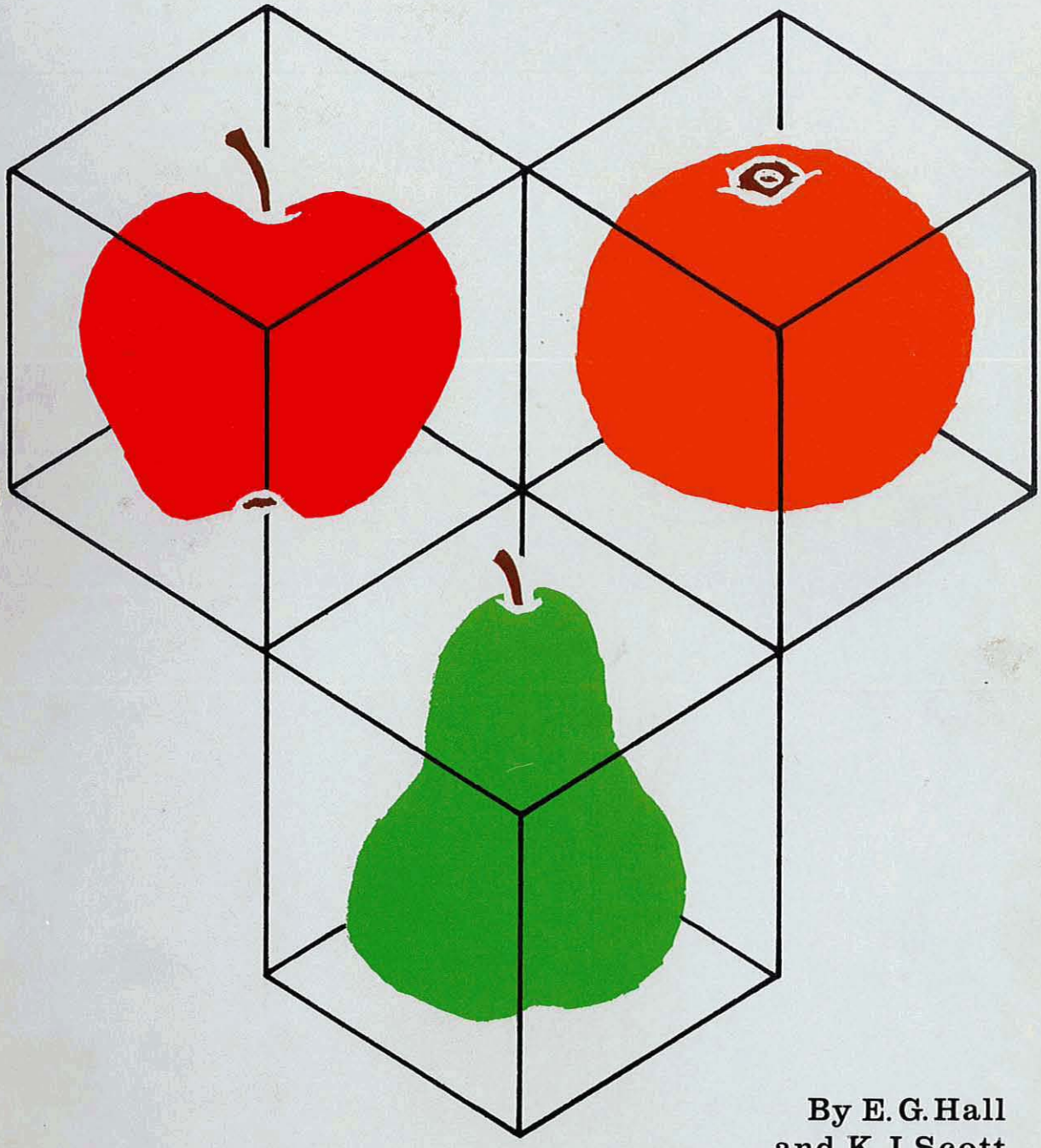
STORAGE AND MARKET DISEASES OF FRUIT



By E. G. Hall
and K. J. Scott

STORAGE AND MARKET DISEASES OF FRUIT

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Collected supplements I–XXIV reprinted from
'CSIRO Food Research Quarterly'

Commonwealth Scientific and Industrial Research Organization,
Australia 1977

ISBN 0 643 00217 0

March 1977

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Printed by CSIRO, Melbourne

76/387-3000

PREFACE

Recognition and knowledge of the physiological disorders and fungal diseases affecting fresh fruit after harvest and during storage and marketing are important to everyone in the fresh fruit industry. In its extension journal, *Food Research Quarterly*, the Division of Food Research, CSIRO, published a series of 24 colour supplements with illustrations and notes on the more important diseases. The supplements appeared in the period 1969–1975 and were greatly appreciated by the *Quarterly's* readers. Moreover, there has been a steady demand, both for complete sets and for particular issues, from a variety of interested people in departments of agriculture, universities, colleges and other teaching establishments. To meet this demand, the Division has decided to make the complete series available in book form.

Whilst research has made it possible to control most of the storage diseases of fruit, considerable wastage still occurs in the period between picking and when the fruit reaches the table. Much remains to be done to improve post-harvest handling generally and it is hoped that publication of the collected supplements will play a part in reducing spoilage during marketing.

Collaborative research by the Division of Food Research and State Departments of Agriculture is continuing; market diseases of some tropical fruits are currently being studied and it may be possible to publish additional information from time to time in the same format so that a suitable loose-leaf binder may be used.

The material for the original supplements was compiled by Mr E. G. Hall, formerly leader of the Fruit Storage Section of the Division of Food Research, CSIRO, and Mr. K. J. Scott, of the New South Wales Department of Agriculture. Most of the photographs were prepared by Mr. P. R. Maguire, the Division's former photographer.

No editorial changes have been made except that in the former supplements IX and X (now pages 20 and 21, and 22 and 23) colour pictures have been substituted for the original black and white ones and the text has been amended accordingly. The imperial units in the earlier supplements have not been metricated and it should be noted that diphenylamine (DPA) is now permitted on fruit exported to the United Kingdom, Singapore and other countries (page 6). Each of the original supplements now constitute each pair of facing pages.

Inquiries or requests for further information may be directed to the Chief, Division of Food Research, CSIRO, Box 52, P.O., North Ryde, N.S.W. 2113. Telephone: 888-1333 (STD code 02).

INTERNAL BREAKDOWN OF APPLES

Internal breakdown, which affects many apple varieties in cool storage, is a disorder in which the flesh of the apple breaks down and browning occurs.

Fruit grown in cool, moist climates, fruit from light crops or from young trees, and large fruit are particularly susceptible to breakdown of all kinds. Fruits previously affected by bruising, bitter pit, or water-core are also more susceptible.

The risk of breakdown is increased by high humidities in the cool store and by storage in bags or liners of polyethylene or other plastic material. Recent work* has shown that many conditions that

* Scott, K. J., and Roberts, E. A. (1967).—Breakdown in Jonathan and Delicious apples in relation to weight lost during cool storage. *Aust. J. exp. Agric. Anim. Husb.* **7**, 87–90.

1

Senescent Breakdown (Fig. 1, in Jonathan) develops if fruit is over-mature when picked, or when it ages in store. Conditions after harvest which lead to this breakdown are delays before cooling, slow cooling, high storage temperatures, and over-long storage. The first symptoms are undue softening of the flesh, followed by mealiness and brown discoloration. In its severest form the fruit becomes very soft and the exterior browns.

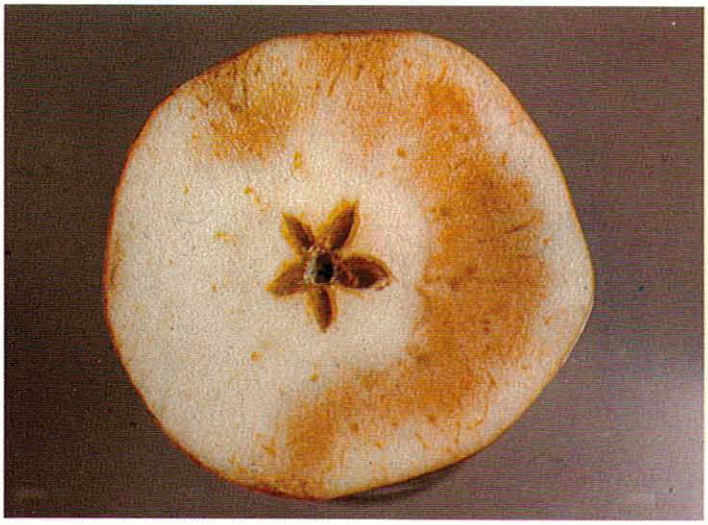
2

Breakdown associated with Water-core (Fig. 2, in Delicious) frequently occurs in storage, particularly with apples affected by radial water-core. Water-core or 'glassiness' is a glassy translucent condition of the flesh of apples that develops before harvest, especially in exposed fruit. Sudden rises of temperature in the orchard and heat waves frequently bring on this disorder, which appears to be due to moisture stress. Late, or radial, water-core, in which discrete areas around the main vascular system are affected, develops late in the life of fruit on the tree and is more likely with late pickings.

increase weight loss (water loss) from the fruit reduce breakdown.

Cox's Orange Pippin, Ribston Pippin, Sturmer, and Jonathan are highly susceptible, Rome Beauty and Delicious are moderately susceptible, and Cleopatra, Crofton, Granny Smith, and Democrat have low susceptibility to breakdown.

Low-temperature Breakdown (Fig. 3, in Jonathan) occurs in some varieties of apple when stored at low temperatures; the flesh is moister and less mealy, firmer and usually darker in colour than with senescent breakdown. Frequently the affected area appears as a band in the mid cortex without any external sign, and it can develop rapidly in fruit apparently sound on removal from storage. Low-temperature breakdown is usually not serious at 36°F, and rarely occurs at 38°F, but accumulation of carbon dioxide in storage atmospheres favours this disorder.



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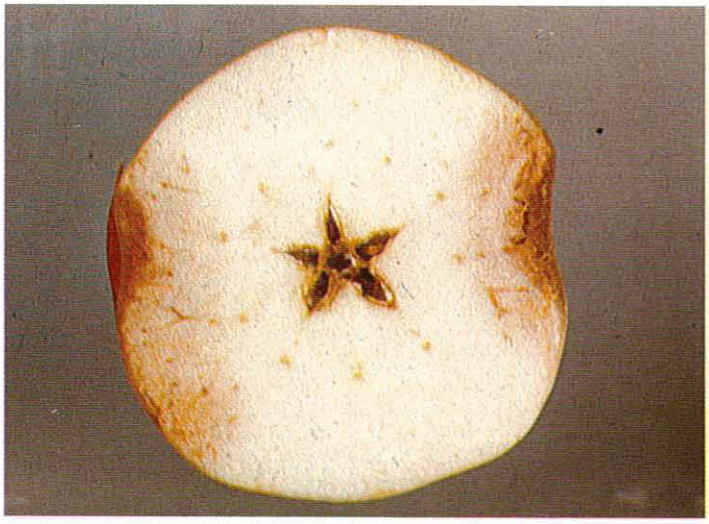
Breakdown following Bruising (Fig. 4, in Jonathan), like breakdown following water-core, or bitter pit, is a premature, senescent type of breakdown induced by the previous injury. As susceptibility to both bruising and senescent breakdown increases with increasing maturity and ripeness of the fruit, it is greatest in over-mature fruit held too long in storage or at too high a temperature, particularly in softer varieties like Cox, McIntosh, and Jonathan. Unless severe, early pre-storage bruises usually dry out and do not induce breakdown.



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SUPERFICIAL SCALD OF APPLES

This appears in some varieties after cool storage as a superficial, or slightly sunken, brown discoloration on the surface of the skin. Early picking (immaturity), growing in hot and dry climates, and restricted ventilation (e.g. in controlled-atmosphere (C.A.) storage or in plastic film bags) favour this disorder. Control involves: allowing the fruit to mature fully before picking; dipping fruit in 0·1–0·2% diphenylamine (DPA) or in 0·15–0·3% Ethoxyquin, or wrapping in DPA wraps; or wrapping each fruit in oiled paper according to Australian Standard N29.

0·1% DPA is usually effective but 0·15–0·2% is recommended when conditions favour scald development. DPA and Ethoxyquin can be used on export fruit only if permitted by the importing country.

Further reading

Fidler, J. C. (1954).—Superficial scald of apples. *Bull. int. Inst. Refrig.* Annexe 1954–1, 49–58.

5

Superficial Scald on Granny Smith (Fig. 5), which is a highly susceptible variety. In addition to the control measures mentioned in the text, apples from hot, dry areas should be stored at 40°F for the first 6 weeks and subsequently at 30–32°F, and fruit destined for C.A. storage should be treated with 0·15–0·2% DPA or stored in DPA wraps.

Further reading

Hall, E. G., Scott, K. J., and Coote, G. G. (1961).—Control of superficial scald on Granny Smith apples with diphenylamine. *Aust. J. agric. Res.* **12**, 834–53.

6

Superficial Scald on Jonathan apple from controlled-atmosphere storage (Fig. 6). While red-coloured (blushed) varieties are less susceptible to this disorder, it can develop on unblushed areas of their skin if the fruit is not fully mature and if it is put into C.A. storage. It is therefore recommended that susceptible blushed varieties, like Delicious, Rome Beauty, and Jonathan, going into C.A. storage be treated against scald.

SUNBURN SCALD OF APPLES

This disorder develops during storage on those parts of fruit that have been damaged by intense sunlight and high temperatures before harvest. The affected areas become smooth, glossy, and dark brown to black. Granny Smith (Fig. 7) is a highly susceptible variety.

While on the tree the injury usually appears on the exposed part of an otherwise green or lightly blushed fruit as a bleached yellow to light brown, slightly 'cooked' colour. An apple is particularly liable to sunburn when exposed to intense sunlight late in its development as branches bend under the weight of fruit. No treatment will prevent the blackening during cool storage and fruit with sunburn should be rejected during sorting.

7

LIGHT-INDUCED SCALD OF APPLES

Fully mature apples may be injured, after removal from cool storage, by exposure to strong sunlight in picking-boxes and bins or in shop windows. The damage may appear as numerous and sharply defined light brown sunken areas or as a general dirt-brown discoloration of the yellow skin of ripe fruit, with noticeably dark lenticels.

The disorder is usually confined to fully mature fruit in which the ground colour has changed from green to cream or yellow; blushed surfaces are unaffected. It is most commonly seen on Cleopatra and Sturmer but other varieties, including Granny Smith (Fig. 8) and Delicious, may be affected.

