by freezing in these potatoes and in those of the following two tests was relatively slight, being indicated by scattered small gray or black spots. In tests 1 and 2 relatively few of the potatoes were injured by either bruising or freezing. In both tests it is doubtful whether any of the freezing injury occurred until after the "transit" period. While only relatively few potatoes were bruised without showing freezing injury, practically an equal number were frozen but not bruised, or both bruised and frozen. Thus it was evident that under these conditions, at least, freezing injury occurred in various parts of the sacks and was not significantly associated with bruising. Where freezing injury occurred in bruised potatoes it was not usually localized at or within the bruised area.

In test 3, potatoes from the same lot as those used in test 1 were loaded on the car as in test 1 but were left quiet for 20 hours at 24° F. and then run for 4 hours, after which they were stored at 70° for 5 days before being inspected. During the 20-hour quiet period undoubtedly some of the potatoes were actually freezing or in an undercooled state (tissue temperature below the freezing point, but with no ice crystals present) and were caused to freeze by jolting during the subsequent transit period. The total time the tubers in this test were exposed to the freezing temperature was practically the same as in tests 1 and 2. In the first two tests it is probable that most of the potatoes did not become undercooled until the quiet period following the run, and in some of these, freezing did not actually occur since they were removed to storage at 70° without further jolting. In test 3, more than twice as many potatoes were frozen without being bruised as were both bruised and frozen, whereas on the other hand no tubers were found that were bruised without being frozen. No sound specimens were found in this test. Here again the location of the lesions indicated that freezing injury was not restricted to areas in or near the bruises.

FLOOR BRUISING AND CHEMICAL INJURY

Receivers often blame chemicals left on the floors of railway cars as the cause of damage to potatoes. The usual reasons for suspecting chemical injury are (1) the presence or suspected presence of chemicals in debris on the car floor, and (2) the presence of soft bruised

areas on the potatoes next to the floor with or without the first condition applying.

As has already been stated, potatoes shipped during the summer months when chemical injury is more likely to be found are usually newly dug and therefore turgid and tender and quite susceptible to floor bruising in transit.

Tests were made to determine the characteristic symptoms of injuries that might be caused by chemicals likely to come in contact with potatoes in transit.

STATIONARY TESTS

In test 1 a number of new-crop Irish Cobbler potatoes were carefully selected for freedom from skin breaks or bruises of any kind. These were placed directly on dry muriate of potash, nitrate of soda, sulfate of ammonia, superphosphate, and hydrated lime, each scattered thinly in enameled pans in a room held at 60° F. The relative humidity in this room was about 95 percent, and the potatoes were held for 4 days. The first three chemicals being readily deliquescent became dissolved during the first few hours in the moisture taken up from the atmosphere so that for the rest of the period the potatoes rested in practically saturated solutions of these chemicals. The liquid in each case crept up about the sides of the tubers, wetting more than half of the surface of each. No softening, discoloration, or other injury occurred in any of the potatoes, except the slight exterior staining incident to their being wet by the deliquesced chemicals.

In test 2 a number of tubers from the same lot were bruised by pressing one side firmly down on a coarse file. This treatment produced a flattened, bruised area with shallow abrasions similar to those found on tubers next to the floor in carlots of sacked potatoes. As in test 1, enameled pans were used to hold thinly scattered table salt, muriate of potash, sulfate of ammonia, nitrate of soda, superphosphate, a 5–10–5 commercial fertilizer mixture,[8] hydrated lime, and one pan with no chemical as a check. One thickness of cheesecloth was spread over the chemicals in each pan and four potatoes were placed thereon with the bruised side down. Free sap from the bruises immediately moistened the cheesecloth slightly, and after 2 days in the laboratory this moisture and that drawn from the potatoes had gradually dissolved the soluble chemicals—salt, nitrate of soda, sulfate of ammonia, and muriate of potash. The exposure of the wounded tissue to these chemicals caused extensive withdrawal of water from the tissues, accompanied by softening or wilting (fig. 9, *A*). The fact that the general supply of chemicals for this work, kept nearby in open containers, remained dry showed that the relative humidity of the laboratory atmosphere was not high enough to cause deliquescence or liquefaction of the chemicals. The potatoes used in this test were dried off and left a few more days in the laboratory.