8

DEEP OR SOFT SCALD OF APPLES

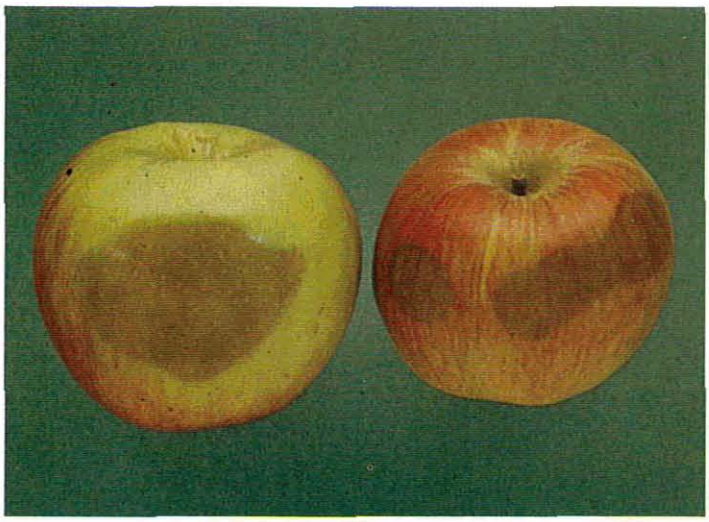
This is a form of low-temperature breakdown that occurs below 38°F. Usually it can be prevented by storing at 36°F for the first month, 34°F during the second month, and thereafter at 31–32°F.

Further reading

Trout, S. A., Tindale, G. B., and Huelin, F. E. (1940).—Investigations on the storage of Jonathan apples grown in Victoria. Bull. Coun. scient. ind. Res., Melb. No. 135.

JONATHAN SPOT OF APPLES

This is a superficial disorder which is worse at higher storage temperatures and which may occur even if harvested fruit is kept at ambient temperatures. It takes the form of slightly depressed brown spots which sometimes coalesce and which develop around the lenticels, mainly on blushed portions of the skin (Fig. 10, on Jonathan apple). Susceptibility to the disorder is greatly increased by delaying picking, for example, to allow the fruit to develop a better red colour.



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Deep (or Soft) Scald on Jonathan apple (Fig. 9). Soft, sunken, sharply defined areas on the surface that are often irregular or banded characterize this disorder. The middle of the fruit is generally affected and damage extends deeply into the flesh. Initially the lesions are light brown but following secondary fungal attack they frequently turn black.

Late rains and delay between picking of fruit and cool storing often increase the disorder. Fruit from light crops and strongly growing trees on heavy soils is most susceptible and should be segregated and marketed early. Jonathan, King Cole, and Rome Beauty are susceptible varieties.

10

Jonathan Spot on Jonathan apple (Fig. 10). Jonathan and Rome Beauty are the varieties mainly affected by this disorder.

To control Jonathan spot:

- Do not store over-mature fruit.
- Cool promptly after picking.
- Maintain correct storage temperature.
- Store in an atmosphere of 2% carbon dioxide, or higher, either in a controlled-atmosphere store or in sealed polyethylene bags. (Such storage is suitable only for fruit with low susceptibility to breakdown.)

Further reading

Carne, W. M. (1948).—The non-parasitic disorders of apple fruits in Australia. Bull. Coun. scient. ind. Res., Melb. No. 238.

Trout, S. A., Tindale, G. B., and Huelin, F. E. (1940).—Investigations on the storage of Jonathan apples grown in Victoria. Bull. Coun. scient. ind. Res., Melb. No. 135.

SENESCENT BLOTCH OF APPLES

This disorder appears as a grey or grey-green superficial discoloration on green-skinned (unblushed) varieties after long storage, particularly when the fruit is removed from storage in warm weather and also when it is held at ambient temperatures for some time. Although the disorder usually develops as blotches, a speckled appearance is common and the affected areas frequently have a slightly russeted texture (Fig. 11, on Granny Smith apple). Senescent blotch may also be of the green late scald type (Fig. 12, on Granny Smith apple) which consists of blotchy areas in which the original green colour of the skin is largely retained and which are often extensive, and less russeted and denser than the more common type.

Granny Smith is the most susceptible variety but Sturmer and Cleopatra also can be affected. A grey, speckled scald often appears on Sturmer.

The use of controlled-atmosphere storage and a diphenylamine treatment reduces the incidence of this disorder, as does avoidance of over-long storage, storing over-mature fruit, and high storage temperatures.

11

12

BITTER PIT OF APPLES

This appears as small brown spots in the flesh, mostly near the surface and towards the calyx end of the fruit. Many pits show through the skin as small, circular, green to brown depressions (Fig. 13). Susceptible varieties are often severely affected and the disorder is often responsible for considerable losses in exported fruit. Bitter pit may occur on the tree (tree pit) or in cool storage on fruit apparently sound at picking (storage pit). Lenticel blotch pit (Fig. 14) is a severe form of shallow pitting occurring on fruit from light crops.

Bitter pit is more common in fruit experiencing warm temperatures and periods of water stress when approaching maturity. Early picking, large fruit size, light crops, excess nitrogen fertilizer, low calcium concentration in the fruit, delay before cooling, slow cooling, and high storage temperatures increase the incidence of the disorder. It can be considerably reduced by the use of calcium-containing sprays while the fruit is growing. Dipping the fruit after harvest in a solution of calcium chloride is sometimes effective. Control of pit is improved by the addition of diphenylamine* to the dip. Pre-shipment cool storage of susceptible varieties for 2–3 weeks allows some of the surface pit to develop and affected fruits may then be removed, thus reducing the risk of pit developing during export. The incidence of pit is less in apples in controlled-atmosphere storage and in fruit waxed before storage.

The most susceptible varieties are Cox's Orange Pippin, Ribston Pippin, and Cleopatra, while Granny Smith, Sturmer, and Dunns are moderately susceptible. However, under favourable growing conditions Granny Smith, Delicious, Golden Delicious, and other varieties may also be affected, at times severely.

Bitter pit on Delicious apple.

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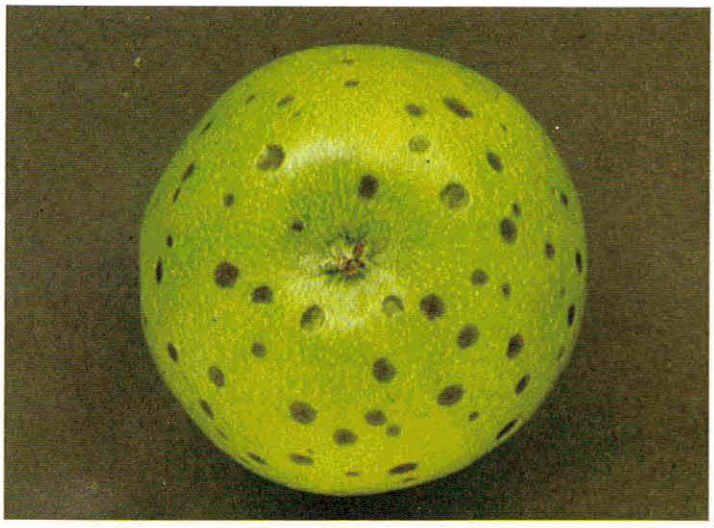
Lenticel blotch pit on Granny Smith apple.



14

Further reading

Martin, D., Lewis, T. L., and Cerny, J. (1960).—Bitter pit in the apple variety Cleopatra in Tasmania in relation to calcium and magnesium. *Aust. J. agric. Res.* **11**, 742-9.

* While the use of this compound on apples is permitted in Australia, it is not permitted in Britain and a number of other countries.

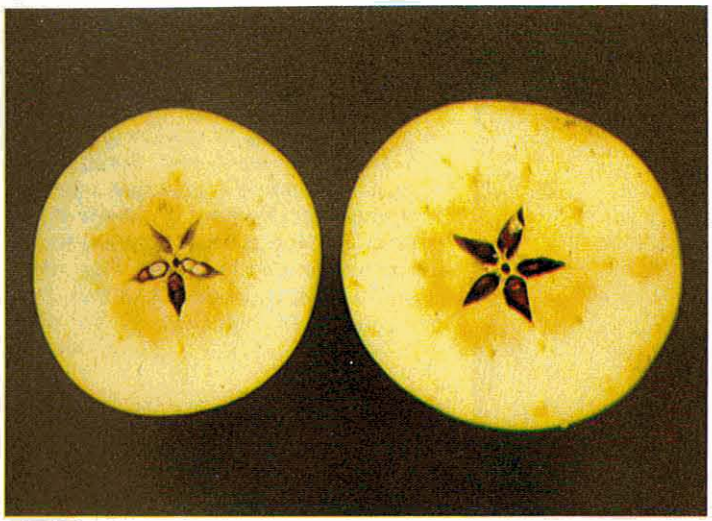
CORE FLUSH OF APPLES

Core flush, or brown core, may show first as a faint pinkish or yellowish discoloration of the core tissue which later turns brown but remains firm and dry. When the disorder is severe it may spread out into the flesh as a rather dry breakdown. Core flush may also start as small brown areas next to the carpels, or as a light brown discoloration along or within the core line. It frequently develops between the horny carpels of the core as separate, dry, brown to dark brown areas shaped like arrowheads.

Overseas and in Queensland core flush (brown core) has commonly been worse at low storage temperatures, at which its appearance is generally of the first-mentioned type. On the other hand, it may be a senescent disorder developing after over-long storage (Fig. 15). There is also another form induced by carbon dioxide (Fig. 16), which is commonly more severe and darker in colour and occurs as arrowhead-shaped separate areas between the carpels. Although the disorder may not show in cool storage it commonly develops rapidly after the apples are transferred to warm conditions.

Large fruits from light crops, especially if heavily fertilized with nitrogen, are very susceptible to core flush. Varieties most commonly affected are Granny Smith, Statesman, and Cleopatra. To avoid the occurrence of the disorder, susceptible fruit should be stored in an atmosphere containing less than 3% carbon dioxide, and they should be removed from storage early.

Core flush (senescent type) on Granny Smith apple.



15

Further reading

Padfield, C. A. S. (1969).—The storage of apples and pears. Bull. N.Z. Dep. scient. ind. Res. No. 111 (rev.), 43.

Core flush (CO_2-induced type) on Granny Smith apple.

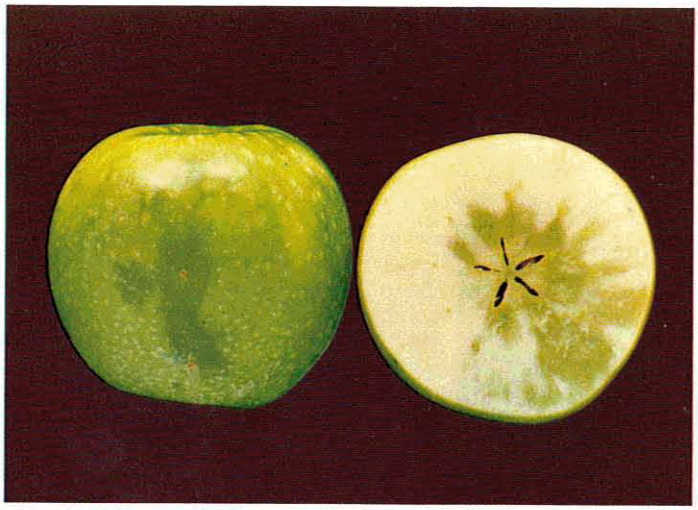
16

WATER CORE OF APPLES

Water core or 'glassiness' is a translucent or glassy condition of the flesh of apples. The disorder develops in growing fruits on the tree that have suffered moisture stress as a result of sudden hot, dry weather in early summer or later. Exposed fruit on the tree receives more solar radiation and therefore suffers greater rises in temperature, with consequent greater evaporation and more severe internal moisture stresses and thus is more susceptible to water core.

These stresses cause premature, localized conversion of starch to sugar and a pronounced leakage of sap from the cells, or an influx of sap into the fruit, which fills the intercellular spaces and produces the glassy appearance. This sap is characteristically sticky and is sweeter than normal.

There are two types of water core. One develops early in the life of the fruit and appears as one or two larger lesions of glassy flesh whereas the other develops later and characteristically shows several translucent areas of flesh oriented radially from the



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18

Early Diffuse Water Core in Granny Smith apples (Figs. 17, 18). Early water core usually occurs as a diffuse and glassy region of the flesh, towards the calyx end. It may be confined to the core or ramify through the flesh, appearing as many lesions on cutting (Fig. 18). When the disorder is severe some firm, shiny, and water-soaked areas may show through to the skin (Fig. 17). Early water core may disappear before picking. The variety Rokewood is particularly prone to develop early water core, but the popular varieties Jonathan, Delicious, and Granny Smith can be affected if growing conditions are unfavourable.

core. Both types may disappear during storage but breakdown is often associated with the later radial type.*

Apples that show more than slight symptoms of water core should not be put into cool storage or exported, especially if they are of a variety susceptible to breakdown. Larger fruits from light crops, particularly when the trees are in heavy growth, are more liable to develop water core.

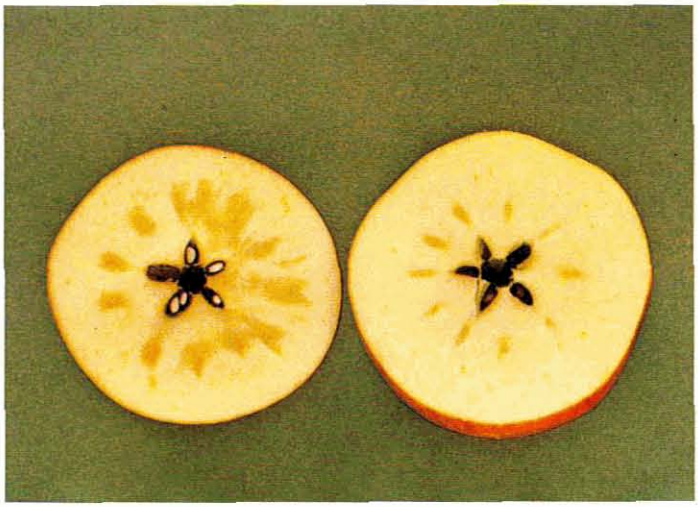
CSIRO Fd Preserv. Q. **29**(2), 1969, Suppl., Fig. 2.

Further reading

Harley, C. P. (1938).—Some associated factors in the development of water core. *Proc. Am. Soc. hort. Sci.* **36**, 435–9.

Carne, W. M. (1948).—The non-parasitic disorders of apple fruits in Australia. Bull. Coun. scient. ind. Res., Melb. No. 238.

Later Radial Water Core in Delicious apple (Fig. 19). In radial water core, discrete and lenticular areas around the main vascular system are affected. There are usually 10 such areas, regularly spaced out from the 10 major vascular bundles. The disorder occurs late in the life of the fruit on the tree and increases as picking is delayed. Radial water core mainly occurs in the softer early and mid-season varieties of apple such as Gravenstein, Jonathan, and Delicious.



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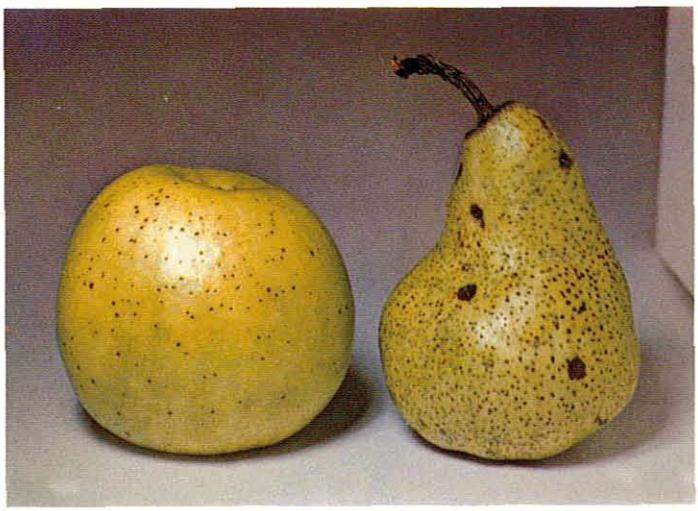
CHEMICAL INJURY TO APPLES AND PEARS

Exposure to ammonia gas from leaking refrigerating pipes may cause injury to apples and pears. Early symptoms are small brownish rings or spots around lenticels and breaks in the skin due to punctures or abrasions. Upon removal from the atmosphere containing ammonia the spots become black. In mild injury the spots are small and superficial (Fig. 20); with more severe exposure they may become enlarged and coalesce, and the discoloration may extend into the flesh. The presence of moisture on the fruit favours ammonia injury. Varieties differ considerably in susceptibility to ammonia and similar injuries.

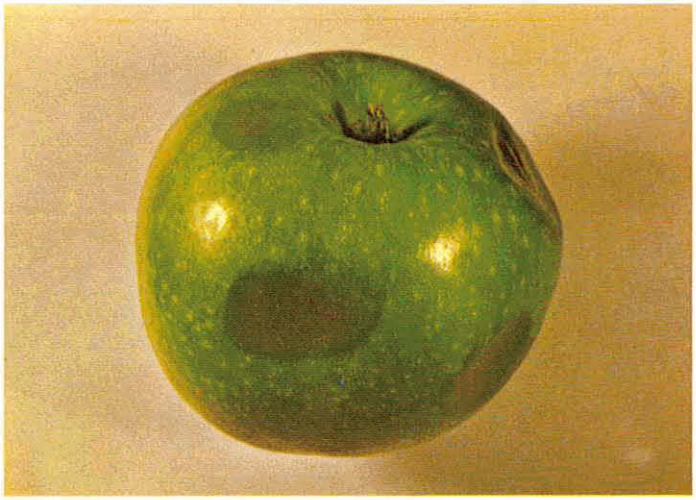
Lenticels are natural breaks in the skin through which injury-producing chemicals may enter or in which they may accumulate. Therefore lenticel spotting varying in colour from pale and bleached through brown to black, according to the particular compound concerned, may be caused by other chemicals, either as gas or in solution.



20

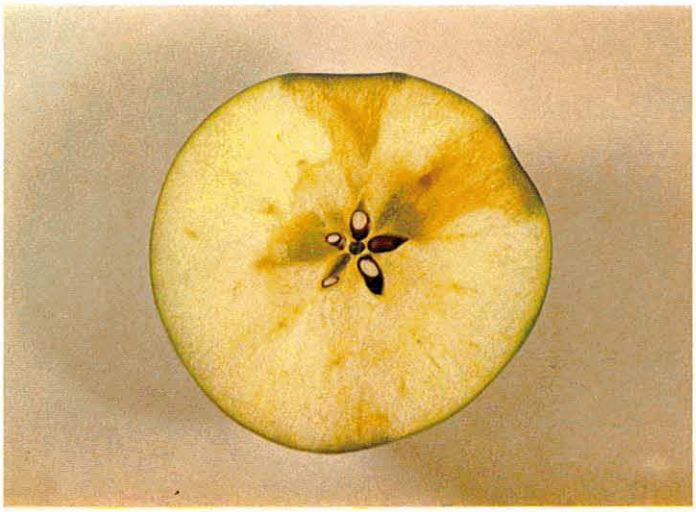
FREEZING INJURY IN APPLES AND PEARS

The juice of apples and pears usually freezes at 28–29°F but rarely as high as 30°F, and fruit may become frozen if exposed to lower temperatures. If completely undisturbed, fruit may supercool to 1–2 degF below its freezing point without freezing, but when ice forms, e.g. if the supercooled fruit is jarred, its temperature quickly rises to the true freezing point. The severity of the freezing injury depends on both the temperature and the duration of exposure to freezing temperatures. The formation of a small amount of ice in the tissue, commonly first in the core, causes little damage if the fruit is not handled while frozen; therefore the presence of ice does not necessarily mean freezing injury. Severely frozen fruit breaks down on thawing, but slightly frozen fruit can be thawed safely with little if any damage, provided that this is done slowly at a temperature of 32–36°F and the fruit is not jarred, even slightly.



21 Bruises in frozen Granny Smith apple—external after thawing.

Bruises in frozen Granny Smith apple—internal after thawing.



22

Apples

Slightly frozen apples may appear normal, or only slightly wrinkled externally, but they feel heavy and wooden, and there are ice crystals in the flesh. With more severe freezing the cells of the vascular bundles are first affected and, on thawing, injury may show as a brown discoloration of the 10 main vascular bundles and of the strands of vascular tissue through the flesh.

Severely frozen apples have a characteristically netted, wrinkled skin, they are reduced in size, and water-soaked flesh may show externally. On thawing, such fruit develops a moist flesh breakdown, initially pinkish and later brown, which is often similar to low-temperature breakdown. The surface of the fruit becomes discoloured in irregular areas and often appears more water-soaked.

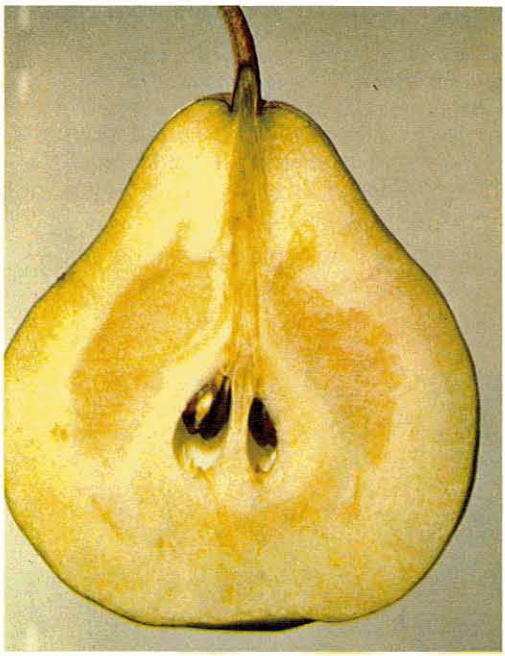
Bruising of frozen apples shows prominently after thawing as brown, conical sectors of damaged tissue, often noticeably sunken, or shiny and injected externally, and extending deeply into the flesh (Figs. 21, 22). The presence of ice crystals, injected flesh, discoloured vascular bundles, and the characteristic conical bruises help in the recognition of freezing injury.

Control

Freezing injury is controlled by keeping fruit temperatures above 29·5°F and by allowing slightly frozen fruit to remain undisturbed and to thaw slowly. Fruit in the cool store should never be stacked close to the cooling coils as this is a common cause of freezing.

Further reading

Rose, D. H., Wright, R. C., and Bratley, C. O. (1944).—Freezing injury of fruits and vegetables. U.S. Dep. Agric. Circ. No. 713.



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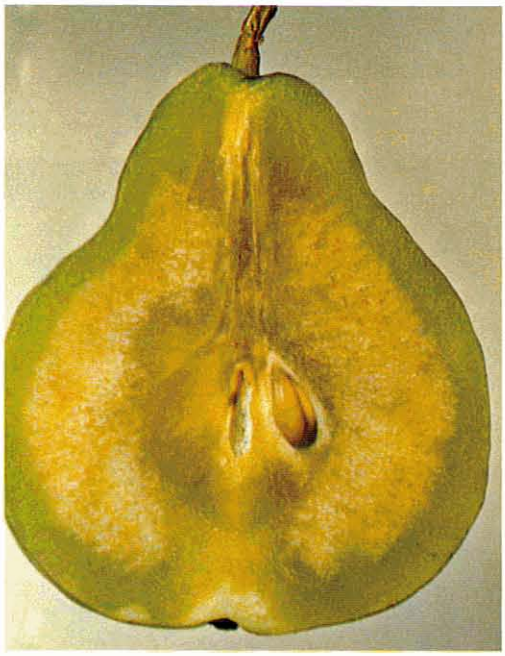
Moderate freezing injury in Packham's Triumph pear, after thawing.

Pears

Frozen pears develop areas of translucent water-soaked tissue, first in the neck of the pear and later generally, but more commonly in the outer flesh. These frequently show externally as water-soaked areas on the skin. As in apples, ice crystals can be seen in the core cavity.

While slightly frozen pears will recover if not disturbed and if thawed slowly, more severely frozen fruit breaks down rapidly on thawing. At first the outer flesh may be water-soaked and colourless while the inner flesh becomes brown and often rather dry and pithy (Figs. 23, 24); in severe cases it cracks to produce cavities in the flesh. When the fruit is cut *transversely* the affected areas often show as rings, or partial rings, around the core.

Severe freezing injury in Packham's Triumph pear, after thawing.



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BLUE MOULD OF APPLES AND PEARS

Blue mould, caused by the parasitic fungus *Penicillium expansum*, is the most common and destructive rot of apples and pears which occurs during storage and marketing. It starts as a light-coloured soft spot which soon spreads on the surface and deeply into the flesh with the decayed portion sharply separated from the healthy tissue. It develops rapidly at higher temperatures, the fruit soon becoming a soft watery mass and having a characteristic musty smell. Blue mould develops slowly at cool storage temperatures and may cause considerable losses under favourable conditions.

25

The fungal growth which soon develops on the surface of infected fruit under warm moist conditions is at first white and later pale blue as the spore masses develop. The rot finally becomes blue-green and powdery, often with the spore masses in separate clumps (Fig. 25). In dry cold air there is generally no or little surface mould growth but it does develop slowly in cool storage where the air next to the fruit is moist. Blue mould is a wound infection but it can readily spread to adjacent fruit by contact, resulting in the development of 'nests' of mouldy fruit (Fig. 26).

Susceptibility to mould attack increases with maturity. Over-mature fruit, or fruit weakened by over-long storage, particularly if temperatures are too high, is easily invaded through the lenticels as well as through any breaks in the skin. Under these conditions multiple infections such as 'spot waste' (Fig. 27) are common. Mould development is favoured by high humidities and blue mould is therefore more of a problem on fruit stored or shipped in plastic film liners.

Control measures are:

Careful handling to avoid skin injuries;

Sanitation to reduce contamination;

Use of fungicides to prevent infection;

Prompt cooling to minimize development.

26

When water dumping is used to remove fruit from bulk bins, when fruit is dipped or sprayed for control of storage scald, or when it is washed, an effective and safe fungicide such as benomyl or thiabendazole should be added to the water. Where blue mould is a problem, copperized tissue wraps should be used to prevent spreading by contact. All varieties of apples and pears can be infected and blue mould spores are almost universally present.

Further reading

Rose, D. H., McColloch, L. P., and Fisher, D. F. (1951).—Market diseases of fruits and vegetables: apples, pears, quinces. Misc. Publs U.S. Dep. Agric. No. 168.

BLACK SPOT OF APPLES AND PEARS

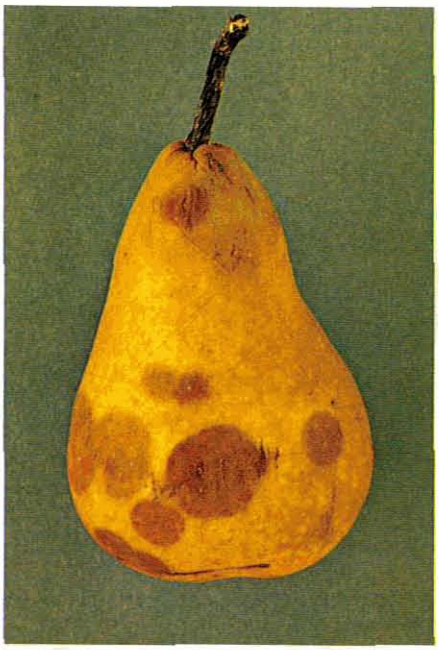
The orchard diseases black spot of apples caused by the fungus *Venturia inaequalis* and black spot of pears caused by the fungus *Venturia pyrina* can develop on the fruit in cool storage as a result of late infections on the tree.

The superficial black spots that develop under the moist conditions in cool storage are up to $\frac{1}{4}$ in. in diameter, usually circular, and produce a more obvious dark grey to black fungal mycelium on the surface than develops on the fruit on the tree (Fig. 28).

Control is by orchard sprays to prevent the late infections. Treatment after harvest with benomyl or thiabendazole is useful.

Further reading

New South Wales Department of Agriculture (1971).—Apple and Pear Scab. 1st ed. N.S.W. Dep. Agric. Bull. No. 9.



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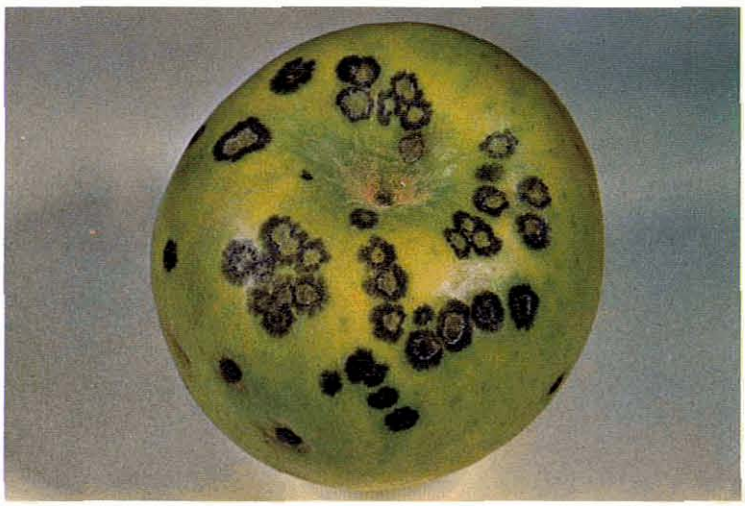


28

BULL'S EYE ROT OR TARGET SPOT

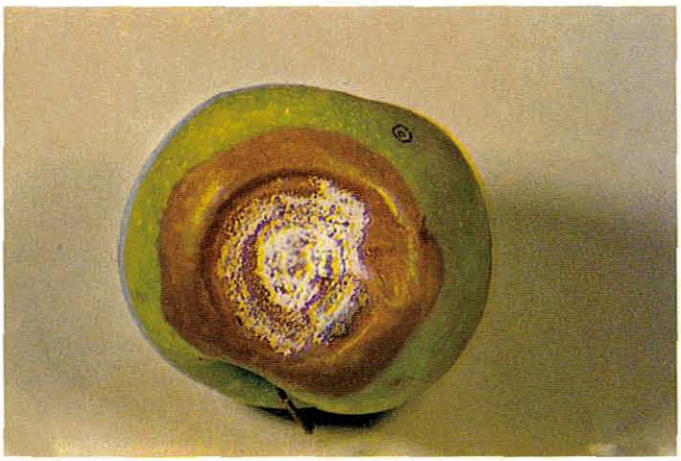
This disorder is often serious in cool-stored fruit when there is wet weather about picking time, especially if picking is delayed. It starts as infections of the lenticels while the fruit is on the tree and first shows in storage as small, firm, discoloured spots, each centred on a lenticel; multiple infections of the one fruit are common (Fig. 29). As these rot spots enlarge they commonly develop more or less concentric zones differing in colour (Fig. 30) and the flesh is invaded to produce a light brown, spongy rot. The external colour may darken and numerous tiny and gelatinous spore masses, initially colourless but later pink, develop on the rotted surface. Later still a whitish growth of mycelium appears (Fig. 30).