[8] This was a commercial fertilizer mixture of 5–10–5 composition in which the source of nitrogen was reported to be one-half organic and one-half inorganic and water soluble; the phosphorus was in the form of phosphates and largely insoluble. The potash was in the form of potassium chloride, which is soluble. Such a commercial fertilizer usually contains the soluble substances in varying amounts; the bulk of the mixture, including the filler, is largely insoluble.

After 2 days two tubers of each group were cut across the injured areas and the tissue was found to have a gray to black discoloration for a depth of about one-eighth inch below the bruise (fig. 9, *C*). Below this was a soft, spongy region extending perhaps an eighth to a half inch farther, over which the skin was considerably wrinkled. After 4 days the injured areas had dried out, leaving a hollow depression one-sixteenth to one-eighth of an inch in depth, below which the tissue seemed to be normal. The potatoes in the other four pans containing the more or less insoluble substances remained firm and sound. The cloth next to the bruised areas of some of these potatoes was still somewhat moist after 2 days but eventually dried, and the bruised areas of all the potatoes resting on these chemicals remained firm and healed over without further injury (fig. 9, *B*).

In test 3 newly dug Bliss Triumph potatoes were used. These were treated like those in test 2 except that two potatoes in each pan were not bruised. The results with the bruised potatoes were similar to those in test 2; the unbruised potatoes were not affected in any way by the chemicals. The results of these tests indicate that certain soluble chemicals left on the floor or walls of a railroad car may, under favorable conditions, cause chemical injury if the potatoes come in contact with them and also become bruised sufficiently to allow the escape of enough sap to wet through the sacks at the point of contact with such chemicals.

In test 4 a study was made to determine whether discoloration always occurs in tissues affected by different chemicals. Specimens of potatoes of the two varieties were bruised and exposed to the soluble chemicals, as described in tests 1, 2, and 3. These potatoes were cut at successive periods after the tissue became soft and it was found that discoloration always occurred but usually not until 2 to 3 days after treatment.

SIMULATED TRANSIT TESTS

Five tests were then run to simulate commercial transit conditions where some of these chemicals might be present on the car floor. These are designated as tests 4, 5, 6, 7, and 8. In test 4, new-crop Irish Cobbler potatoes were placed in two peck-size burlap sacks. One sack was placed on nitrate of soda and the other on table salt that had been sprinkled on the car floor. A weight of 475 pounds was held in place over both sacks. This test was run 8 hours on each of 3 successive days in a temperature ranging between 70° and 75° F. Inspection at the end of the experimental run showed that where the potatoes were bruised, the burlap and the chemical in contact with it at these points were both wet and that a certain amount of moisture had crept out along the sides of the bruised specimens. On these potatoes the bruised areas and the adjacent tissues were soft and flabby or rubbery and the skin covering these areas was wrinkled. No difference was noted in the effect of the two materials. The injured tubers were spread out on a table for 5 days and at the end of this time the soft areas had dried down somewhat, leaving depressions below which the tissue was brownish in color to a depth of an eighth to a quarter of an inch. Below this the tissue was firm and sound, except in a few instances where decay had set in. In test 5 newly dug Irish Cobbler potatoes were used, and the procedure was a repetition of test 4. The results were practically identical.

Test 6 was made with potatoes from the same lot as test 4. The procedure was the same except that no chemicals were used and the floor and sacks were thoroughly washed to eliminate any soluble chemicals. At the end of this test, inspection showed that the potatoes that touched the floor were bruised enough to show the imprint of the sacks, and the burlap was damp at these places. However, the tissue adjacent to the bruised areas was not soft. Tissue affected by soluble chemicals was soft adjacent to the bruised areas. After drying, the salability of these potatoes would scarcely have been discounted.