Bull's eye rot is generally caused by the fungus *Gloeosporium alba* but *Gloeosporium perennans*, which causes cankers on the tree, may also be involved.

Control depends on field sprays, a late spray of a suitable fungicide, such as thiram, benomyl, or thiabendazole, being most important. When the fruit is exposed, by dipping or spraying, to water after harvest, the addition of a fungicide such as thiabendazole to the water will considerably reduce rotting by this and other fungi. The varieties Delicious and Statesman seem to be most susceptible, but bull's eye rot also occurs on the Granny Smith (as illustrated).

29 Multiple infections of bull's eye rot on Granny Smith apple (note spore masses).

Old lesion of bull's eye rot on Granny Smith apple showing growth of mycelium.



30

GREY MOULD OF APPLES AND PEARS

Grey mould rot caused by the fungus *Botrytis cinerea* is common in cool-stored pears and is sometimes a problem in apples.

The disease develops as a soft, brown, somewhat wrinkled rot (Fig. 31) which later becomes covered with often sparse, ash-grey, powdery, spore masses (Fig. 32). It is darker and firmer than blue mould rot. Grey mould readily spreads by contact to produce nests or pockets of several rotted fruits. Like blue mould it is a wound infection, commonly through an open or damaged calyx, or at the stalk when it is damaged in picking or through any breaks in the skin.

Control is by:

Careful handling to avoid skin injuries;

Sanitation to reduce contamination;

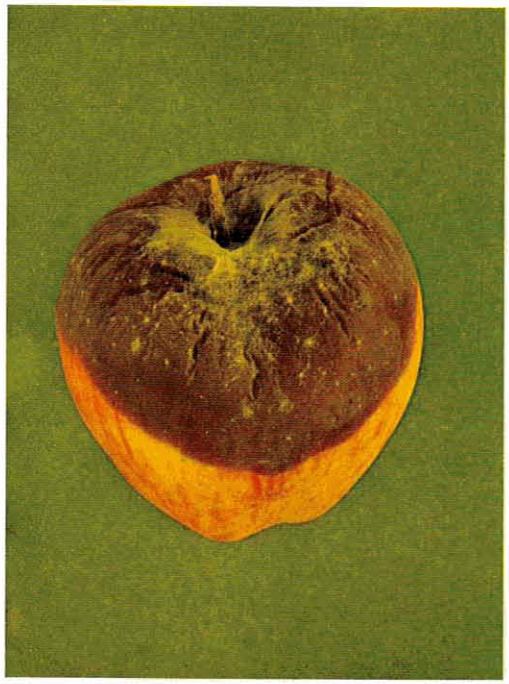
Wrapping the fruit in copperized wraps to prevent contact spread in storage;

Treatment after harvest with an effective fungicide such as Allisan, Botran, benomyl, or thiabendazole.

Further reading

Rose, D. H., McColloch, L. P., and Fisher, D. F. (1951).—Market diseases of fruits and vegetables: apples, pears, quinces. Misc. Publs U.S. Dep. Agric. No. 168.

Beattie, B. B., and Outhred, Nerida L. (1970).—Benzimidazole derivatives as post-harvest fungicides to control rotting of pears, cherries and apricots. *Aust. J. Exp. Agric. Anim. Husb.* **10**, 651-6.



31

Grey mould on Delicious apple at higher temperature.

Grey mould on Granny Smith apples in cool storage.

32

BROWN HEART OF APPLES AND PEARS

This disorder first appears as firm, brown, moist, sharply defined areas of breakdown within the flesh, usually at first in the mid-cortex (Figs. 33, 35). It is often associated with the main vascular tissues and the core area may also be involved (Fig. 33). In more severe forms or advanced stages external symptoms appear, the fruit may have a dull dark or even water-injected appearance and a resilient, spongy feel. Brown heart commonly appears early in storage and the lesions usually later dry out to leave characteristic cavities in the flesh which may be quite large, especially in pears (Fig. 36). Externally such fruit is often consequently deformed due to collapsing of the flesh.

Brown heart in apples is initially similar to low-temperature breakdown but is more localized and defined. Further, concentrations of carbon dioxide below the critical levels for brown heart, which may be as high as 10%, commonly aggravate low-temperature breakdown in apples so that at low storage temperatures, the two disorders may be confused, especially in varieties such as Sturmer and Cox which are very susceptible to both disorders.

33

Brown heart of apples in Jonathan.

Brown heart of apples; core flush type, var. Granny Smith.

34

In the Granny Smith, Statesman, and Cleopatra varieties of apples levels of carbon dioxide greater than about 3% induce a dark, often severe type of core flush (Fig. 34 and also Fig. 16, page 11). When such lesions age they may dry out to produce a series of small radially lenticular cavities.

Sturmer Pippin is the most susceptible variety of apple followed by Cox's Orange Pippin, Cleopatra, Tasman's Pride, and Jonathan, while Winter Cole and Winter Nelis are the common varieties of pears more sensitive to carbon dioxide.

To avoid brown heart, the level of carbon dioxide in cool stores and similar storage spaces holding apples or pears, in which the storage atmosphere is nominally air, should not exceed 1%. Warm fruit produces more carbon dioxide than cool fruit so that special care must be taken when large masses of fruit are being cooled in a closed space. In controlled-atmosphere (C.A.) storage higher levels of carbon dioxide are used only when more tolerant varieties are involved.

Of the principal varieties of apples Granny Smith, Delicious (Red and Golden), Jonathan, Democrat, Crofton, and Rome Beauty can be stored in the normal C.A. storage atmosphere of 2–3% CO_2 and 2–3% O_2 without risk of brown heart occurring. Williams, Packham's Triumph, Beurre Bosc, and

Josephine pears are also safe in such atmospheres. However, for Sturmer, Cleopatra, and Cox's apples and Winter Cole and Winter Nelis pears, the carbon dioxide content should be kept below 1% to be safe.

When apples or pears are stored in sealed plastic bags and the fruit is packed hot, or cooling is delayed or slow, damaging levels of carbon dioxide are likely to occur in the bags and the fruit is likely to develop brown heart.

Further reading

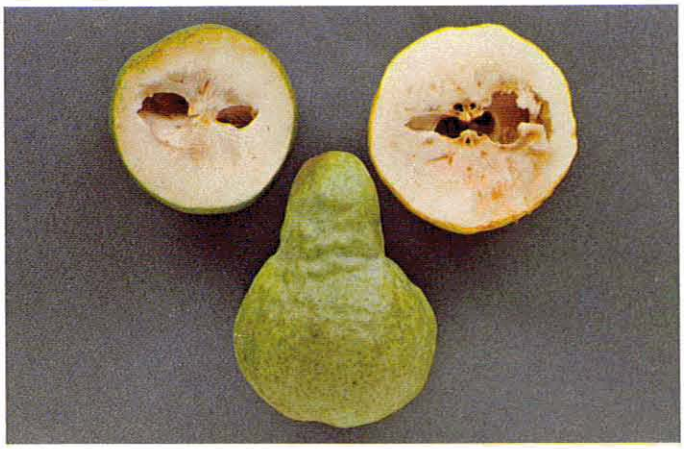
Carne, W. M. (1948).—The non-parasitic disorders of apple fruits in Australia. Bull. Coun. scient. ind. Res., Melb. No. 238.

Roberts, E. A., Scott, K. J., and Wills, R. B. (1964).—The effects of composition of the atmosphere and length of storage on the development of brown heart in Williams Bon Chrétien pears held in polyethylene bags. *Aust. J. exp. Agric. Anim. Husb.* **4**, 371–5.

35

Brown heart of pears—young lesion, var. Packham's Triumph.

Brown heart of pears—old lesion with cavities, var. Packham's Triumph.



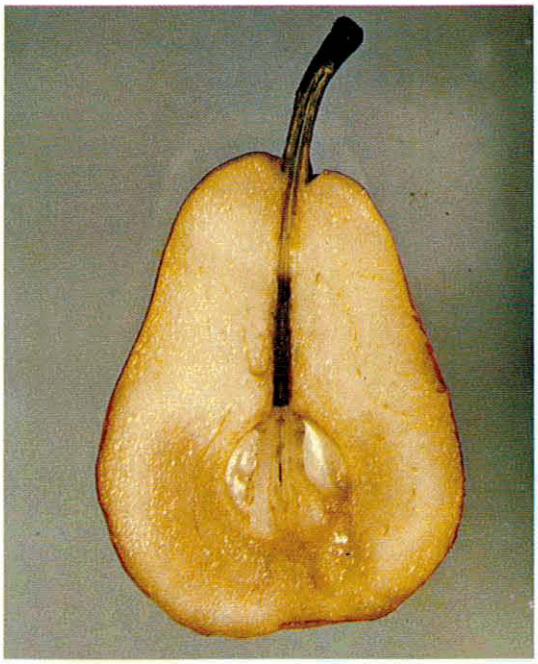
36

CORE BREAKDOWN IN PEARS

Pears kept too long in storage fail to ripen normally after removal to ripening temperatures. As pears approach the end of their storage life there is a progressive decline in the quality of the fruit when ripe and a progressive development of scalding of the skin and/or breakdown of the core and flesh. Finally, badly over-stored fruit, while it will colour, will not soften or develop characteristic flavour after removal, but develops scald and breakdown and a fermented flavour.

37

Core breakdown in pears due to over-storage.



38

Breakdown in pears, var. William's Bon Chrétien, due to over-maturity and over-storage. Note that the vascular system is also affected.

Core breakdown is a brown mushy breakdown of the core and surrounding tissue (Fig. 37). It is often part of the normal sequence of over-ripeness changes, in which case it is preceded by normal ripening. When due to over-storage this will not be so and the disorder develops soon after removal from low temperature. In less severe over-storage the fruit may soften satisfactorily but the flavour will be poor and core breakdown develops early so that at no stage is the pear fit to eat. Especially in over-stored fruit, core breakdown may merge into a more general discoloration and breakdown of the flesh.

Anything which reduces storage life, such as over-mature fruit or higher storage temperatures, will cause earlier development of the disorder.

When over-stored, pears, particularly elongated varieties like Beurre Bosc, often develop a brown to black discoloration of the vascular tissue connecting the stem to the core (Fig. 38) and often an associated discoloured breakdown of the flesh of the neck of the fruit around these vasculars. There may be a neck breakdown in over-ripe fruit but in this type there is no marked discoloration of the vascular strands and the breakdown is not associated with poor flavour and lack of juiciness in the ripe fruit.

As with core breakdown, factors that reduce storage life induce earlier development of neck breakdown and those, such as C.A. storage, which lengthen life delay the disorder.

Further reading

Hall, E. G., and Scott, K. J. (1964).—Cool storage of pears. *Agric. Gaz. N.S.W.* **75**, 1216–21. (Also issued as N.S.W. Dep. Agric. Div. Hort. Bull. No. H148.)

ALCOHOLIC POISONING OF APPLES

Alcoholic poisoning, or alcoholic breakdown, is an oxygen deficiency disorder caused by very low levels of oxygen around the fruit. The actual damaging level depends on the temperature and the condition of the fruit; at cool storage temperatures it is usually 1% or less. Therefore the disorder is often associated with brown heart.

Externally affected fruit shows extensive dark brown areas, usually smooth and shiny, which may be somewhat water-soaked (Fig. 39). The flesh under the skin may be affected with a brown breakdown to a depth of usually only about $\frac{1}{10}$–$\frac{1}{5}$ in. Characteristically the normal red colour of the skin of affected coloured varieties becomes bluish. After removal to air the affected flesh dries out and the skin above may become crinkled and depressed. A slight browning of the core may be an associated

symptom. The deficiency of oxygen also results in fermentation of the fruit and the development of an alcoholic flavour.

The disorder has occurred commercially in apples stored in sealed plastic bags under conditions causing a rapid consumption of oxygen which cannot be replaced fast enough. Similarly, it may also occur in fruit heavily waxed or coated with some other preservative film, when the coating is too thick or the temperature too high.

Further reading

Carne, W. M. (1948).—The non-parasitic disorders of apple fruits in Australia. Bull. Coun. scient. ind. Res., Melb. No. 238.

39

Alcoholic poisoning of apples, var. Delicious.

DIPHENYLAMINE INJURY TO APPLES

Before storage, apples are generally treated with a chemical inhibitor of superficial scald, usually with diphenylamine. If the concentration of the chemical is too high or the fruit is in the liquid too long, or if the temperature of the fruit is too high, or if previously treated fruit is stored in wraps impregnated with diphenylamine, the fruit may absorb injurious amounts of the chemical.

Diphenylamine injury takes several forms (Fig. 40) and visible damage is confined to the skin. It may be grey to brown to black, as small black spots or larger, lighter-coloured depressed spots, or light grey to brownish or black patches. Slight injury from pre-storage treatment by dipping or spraying is often only a light discoloration in the calyx or stem cavity. Slight injury from storage in treated wraps is usually a light, diffuse, greyish discoloration of the skin. Severe injury as a result of absorption of high levels of diphenylamine is dense and almost black and the flavour of the fruit is affected by the presence of the chemical in the flesh.

With most varieties injury can be prevented by avoiding over-exposure of the fruit to the chemical but the Sturmer and Golden Delicious varieties are so sensitive to diphenylamine that all contact with it must be avoided.

Further reading

Hall, E. G. (1971).—Cool storage of apples and pears, directions for practical scald control. (CSIRO Div. Fd Res.)

40

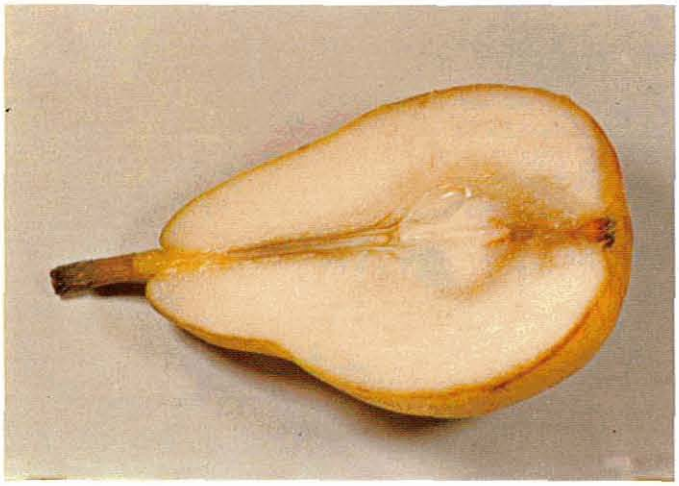
Chemical injury by diphenylamine scald inhibitor, var. Granny Smith.

VASCULAR BROWNING OF PEARS

A common sign of approaching over-storage and end of storage life in pears is browning of the vascular tissue from the stem to the core during ripening. The first clearly discernible vascular browning should be taken as a sign of the approaching end of commercial storage life and any remaining fruit of the line should be marketed without delay. Vascular browning is often associated with core breakdown (Fig. 37, Suppl. No. X, 1971) and the first signs of both, indicating incipient over-storage, may appear at about the same time. Pears with such discoloured central vascular tissue, while they may be edible, are usually of rather poor eating quality. In over-stored fruit, which has lost its capacity to ripen normally, the central vasculars may be severely discoloured and almost black.

While the variety Beurre Bosc is most prone to this disorder, other varieties may also be affected.

Control is by avoiding over-storage and the factors associated with short storage life, such as over-maturity at harvest, delayed storage, slow cooling, and storage temperatures that are too high.



41 Vascular browning of Beurre Bosc pears due to over-storage.

42 Superficial scald of Packham's Triumph pears.

SUPERFICIAL SCALD OF PEARS

This is a grey to brown, often speckled, discoloration of the skin of the Packham's Triumph and Beurre d'Anjou varieties of pears in cool storage. Unlike over-storage scald (pear scald), which it resembles, it does not occur on other varieties; it may occur relatively early in storage, long before the fruit has lost its ability to ripen normally, and the skin does not slough off.

As with superficial scald of apples the disorder on pears is worse in fruit picked prematurely and develops considerably after removal from cool storage. Like superficial scald of apples it can be controlled by using oiled wraps, or by dipping or spraying the fruit with either diphenylamine or ethoxyquin, or by using wraps impregnated with one of these scald-inhibiting chemicals. Ethoxyquin is the more effective on pears though it tends to result in shortened storage life and faster yellowing, but this is only significant for fruit cool-stored for a long time.

Warning: While use of these chemicals is permitted in Australia, they should not be used on export fruit unless specifically permitted by the importing country.

Further reading

Hall, E. G., Scott, K. J., and Riley, T. J. (1962). —Control of superficial scald on Packham's Triumph pears. *CSIRO Fd Preserv. Q.* **22**, 15–18. (Also in *Agric. Gaz. N.S.W.* **73**, 73–4 (1962).)

OVER-STORAGE SCALD OF PEARS

Many varieties of pears, particularly Williams (Bartlett), when kept in storage too long, develop a brown discoloration of the skin, often first evident as a fine spotting of the lenticels. The scald later becomes continuous but with indistinct edges, often shiny and darker brown, and, unlike superficial scald, the affected skin later readily sloughs off.

Affected fruit shows other symptoms of over-storage—yellowing of the skin while still in cool storage, failure to soften and to ripen after removal to ripening temperatures, and the development of an unpleasant, fermented taste, as well as rapid development of core breakdown and of rots.

Early development of over-storage disorders may be due to over-maturity at picking, delay before storage, slow cooling, or high storage temperatures. To avoid over-storage, pears should be removed from the cool store while still hard and green to light green. Over-storage scald is not controlled by wrapping the fruit in oiled wraps or by treating it with diphenylamine or ethoxyquin.

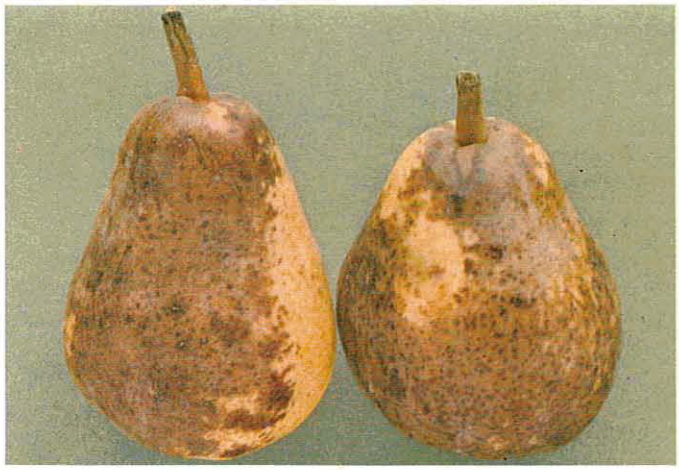
Further reading

Hall, E. G., and Scott, K. J. (1964).—Cool storage of pears. N.S.W. Dep. Agric. Bull. No. H148. (Also in *Agric. Gaz. N.S.W.* **75**, 1216–21 (1964).)

STORAGE SCALD OF OHANEZ GRAPES

The Ohanez (Almeria) is a late white grape with a tough skin and keeps well. However, it develops a scald-like discoloration of the skin in storage which ranges from a general dull appearance to a distinct brown discoloration that may involve the whole surface of individual berries. Discoloration is confined to the skin and subepidermal tissue. Flavour of the affected berries remains normal.

Little is known of the cause of the disorder and there is no satisfactory control. Nevertheless it has been found that fruit from strong vines and fruit picked in the middle of the normal picking period discolour less, and also that the greener, less mature berries are more prone to scald.



43

Over-storage scald of Williams Bon Chretien pears.

44

Storage scald of Ohanez grapes.

GREY MOULD ROT ON GRAPES

The fungus *Botrytis cinerea* is widespread and causes decay in many kinds of fruits,* vegetables, and ornamentals. Grey mould, caused by this fungus, is usually the principal cause of spoilage of grapes in cool storage. This is particularly so in wet seasons when infection and losses of fruit on the vine may be serious. In wet, cool seasons flowers, stems, and young berries may be infected, leading to a high spore load at harvest which may cause heavy losses in storage. Varieties of grapes that form tight bunches are worst affected because of damage to berries by growth pressure and because the bunches dry out slowly.

In the early stages the infection is inside the berry and the symptoms are a 'slip-skin' condition or a slight browning of the affected areas of the berry. Later it grows to the surface and spreads to other berries, forming a cottony white mass which becomes grey by the production of immense numbers of spores and a slight darkening of the mycelium; in storage a large 'nest rot', involving whole bunches, may be formed (Fig. 45).

Initial infection is via breaks in the skin, e.g. rain cracks, or into berries loosened by rough handling.

* *See* Grey mould of apples and pears, Figs. 31–2, Suppl. No. VIII, 1971.

Control requires:

- Spraying with a fungicide in the vineyard to prevent early infections; this is essential in wet or cool weather. Benomyl is very effective and Captan is also recommended.
- Careful handling.
- Prompt cooling.
- In storage—fumigation with sulphur dioxide or packing with sulphur dioxide-releasing chemicals; post-harvest treatment with benomyl is also effective.

45 Grey mould rot (*Botrytis* sp.) on Purple Cornichon grapes.

BLUE MOULD ROT ON GRAPES

Blue mould rot caused by *Penicillium* sp. is relatively common on grapes in storage. It is characterized by a rather scanty growth of mycelium which later turns bluish green as spore masses develop (Fig. 46). The fungus is a weak parasite and commonly first attacks dead or damaged stem tissue or damaged berries. It is usually only a problem on grapes after relatively long storage, when stems and cracked or loosened berries may be extensively affected. Berries on affected bunches commonly have a noticeably musty or mouldy taste.

Control is by careful handling, treatment before storage with a suitable fungicide such as benomyl, prompt cooling, and avoidance of over-long storage. Treatment with sulphur dioxide is also useful.

46 Blue mould rot (*Penicillium* sp.) on Purple Cornichon grapes.

SULPHUR DIOXIDE INJURY ON GRAPES

Treatment of grapes in storage or transport with sulphur dioxide is most effective in reducing decay and 'shatter' (loosening and dropping of berries from the bunch) and in preventing blackening of the stems. Nevertheless, injury by sulphur dioxide can readily occur unless adequate precautions are taken.

The injury is commonly a bleaching or discoloration of the berries which is most pronounced and first occurs at breaks in the skin or the loosened attachment of the berry to the pedicel, thus allowing ready absorption of the gas (Fig. 47). Because of the bleaching effect the injury is more apparent on dark-skinned varieties (Fig. 48).

When milder injury occurs at the point of attachment of the berry, that part of the skin and flesh may dry out and collapse forming a small, pale straw-coloured pit or depression which is a characteristic symptom. Under warm conditions the injured tissue generally turns brown. Badly injured berries have a disagreeable, astringent, 'sulphur' taste.

Injury can be prevented by avoiding excessive levels of sulphur dioxide and by careful handling to avoid mechanical damage to the berries. Grapes that are weak, immature, or very warm take up the gas more readily and are therefore more likely to be injured than grapes that are firm, mature, or cold.

Further reading

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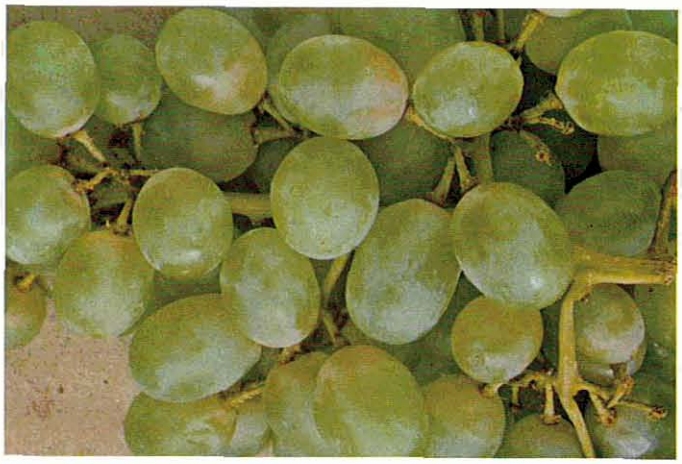
Ryall, A. L., and Harvey, J. M. (1959).—The cold storage of *Vinifera* table grapes. U.S. Dep. Agric. Agric. Handb. No. 159.



47 Sulphur dioxide injury on Sultana (Thompson's Seedless) grapes.

48 Sulphur dioxide injury on Purple Cornichon grapes.

COOL STORAGE DISORDERS OF CITRUS FRUITS

Citrus fruits are sensitive to chilling and are liable to develop a variety of physiological injuries to the rind in cool storage. Storage spot is the most important of these injuries.

Storage Spot (Cold Storage Pitting)

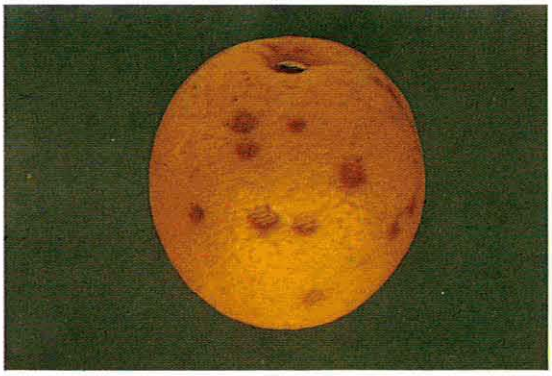
The term storage spot refers to sunken spots or pits, usually comparatively shallow, or areas of varying size and shape, generally brown in colour, which may develop on the skin during cool storage over a wide range of temperatures from −1°C to 10°C but most commonly in the range 3–8°C. True storage spot is a physiological cold injury, but because of wide variation in symptoms and similarity to lesions of fungal origin, the disorder cannot be identified on appearance alone. It is useful to separate storage spot disorders into *lateral spot* and *button spot*; the latter originates around the button, the weakest part of the fruit, and is more likely to be infected with weak parasitic fungi like *Colletotrichum* and *Alternaria*.

At the generally recommended storage temperatures of 4–7°C the most common form of lateral spot on oranges consists of irregular, discrete, moderately sunken, brown spots (Fig. 49). The disorder may also show as small more or less circular and deeply sunken spots (Fig. 50), or as diffuse darker and less sunken areas more scald-like in character (Fig. 51). Button storage spot (Fig. 52) may be quite extensive and show evidence of considerable desiccation or, at higher temperatures, of fungal infection via the button, which may penetrate into the albedo (inner white pith of the skin) and produce button rots or centre rots. These low-grade infections are more active on weaker, more mature, or long-stored fruit. Somewhat similar lesions occur on grapefruit and mandarins; on the latter storage spot is often associated with *oleocellosis* (rind oil burn).

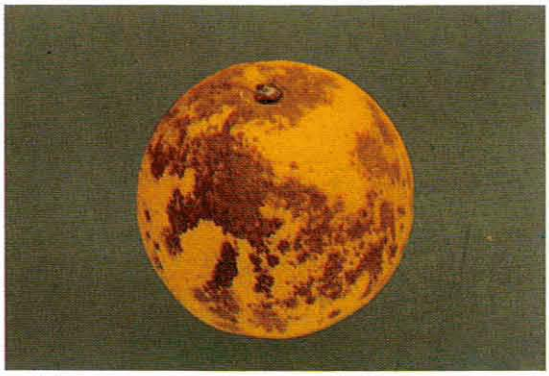
On grapefruit, storage spot is often pale at first and the spots are small and numerous with dark oil glands; later they often coalesce to form dark patches (Fig. 53). On lemons storage spot is usually a more definite pitting, with the oil glands showing darkly in the lesions (Fig. 54).

Little is known about the cause of storage spot, except that it is a chilling injury and is often

49 Storage spot (pit) on Valencia oranges. Lateral type, normal.



50 Storage spot (pit) on Valencia orange. Lateral type, small sunken pits.



51 Storage spot on Valencia orange. Lateral type, diffuse, scald-like.

associated with fungal infections. It develops most rapidly at about 7°C, and can be avoided by storage above a certain critical temperature, which is about 10°C for oranges and mandarins and 13°C for grapefruit and lemons. Temperatures high enough to avoid chilling injury, however, are generally unsatisfactory for storage because of more rapid staling and development of fungal infections. At lower temperatures storage life can be short because of the development of bitter off-flavours and scald. Less mature fruit picked early in the season is usually more susceptible. Grapefruit and lemons are more susceptible than oranges and mandarins and should be stored at 10°C and 12°C respectively, compared with generally about 5°C for the latter. Any weakening of the rind by infection, or mechanical or chemical injury, predisposes to storage spot; lower humidities, with accompanying higher evaporation, accentuate the lesions.