At this point it seemed desirable to determine whether any difference in the amount or character of injury resulted when different chemicals were used under the same conditions. Therefore, in test 7 the floor of the test car was marked off into four parallel strips, three of which were sprinkled thinly with table salt, nitrate of soda, and 5–10–5 fertilizer, respectively; the fourth area was left clean for use as a check. The floor was then covered with a single thickness of burlap upon which was placed a double layer of new-crop Green Mountain potatoes of fairly uniform size. A wooden platform carrying a weight of about 475 pounds was placed on top of the potatoes. The test car was run at room temperature (about 70° F.) for 8 hours a day for 3 days and then left quiet for 3 days. When unloaded, the potatoes were inspected and then left spread out for 6 days in a room kept at 70° F. with a high relative humidity (95 percent). At the end of this time much decay was found in the bruised areas next to the floor. The results of the two inspections are given in table 3.

TABLE 3.—*Bruising injury and decay present in potatoes after an experimental test with different chemicals placed on the floor of the test car*

Material used	Condition when unloaded 3 days after test run		Condition after 6 days' storage at 70° F. with 95-percent relative humidity		
				Decay in bruises	
	Sound	Bruised	Sound	Slight	Extensive
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Table salt	65	35	35	30	35
Nitrate of soda	52	48	24	31	45
Fertilizer (5–10–5)	62	38	57	19	24
None	48	52	59	41	0

At the first inspection most of the bruised areas as well as the burlap touching them were moist. Where table salt and nitrate of soda were used the tuber tissue adjacent to the bruises was soft and wrinkled to a depth of about one-fourth inch. In the potatoes placed in contact with the commercial fertilizer, as well as in the checks, the injury was slight and there was no soft tissue. However, the percentage of potatoes showing actual bruises was greatest where no chem-

ical was used, due perhaps to unequal distribution of the weight resting upon them. The high humidity in which the potatoes were held after jolting did not permit the wounded areas to dry out but seemed to encourage the development of decay. Where effects of soluble chemicals were present there were fewer sound potatoes at the second inspection than at the first, probably due to the entrance of infection into undetected wounds. The number of potatoes classified as sound in the check lot was greater at the second inspection, owing to favorable conditions encouraging the healing over of wounds. The decay in the check potatoes was very slight, whereas considerable was found in those lots having contact with table salt and nitrate of soda, the latter causing the most damage.

A final test (No. 8), consisting of two runs, was made with the experimental apparatus to determine the effect of the presence or absence of chemicals on the percentage of tubers that would be bruised by contact with the floor of the test car. In the first run Green Mountain potatoes from the same lot used in a previous test after storage at 32° F. for about 3 months were put into peck bags. One such bag was placed over thinly scattered table salt on the floor of the test car; the other was placed on a clean floor. The usual 475-pound weight was placed on top of the bags. The test runs were made in a room held at 32° and the test car was operated for 7 hours on 2 successive days and for 4 hours on the third day. The potatoes were then unloaded, stored at 70° for 24 hours, and then inspected. The next test run was made at 50° with Green Mountain potatoes from 50° storage, the test being run for the same length of time as the preceding. The results of both inspections are shown in table 4 from which it is seen that although there were more bruised potatoes at 32° than at 50° the percentage of such tubers in the lots resting upon the salt and in those on the clean floor was practically the same in both runs. At 32° there were 2 percent more injured potatoes on the clean floor and at 50° there were 6 percent less.

The conclusion drawn from these results is that under the conditions given the presence or absence of salt on the car floor caused little or no difference in the number of bruised potatoes.

TABLE 4.—*The effect of the presence or absence of salt on the car floor on the number of bruised potatoes*

Treatment	Storage temperature	Condition	
		Sound [1]	Bruised
	° *F.*	*Percent*	*Percent*
Table salt on car floor	32	34	66
Floor clean	32	36	64
Table salt on car floor	50	72	28
Floor clean	50	66	34

[1] Based on the total number of tubers in each bag.