Further reading

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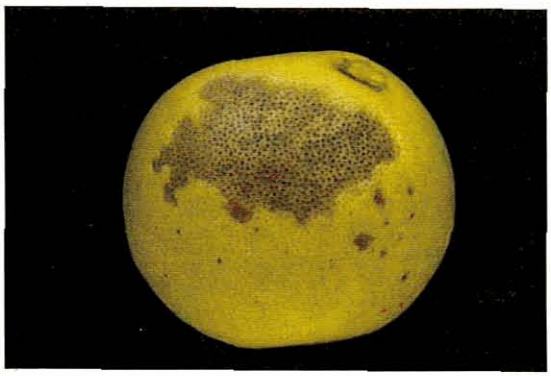
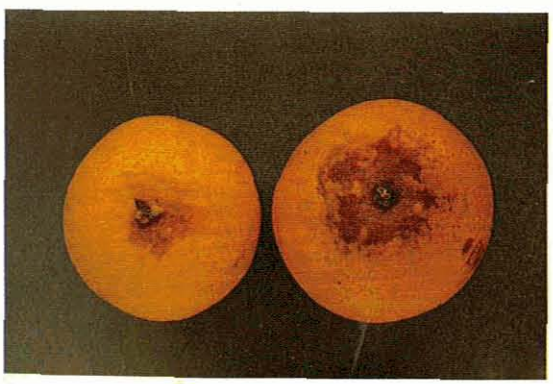
Fawcett, C. S. (1936).—'Citrus Diseases and Their Control.' 656 pp. (McGraw-Hill: New York.)



53

Storage spot on Marsh grapefruit. Lateral type.



52

Storage spot (pit) on Valencia oranges. Button or stem-end type.

54

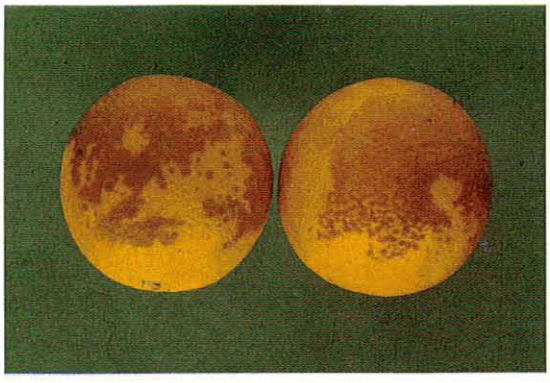
Storage spot (pit) on Eureka lemons.

COOL STORAGE DISORDERS OF CITRUS FRUITS

Cold Scald (Scald or Browning)

Cold scald is a superficial grey to brown discoloration of the rind, mainly affecting oranges, which develops in cold storage at temperatures below about 3°C. It may be just a faint grey discoloration over small areas that is readily confused with *sooty blotch*, or an extensive, often dense, and sometimes shiny browning (Fig. 55). There is often a sharp margin, characteristically on one side of the lesion, between sound and affected rind. When severe the lesion may become slightly depressed, especially between the oil glands which do not collapse as in storage spot. The early stages of the brown type may show up as many very small pale shallow pits and some forms remain somewhat speckled in appearance.

An 'oleocellosis scald', pale in colour and with indistinct margins, may develop, usually around the stem end; the first sign is when the tissue between the oil glands sinks, giving the rind a 'pebbly' appearance. It often merges into speckled storage spot or *flavocellosis* and may be followed by rind breakdown, especially on frosted fruit. Scald may be induced by mechanical injuries or oleocellosis (Fig. 56). Scald develops early and rapidly in cool storage but unlike storage spot does not become more pronounced after removal from low temperature; indeed, it may become less obvious as the general colour of the fruit deepens. Moreover, unlike storage spot, mature fruit is more susceptible to cold scald than that picked earlier in the season.



55 Cold scald on Washington Navel oranges.

56 Cold scald on Washington Navel oranges. Note induction by injuries.

Flavocellosis (Skin Bleach)

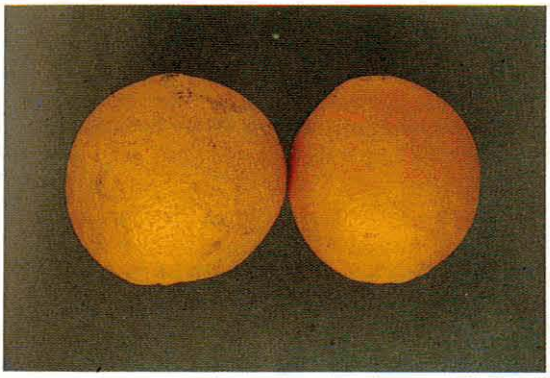
The initial symptom of this disorder on oranges is a bleaching of the rind between darkened oil glands with the development of a light yellow or cream, somewhat opaque, discoloration of a considerable portion of the skin which becomes rather soft and readily invaded by fungi (Fig. 57). Later the affected area extends and the older parts may dry and harden. In advanced cases the oil glands usually collapse and the affected rind becomes depressed but the colour remains pale. At low temperatures it may develop into a greyish, somewhat water-soaked rind breakdown. Flavocellosis mostly occurs at temperatures below 2°C, rarely at 5°C, and is more common on inland fruit, especially if slightly frosted.

Glazed Scab

This disorder occurs more frequently at temperatures in the range 7–10°C. Oranges develop hard, slightly raised, glazed ('enamelled') areas which are cream to grey in colour and in which the oil glands may or may not show through (Fig. 58). The disorder may develop into a general greyish breakdown with the development of secondary fungal rots. Glazed scab is most common on Navel oranges picked early in the season.

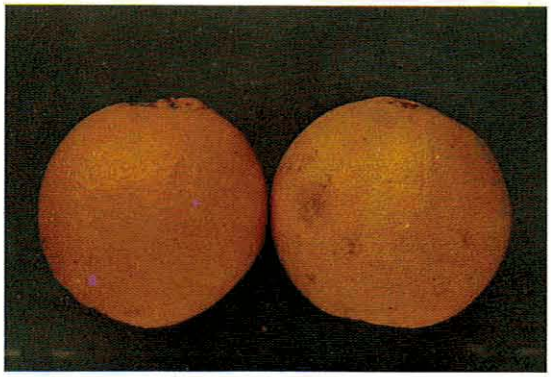
Further reading

Huelin, F. E. (1942).—The handling and storage of Australian oranges, mandarins and grapefruit. Coun. sci. industr. Res. Aust. Bull. No. 154.



57

Flavocellosis on Washington Navel orange. Diseased fruit on left, normal fruit on right.



58

Glazed scab on Washington Navel orange. Diseased fruit on right, normal fruit on left.

MARKET AND STORAGE DISEASES OF CITRUS FRUITS

Green and Blue Mould Rots

Green mould (Fig. 59), caused by the fungus *Penicillium digitatum*, is the most important cause of wastage of citrus fruits after harvest; blue mould (*Penicillium italicum*) (Fig. 60) is similar but much less common. All species of citrus fruits are susceptible to these rots, particularly when more mature.

The first sign is a soft water-soaked area on the surface of the fruit. Under favourable conditions of warmth and high humidity the soft rot develops rapidly, the fruit becoming covered with a dense whitish growth of mycelium, from the centre of which masses of fungal spores form and spread out, producing a dense, coloured growth of spores which rise in clouds at the slightest touch.

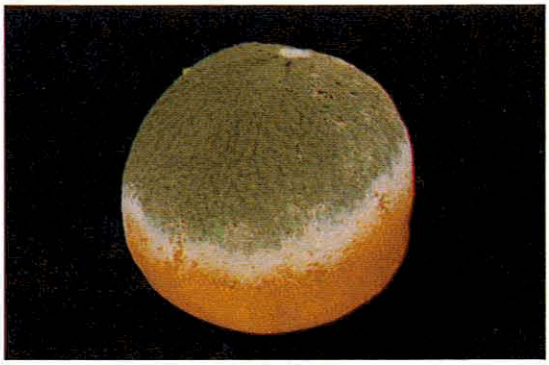
Generally, sound undamaged fruits are not affected unless by contact-spread from rotted specimens. However, even slight damage to the rind opens the way to infection, and therefore careful handling is a basic safeguard. Mould development is rapid at temperatures of 20–25°C and very slow at temperatures below 5°C and above 30°C.

Control requires careful handling at all times, and treatment promptly after picking with a recommended fungicide such as Tecto 90 or benomyl (Benlate). The fruit should be treated within 36 hours of picking in summer and 72 hours in winter, otherwise the infection may be too deep-seated to be eradicated.

Further reading

Long, J. K., Leggo, D., and Seberry, J. A. (1965).—Washing, sterilizing, and waxing citrus fruits. N.S.W. Dep. Agric. Bull. No. H168.

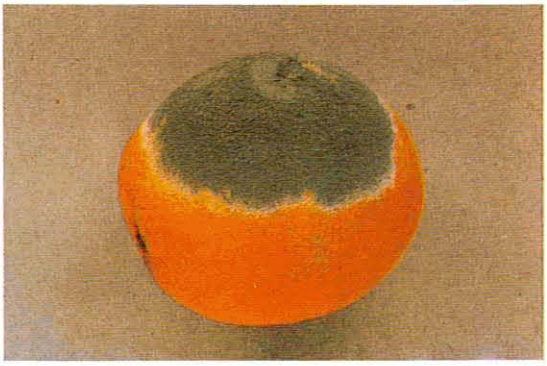
Citrus Wastage Research Laboratory (1970, 1972).—Citrus Wastage Research News Nos. 4 and 5.



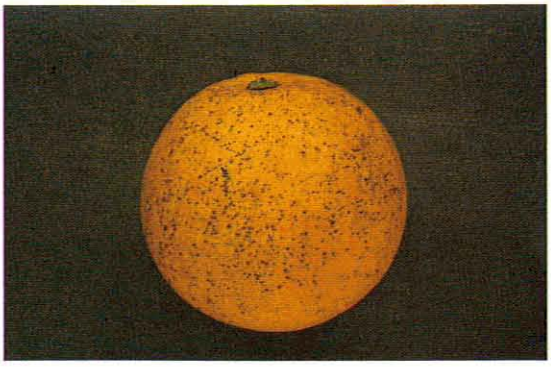
59 Green mould on Washington Navel orange.

Melanose

Melanose, an orchard disease that disfigures the skin of fruit grown in coastal areas, is caused by the fungus *Diaporthe citri*, which also causes stem-



60 Blue mould on Valencia orange.



61 Melanose—'fly-speck' form—on Washington Navel orange.

end rot (*q.v.*). The characteristic appearance of melanose is due to the many pinpoint infections scattered over the rind; by the time the fruit matures, each of these becomes a raised spot up to 1 mm in diameter and reddish brown to black in colour, giving the common 'fly-speck' appearance (Fig. 61). More severe infections, in which large numbers of the water-borne spores wash down over the fruit, produce the 'tear-stain' or 'mud-cake' forms of the disease (Fig. 62). Oranges and grapefruit are most affected. Control is by spray application of a recommended copper-containing fungicide at the petal-fall stage.

Stem-end Rot

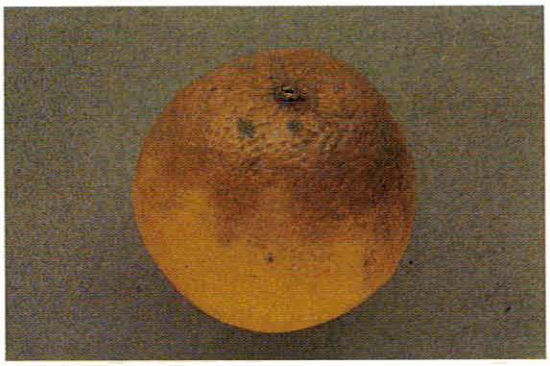
This is a firm, pliable, light brown rot which commences at the stem end and grows slowly with very little surface development of the fungus (Fig. 63). Most stem-end rots in fruit grown in coastal areas are caused by the fungus *Diaporthe citri*, and all commercial varieties of citrus are affected. Stem-end rots are much less common in fruit grown in inland areas but other fungi, such as *Alternaria*, may produce stem-end rots in weak fruit (Fig. 64).

Diaporthe citri infects the green button while the fruit is on the tree, but remains dormant until after harvest, when aging of the fruit allows the rot to develop. Old and weak trees in high-rainfall areas are most likely to be heavily infected by the fungus, especially if orchard sanitation has been neglected; fruit from them should not be stored. Susceptibility increases with increasing maturity of the fruit at harvest and with higher storage temperatures.

Control can be achieved by orchard sanitation and field sprays, and by treating the fruit after harvest with an effective fungicide such as benomyl, and with 2,4-D to delay aging of the buttons.

Further reading

Anon. (1972).—Melanose of citrus. 2nd Ed. N.S.W. Dep. Agric. Pl. Dis. Bull. No. 22.

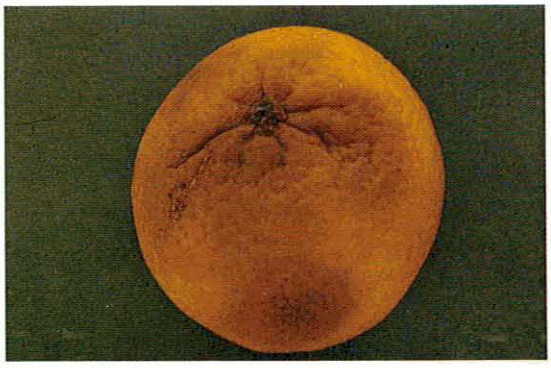


63

Stem-end rot on coastal fruit.

62

Melanose—'tear-stain' and 'mud-cake' forms—on Washington Navel orange.



64

Stem-end rot on inland fruit.

MARKET AND STORAGE DISEASES OF CITRUS FRUITS

Black Centre Rot

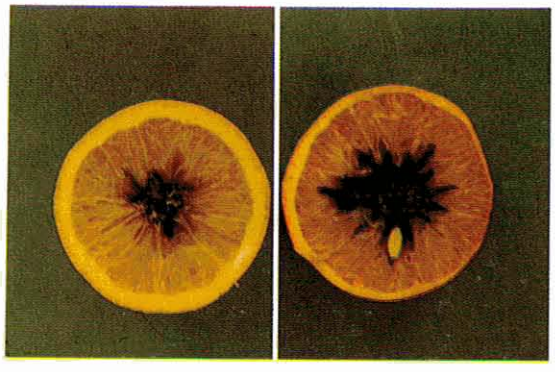
This is a slow-growing rot usually confined to fruit weakened by over-maturity, adverse climatic conditions, and/or long storage. Infection is via the button or the stylar end of the fruit, and it proceeds slowly down the 'core' where a black centre rot develops, often without any external indication of its presence (Fig. 65). It is caused by the fungus *Alternaria citri*.

Mandarins are more often affected, particularly if cool stored at higher temperatures (7–10°C) for several weeks.

Alternaria rot is not controlled by benzimidazole compounds such as TBZ and benomyl, and fruit treated with these and thus protected from green and blue moulds may eventually develop considerable black centre rot after long storage. The problem can be overcome by avoiding long storage at higher temperatures, and storage of over-mature fruit.

Sour Rot

This is a pale soft decay (Fig. 66), which later develops a creamy slimy surface growth. It usually has a putrid sour odour and is especially attractive to ferment flies, which lay their eggs in the rotten fruit. Sour rot is caused by the fungus *Gleotrichum candidum* var. *citri-aurantii*. It occurs in fruit weakened by over-maturity and long storage, more commonly in lemons and grapefruit after long storage at higher temperatures. Initial infection is mainly through injuries, and it spreads by contact to produce a putrid, sour, leaking, maggot-filled mass. As with black centre rot, the remedy lies in choosing sound young fruit for storage, and in not storing for too long or at too high a temperature.



65 Black centre rot (*Alternaria*) on (*left*) Valencia orange and (*right*) Ellendale mandarin.

66 Sour rot on Washington Navel orange.

Black Spot

Black spot is a serious disease of the rind affecting all commercial varieties of mature citrus fruits in the orchard and during storage. It is confined to the coastal areas of high rainfall and principally affects the Valencia variety since this matures during warm weather, when conditions favour the disease. It is caused by the fungus *Guignardia citricarpa* which infects the fruit during the first 20 weeks after petal fall; the disease itself does not appear until the fruit matures 12 months later.

In one form, which develops early and grows slowly, the spots are small, sunken, and black-edged, with pale centres in which pinpoint black dots can be seen (Fig. 67). A later, more virulent form develops very rapidly, especially when hot dry winds occur in late spring and early summer; many small reddish brown spots rapidly enlarge to form brown sunken areas up to 15 mm in diameter and these may coalesce to affect most of the rind.

Because of latent infections, the disease can also develop on apparently sound fruit in cool storage, especially at higher temperatures, or it can develop when the fruit is held at high temperatures after cool storage. It may show as irregular sunken light brown areas, or as larger irregular dark brown to black areas that may coalesce (Figs. 68 and 69).

Black spot is not to be confused with septoria spot, which is similar in appearance but has a persistent reddish purple tinge to the lesions and occurs only on inland fruit.

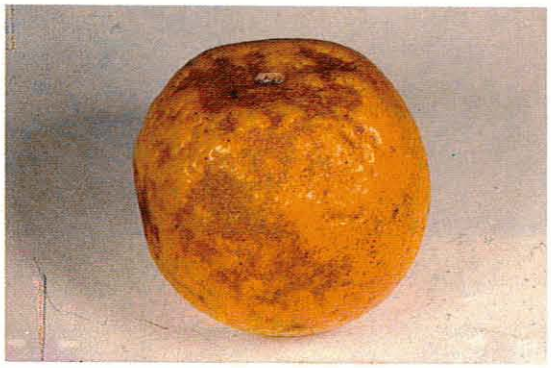
Control is by spray applications of Bordeaux mixture at petal fall, with follow-up sprays of mezineb and oil 9 and 16 weeks after the initial spray.

Further reading

Kiely, T. (1970).—Black spot of citrus. 5th Ed. N.S.W. Dep. Agric. Pl. Dis. Bull. No. 11.

67

Typical field symptoms of black spot on Valencia orange.



68

69

Black spot developed in cool storage on Valencia orange.

MARKET AND STORAGE DISEASES OF CITRUS FRUITS

Wind Rub

Very young and young fruits may be abraded by wind action causing them to rub against a twig or the edge of a leaf. As such damaged fruits mature they develop characteristic silvery, scurfy areas on the rind (Fig. 70). The rind of injured lemons may thicken into ridges.

Although young fruits with their delicate rind are more susceptible to wind injury, older fruits may also be blemished by being tossed about by wind. This may result in twig or thorn punctures or scratches, or rub damage. Such injuries occurring later in the development of the fruit are less silvery and scurfy and more brown in colour.

Control is by sheltering the trees and fruit from wind—by selection of site and aspect, by growing trees for wind-breaks or erecting artificial wind-breaks, and also by pruning out dead wood and twigs and avoiding or getting rid of strong thorny growths in the tree.

Further reading

Freeman, B. (1973).—Control of rind blemishes in citrus fruits. *Agric. Gaz. N.S.W.* **84**(1), 23-5.

70 Blemish due to wind rub.

Crinkle or Creasing

This condition occurs in mature and over-mature oranges and is characterized by narrow sunken grooves in the rind, commonly longitudinally but often crosswise. In severe cases they may run together giving the fruit a lumpy appearance and a soft feel. It is a consequence of the cracking of the underlying albedo or inner white part of the rind (Fig. 71). At first, crinkle is not discoloured but larger grooves are usually yellowish green or greyish in colour. The flavedo, or outer yellow part of the rind, may also split if the rind is thin and brittle, and this opens the way for development of rots.

The condition develops on the tree and the cause is not known, but water stresses and associated growth stresses are probably involved. It has been more common when rain has followed long periods of dry weather.

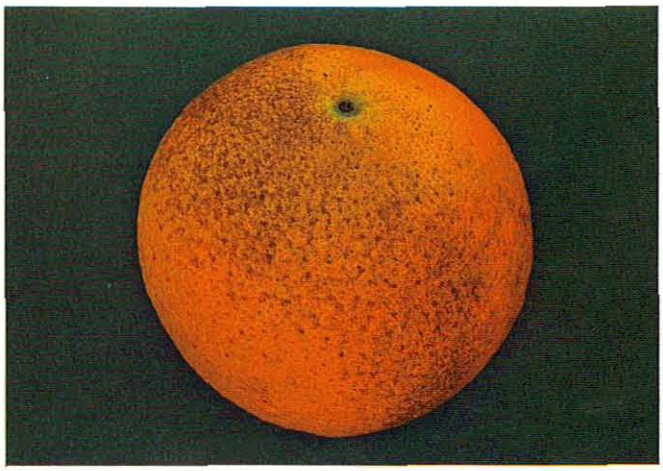
71 Crinkle or creasing.

Rust Mite Injury

There are two species of mites which attack oranges and grapefruit in Australia, producing rusty stains on the fruit as a result of their feeding. One, *Tegolothus australis*, produces a brown shiny superficial stain-like blemish (Fig. 72). The other, *Phyllocoptruta oleivorus*, occurs in several countries and produces a silvery grey russeting of the rind. Injury is often due to mixed populations of both species.

Affected fruit shrivels more rapidly than unaffected fruit.

Control is achieved by sulphur sprays or more commonly, in coastal areas of Australia, by spraying with a fungicide with a miticidal action, such as zineb.



72

Rust mite injury.

Lemon Scab

This is an orchard disease which disfigures the fruit as well as attacking twigs and leaves. It is caused by infection with the parasitic fungus, *Sphaceloma fawcetti scabiosa*, and although other kinds of citrus may be attacked, it mainly affects lemons in coastal districts where climatic conditions are favourable for its development. Fruit is infected at the time of blossoming and petal fall and only in damp weather. The infection produces irregular, scabby areas, ridging, russeting, and wart-like, deforming outgrowths of the rind (Fig. 73).

Control is readily obtained by spraying with Bordeaux mixture at blossom time in the spring and again in summer with zineb to protect the young fruit developing from a summer bloom.

73

Common or lemon scab.

Further reading on market diseases of citrus fruits

Keily, T.B., and Long, J.K. (1960).—Market diseases of citrus. *Agric. Gaz. N.S.W.* **71**, 132-5, 157, 187-92.

Rose, D.H., *et al.* (1943).—Market diseases of fruit and vegetables—citrus and subtropicals. U.S. Dep. Agric. Misc. Publ. No. 498.

MARKET AND STORAGE DISEASES OF CITRUS FRUITS

Oleocellosis

Oleocellosis, or oil spotting, is a characteristic injury to the skin of citrus fruits caused by oil released from ruptured oil glands. The typical symptoms are greenish, yellowish, or brown, firm irregular spots or patches on the skin in which the oil glands stand out due to collapse of the tissue between them (Fig. 74).

The affected areas commonly turn brown with age and the oil glands then collapse. At this stage oleocellosis on cool-stored fruit can look like cold injury storage spot (*Figs. 50-54*).

If the damage occurs to green fruit the affected area does not colour normally and remains green. Oleocellosis may occur at any time on the tree or after harvest as a result of abrasive or other injury. Fruit is particularly liable to this rind-oil spotting during cool, wet periods early in the season, when the rind is very turgid and the oil more injurious than later in the season.

Control is by careful handling to avoid rind injury; fruit should not be harvested while wet from rain or dew, nor while very turgid in cool moist weather, particularly early in the season. If it is suspected that damaging oil has been released injury can be prevented by washing it off without delay. De-greening early Navel oranges, lemons, or mandarins picked in cool, wet, winter weather commonly causes severe injury.

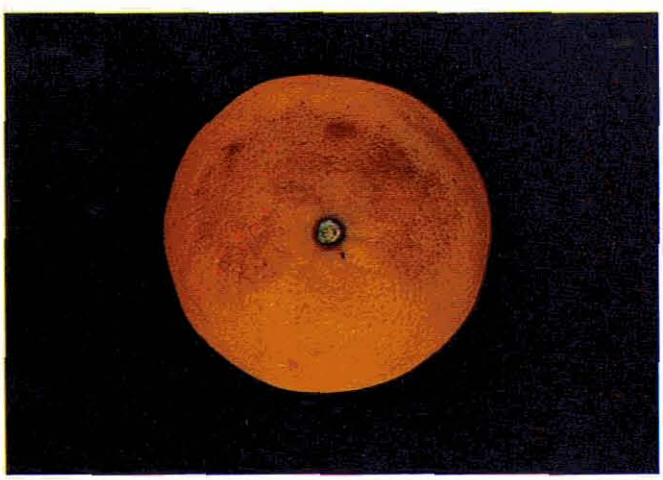
74 Oleocellosis or oil burn.

Stem-end Browning ('Aging')

This is a condition mainly of oranges and grapefruit, in which the rind around the stem end of the fruit becomes wilted and shrivelled, with later collapse and brown discoloration of tissues of the outer rind, or flavedo (Fig. 75).

It is due to loss of water from the fruit and mainly affects Valencia oranges picked in warmer weather, when the trees are under some water deficiency stress. The condition may become apparent during storage. Fruit showing severe symptoms usually has a stale flavour.

Control is by minimizing evaporation of water from the fruit, firstly, by not picking when the trees (and the fruit) are stressed by lack of water and, secondly, by minimizing water loss after harvest by waxing the fruit and holding it at lower temperatures and higher humidities.



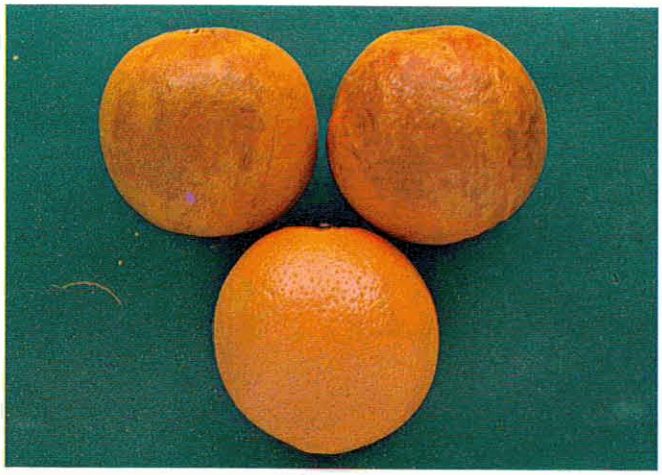
75 Stem-end browning or 'aging'.

Rind Blemish due to Rough Handling

Rind Staining

As a result of mechanical abrasion during harvesting, processing, packing, or transport, mature soft-skinned oranges, especially Navel oranges, may develop a brown, or reddish brown, discoloration of the damaged areas and most of the surface of the rind may be affected (Fig. 76). In more severely blemished fruit some collapse and shallow pitting of the rind develop. This browning due to mechanical injury can be distinguished from cold injury (scald or storage spot) by evidence of abrasion, the reddish brown colour, absence of exposure to cool storage, and the usually greater desiccation.

Control is by careful handling of soft, mature fruit, picking the fruit before it becomes over-mature, and by delaying maturation and aging by spraying with gibberellic acid a few weeks before harvest; details may be obtained from State Departments of Agriculture.



76

Rind staining.

Rub Injury

Abrasive, rough handling may produce a different type of rind injury on fine-skinned or very turgid fruit at any time during the season. This injury, which can be described as 'rub injury', is due to abrasion of high spots on the rind, and appears as multiple, abraded, brown to dark brown areas on the rind (Fig. 77). It has been seen on slightly frost-affected, very turgid, Navel oranges as well as on soft, over-mature lemons and is accentuated by degreening and processing treatments. The only practicable control is by careful handling at all times, especially of very turgid, aged, and soft, or very fine-skinned, fruit.

77

Rub injury.

Further reading on market diseases of citrus fruits

Keily, T.B., and Long, J.K. (1960).—Market diseases of citrus. *Agric. Gaz. N.S.W.* **71,** 132-5, 157, 187-92.

Rose, D.H., *et al.* (1943).—Market diseases of fruit and vegetables—citrus and subtropicals. U.S. Dep. Agric. Misc. Publ. No. 498.

MARKET AND STORAGE DISEASES OF CITRUS FRUITS

Septoria Spot

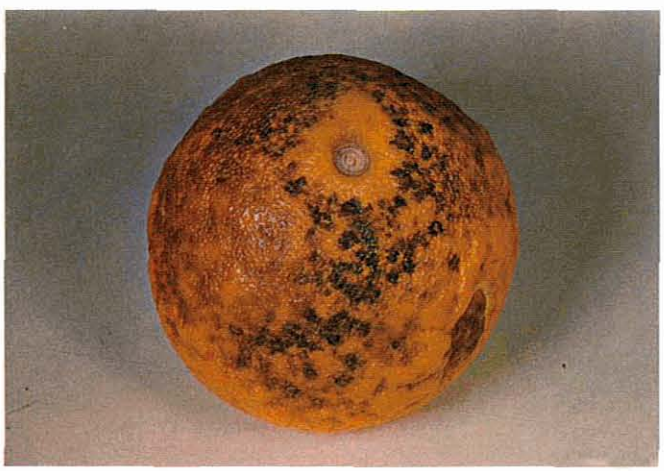
While the symptoms of septoria spot, caused by the fungus *Septoria depressa,* are similar to those of black spot (see Supp. XVI, Figs 67–69), the disease does not occur on coastal fruit, being confined to maturing citrus fruit in inland areas, where black spot does not occur.

The disease produces round, dark brown sunken spots on the rind which may vary in size from 1 to 10 mm and which may coalesce to form large blemished areas (Fig. 78). The lesions often exhibit a characteristic purplish tint and in later stages of the disease tiny black spots (pycnidia) can often be seen in the lesions. The rind underneath is discoloured and greyish. Septoria spot is often associated with frost injury which considerably reduces the resistance of the rind.