SUMMARY AND CONCLUSIONS

Claims are frequently made of injury in potatoes next to the floors or floor racks in carlots of sacked potatoes and less frequently in those next to the walls. The injured tubers are flattened, bruised, and often cracked or split. The bag material becomes indented into the surface tissue. Sometimes it leaves only its imprint, but if the potatoes are turgid or brittle the burlap may cut through the skin, causing the area to become wet. This injury has sometimes been attributed to freezing and often to damage from chemicals on the surface of or impregnated in floors or walls. Experimental evidence and general observations reported in this bulletin show that the injury discussed, whether complicated by either of these factors, is in most cases the result of mechanical bruising against the floor or walls caused by the weight of the load and the movement of the car. Newly dug potatoes are more subject to such injury than old ones, because they are more turgid, and potatoes from storage at relatively low temperatures (32° to 40° F.) are more susceptible than those from higher storage temperatures, because they are more brittle.

In simulated transit tests to determine the effect of storage treatment and tuber temperature on susceptibility to floor bruising, 65 percent of the potatoes in lots that had been in storage at 32° F. for 3 months were injured, while only 31 percent of those from a 50° temperature were injured. In potatoes that had been stored in a cellar averaging about 50°, and then held at 32° for the 3 days preceding the test, 54 percent were injured as compared with 31 percent in those held continuously at 50°. These tests demonstrated the relation between the temperature of potatoes and their susceptibility to injury when subjected to bruising. Transit bruising produced under experimental conditions was identical with that found under commercial conditions.

Claims for freezing injury are sometimes filed for potatoes injured by bruising. The basis for this is usually the soft, damp condition of tubers adjacent to the floor, which is said to be a symptom of freezing injury. Tubers that are cracked or split and have become darkened or discolored because of oxidation of the exposed inner tissues are also frequently regarded as exhibiting freezing injury. The presence of wet spots on the side of the bags next to the floor where potatoes have been bruised suggests the presence of "leakers" or badly frozen tubers.

Under the experimental conditions described, where freezing was produced along with floor bruising, the characteristic symptoms of freezing usually were not confined to the bruised areas but occurred throughout these tubers. They occurred also in tubers that were not bruised.

Transit injury to potatoes hauled in boxcars that are commonly used also for carrying various chemicals frequently give rise to complaints of suspected chemical injury. The presence of wet bruised areas and the discoloration due to oxidation of the exposed tissues along cracks are the usual grounds for these complaints.

Under laboratory conditions, potatoes were pressed on surfaces thinly sprinkled with chemicals that might be found on the floors of cars that were not swept or washed. Where the skins of the potatoes were not broken no apparent injury resulted even after certain of these

materials had taken up enough moisture from the atmosphere to become dissolved into concentrated solutions that wetted a large part of the tuber surfaces. Where the potato skin was broken from previous bruising, however, certain soluble chemicals plasmolyzed, or withdrew water from, the tissues, so that the areas adjacent to the bruises became soft and wrinkled. In the absence of these chemicals this soft, flabby condition of the tissues adjacent to the bruise was not found. In these tests the presence or absence of chemicals on the car floor caused no significant difference in the actual number of bruised potatoes.

The symptoms of the injuries described in this bulletin may be briefly stated as follows:

Floor bruising.—Potatoes are flattened at the point of contact with the floor and usually show the imprint of the bag. The tissue may be bruised and soft to a depth of one-sixteenth to one-eighth of an inch. It may be cracked somewhat deeper than this with the exposed tissues somewhat discolored, owing to oxidation. Below the bruised area the flesh is firm, if secondary decay has not developed. Tissue not exposed to the air is not likely to become discolored.

Freezing injury.—Moderate freezing injury is marked by a blue-gray to black vascular discoloration and can be detected only by cutting the suspected tuber. More severe injury is characterized by a general gray to black blotching or discoloration of much of the internal tissue. Additional freezing will result in entire collapse of the potato tuber followed by the exudation of sap.

In these studies of potatoes subjected to transit conditions, the symptoms of floor bruising and freezing injury were always found to be characteristic and distinct from each other and unrelated as to contributing causal factors.

Chemical injury.—Injury caused by contact with soluble chemicals is usually marked by the same symptoms described above for floor bruising. In addition, the tissue directly below the bruised area may be soft and flabby or rubbery to a depth of an eighth to a half inch and the skin wrinkled. A few hours after exposure this tissue usually becomes gray or black. Chemical injury occurs only in conjunction with bruising injury.

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