The infection occurs in the autumn or early winter and is favoured by cool showery weather or heavy dews. Development stops with the coming of warm weather. After harvest, if the temperatures are low or the fruit is in cool storage, fruit that is apparently healthy may develop severe septoria spot or even septoria rot (Fig. 79). Navel oranges seem to be more susceptible than other kinds, probably because they are maturing during winter months.

The disease can be controlled by spraying, in March, with Bordeaux mixture or the equivalent, following recommendations put out by the State Departments of Agriculture. Post-harvest treatments, e.g. in the packing house, are ineffective.

78 Septoria spot.



79 Septoria rot.

Sooty Mould

Sooty mould is the heavy, almost black growth of *Capnodium* spp. and related fungi on the surface of fruit, leaves and twigs of citrus (Fig. 80). It grows on the sugary secretions of 'honey dew' produced by certain scales and other insects such as aphids that may infest citrus trees; it is entirely superficial and in no way parasitic. Sooty mould may interfere with normal colouring on the tree and should therefore be prevented where possible.

As it is entirely dependent on insect infestation and the presence of 'honey dew', control is by controlling scale insects and aphids, following the recommendations of State Departments of Agriculture. The growth can be rubbed off and if heavy, may break away in flakes. Affected fruit can readily be cleaned by using the efficient washing and wet-brushing methods recommended for routine use in the packing house.

Further reading

Anon. (1970). Sooty mould. N.S.W. Dep. Agric. Pl. Dis. Bull. No. 21.
Long, J.K., Leggo, D. and Seberry, J.A. (1965). Washing, sterilizing and waxing citrus fruits. N.S.W. Dep. Agric. Bull. No. H168.

Sooty Blotch

Sooty blotch is a superficial disease of citrus fruits, apples and pears. It is a superficial growth of the fungus *Gloeodes pomigena,* the closely packed fine threads (mycelium) of which produce dark filmy smudges on the fruit as if it were lightly dusted with soot (Fig. 81). Sooty blotch develops on the tree and is favoured by moist conditions and shade. When the disease is severe the individual growths coalesce and become heavier and darker.

The fungal growth is entirely superficial, and can readily be removed by rubbing or efficient spray-washing of the fruit over brushes. The disease is more common on mature fruit and is usually confined to fruit from coastal areas. It can be controlled by the spray programs recommended for control of black spot (Supp. XVI, Figs 67–69).

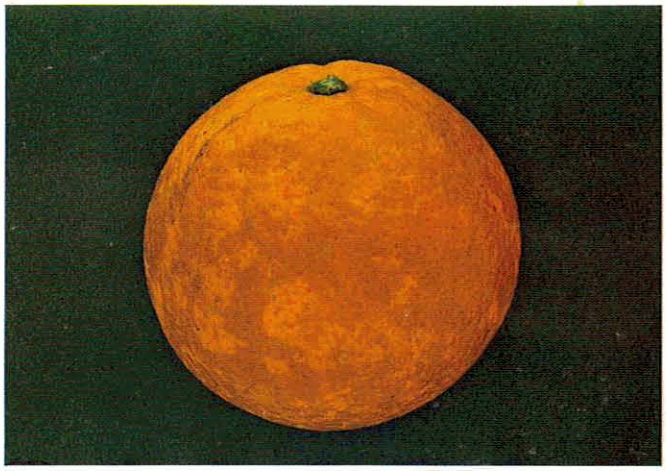
The unsightly blemishes produced by the fungus can also be bleached out by dipping the citrus fruits, apples or pears for 90 s in a solution of 25 g calcium hypochlorite (bleaching powder) plus 25 g boracic acid *or* 15 g sodium bicarbonate in 1 l water, in a non-metal container. Add the bleaching powder to the full volume of water and then add the other ingredient. Afrer dipping, the fruit should be rinsed in clean water and dried.

Further reading

Anon. (1965). Sooty blotch and fly speck. N.S.W. Dep. Agric. Pl. Dis. Leafl. No. 23.

80

Sooty mould.



81

Sooty blotch.

MARKET AND STORAGE DISEASES OF CITRUS FRUITS

Ethylene-gas Burn

Citrus fruits may be quite palatable although unattractively greenish in colour. Early in the season Navel oranges and mandarins may become ripe enough for eating before the skin is fully coloured, Valencia oranges commonly regreen late in the season, while citrus grown in semi-tropical areas never take on their full yellow or orange colour. Such fruit may be degreened by exposure to ethylene gas at suitable temperatures and high humidity.

During this procedure the rind of the fruit may be 'burned' by ethylene if the concentration of ethylene or the temperature of the air is too high, or if the fruit is in a very susceptible condition. Navel oranges are readily injured if picked early in the season in cold wet weather, when the risk of rupture of oil glands and consequent oleocellosis (see Supp. XVIII, Fig. 74) is great.

Ethylene-gas burn is a grey-to-brown or slightly purplish injury to the skin that shows as irregular more or less sunken patches (Fig. 82). It appears during the degreening treatment which may take up to six days, and may continue to develop afterwards. Affected fruit may be so unsightly as to be valueless and severely affected fruit may have an unpleasant flavour.

The trouble can be avoided by ensuring that the recommended conditions are maintained during degreening. For mandarins the ethylene concentration should not exceed 10 p.p.m.

Further reading

Hall, E.G., Leggo, D. and Seberry, J.A. (1968). Ethylene degreening of citrus fruit. *Agric. Gaz. N.S.W.* **79**, 721–8.

82 Ethylene-gas burn.

83 Fumigation injury.

Fumigation Injury

It is often necessary to give citrus fruits a post-harvest disinfestation treatment so that they can be marketed in areas or countries free from fruit fly. The treatment consists either in storing the fruit at low temperatures for about 14 days or fumigating it with ethylene dibromide (E.D.B.) for two hours; as fumigation is quick it is generally preferred. However, there is always a risk of injury, and with some kinds of fruit the risk is so great that treatment is not practicable. In laboratory trials of treatment by fumigation Ellendale mandarins and Marsh grapefruit were frequently injured.

Injury by E.D.B. (Fig. 83) is a rind burn which may vary in appearance, sometimes looking like storage spot (see Supp. XIII, Figs 49–54) and sometimes more like ethylene-gas burn.

It is usually the result of fumigating susceptible fruit or of having failed to maintain the correct conditions of gas concentration, temperature, duration of exposure and load of fruit in the chamber. Immature or overmature fruit is more likely to be injured and there is considerable risk of damage if the fruit was picked while wet early in the season or was affected by frost.

Further reading

Fresh Fruit Disinfestation Committee (1969). The Design, Construction, Testing and Operation of Chambers for the Fumigation of Citrus Fruits with Ethylene Dibromide'. (CSIRO Division of Food Research: North Ryde.)

Brown Rot

This rot starts as a slight surface discoloration which extends rapidly, the fruit becoming drab, and slightly greenish brown in colour (Fig. 84). It is a firm somewhat leathery rot not easily ruptured by finger pressure and, unlike stem-end rots caused by *Diaporthe* or *Alternaria* (see Supp. XV, Figs 63–64), has a characteristic pungent odour. It is caused by fungi of the genus *Phytophthora,* commonly *Phytophthora citrophthora.*

The disease is only important under wet conditions in the orchard, the fruit usually being infected by spores produced by the fungus in wet soil and splashed by rain onto lower fruit on the tree.

The rot develops quickly on infected fruit and may develop a delicate white surface growth of mycelium, and by this means may spread to adjoining fruit.

It can be controlled in the orchard by application of Bordeaux mixture or similar sprays, following the recommendations of the Departments of Agriculture. The lower parts of the tree and surrounding soil should be sprayed as soon as the first sign of brown rot is seen on the tree. In the packing house the only effective treatment is by dipping the fruit in hot water, which is difficult to do effectively without injuring the fruit. Brown rot is not controlled by the benzimidazole compounds (T.B.Z. and benomyl) which are so effective against the common green and blue moulds.

Further reading

Kiely, T.B. and Long, J.K. (1960). Market diseases of citrus. *Agric. Gaz. N.S.W.* **71**, 132–5, 157, 187–92.

Frost Injury and Secondary Septoria

In inland areas during winter, freezing temperatures may occur in the orchard. If the fruit freezes it causes collapse of the rind and drying out of the juice sacs. Rind injury is much more common on the exposed face of the fruit as it hangs on the tree and the collapsed rind usually discolours and develops oleocellosis. The weakened tissue is commonly invaded by fungi, especially *Septoria.*

Crystals of the bitter principle, hesperidin, are often present as white spots in affected pulp and the fruit may develop a bitter flavour. Lemons are more susceptible to frost injury than other citrus.

Frost injury infected by *Septoria* develops the reddish brown to purplish colour commonly associated with septoria spot (Fig. 85) and as the fruit ages the infected area becomes increasingly dark in colour and leathery in texture. However, under moist conditions at low temperature, as in cool storage, invaded tissue may become soft and rotten.

Control is in the orchard by adopting frost protection methods and spraying to control *Septoria* infection.

84

Brown rot.

85

Frost injury and secondary *Septoria.*

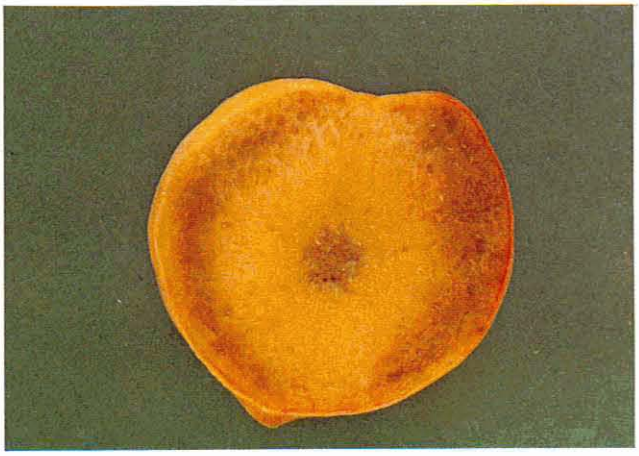
MARKET AND STORAGE DISEASES OF PEACHES

Cold Storage Breakdown

If peaches in cool storage do not succumb to attack from rots, their storage life is terminated by loss of ability to ripen normally after removal to ripening temperatures. While fruit that is already ripening can be stored for short periods, longest life is obtained when fruit is harvested still hard and unripe but sufficiently mature to be capable of ripening with good development of juiciness and flavour and no discoloration. Fruit which is stored too long will, for a time, look normal while it is at low temperature but will be unable to ripen normally.

Physiological breakdown in cool storage is progressive. Abnormal ripening shows as a loss of natural bright colour and a failure to develop juice; the flesh becomes dry and 'woolly', the whole fruit has a 'soft tennis ball' feel and flavour deteriorates. Varieties which normally show red pigmentation of the skin or around the stone commonly show excessive reddening of the flesh (Fig. 86). With further storage the flesh becomes increasingly brown (Fig. 87). Varieties without natural red pigmentation first show a paler flesh as woolliness develops, the flesh becoming brown later. After prolonged storage the flesh will dry out and discolour even at low temperature.

The length of life of peaches in cool storage depends on maturity, variety, season and storage temperature. At the optimum temperature of −1°C, storage life will vary from 2 to 7 weeks; it will tend to be longest in a warm dry season.



86 Cold storage breakdown.

87 Cold storage breakdown.

Brown Rot

Brown rot is a serious disease of peaches, nectarines, plums and cherries on the tree and during marketing and storage. In most cases it is caused by the fungus, *Sclerotinia fructicola,* which produces both blossom and twig blight and rapid rotting of mature fruit. Trees must be wet for infection to occur in the field. Infected flowers turn brown, remain attached to the twig and become dry and brittle; grey or buff coloured spores may be seen on them.

The rot appears first as a light brown watery spot which enlarges rapidly and darkens in colour. At higher temperatures it soon becomes partly covered with powdery tufts of grey or buff spores (Fig. 88). The whole fruit may rot in 3–4 days. Eventually the rotted fruit darkens further and mummifies, remaining as a major source of infection for the next season.

Control is by careful handling, good sanitation, quick cooling and, most important, by pre-harvest spraying and immediate post-harvest treatment with an effective fungicide. Benzimidazole compounds such as TBZ and benomyl are particularly effective against brown rot and can be used on the tree and after harvest. Temperature has a marked effect on development of the rot: there is practically no growth at 0°C and very little at 5°; growth is most rapid at 20–30° but virtually stops at 39°.

To control both brown rot and transit rot it is recommended that, in addition to tree sprays, the fruit should be dipped as soon as possible after harvest in a mixture of 500 ppm of benomyl and 400 ppm of dichloran (w/v), thoroughly wetting and dipping the fruit for at least 30 seconds.

Further reading

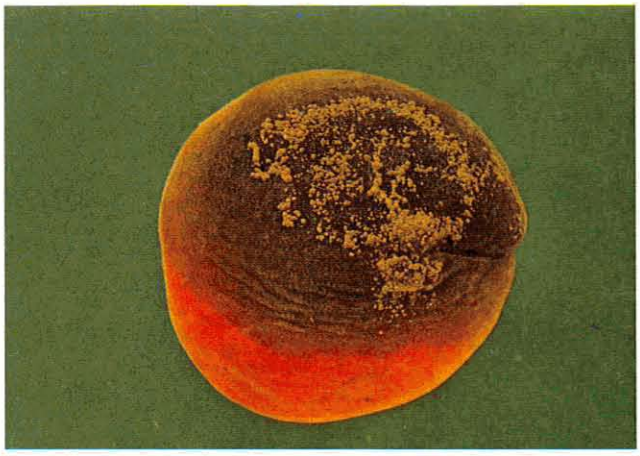
Stone, J. G., Wade, N. L., and Beattie, B. B. (1972). Controlling post-harvest rots of peaches. N.S.W. Dep. Agric. Bull. No. H224.

Transit Rot or *Rhizopus* Rot

This soft wet rot develops very rapidly under warm conditions; it is characterized by a coarse white fungal growth on which grey or black sporangia (spore-bearing bodies) appear, like tiny dark pinheads on stalks. It spreads readily by contact, producing a characteristic nest of several rotted fruits (Fig. 89). The rot is inhibited at 0°C and grows only very slowly at 5°, but is less inhibited than brown rot by holding the fruit at 39°. The causal organisms are *Rhizopus* spp., mainly *Rhizopus nigricans,* and they attack all kinds of stone fruit. An acidic odour is usually noticeable when the rot is well advanced.

The danger of attack by *Rhizopus* during transit is greatly increased by the presence of skin breaks and moisture.

Control is by careful handling, good sanitation and, most important, by using an effective fungicide and cooling the fruit to below 10°C within 24 hours of harvest. Benzimidazole compounds are not particularly effective against *Rhizopus* but dichloran has consistently given good control in trials and in commercial practice.



88

Brown rot.

89

Transit (*Rhizopus*) rot.

MARKET AND STORAGE DISEASES OF FRUIT

PLUMS

Cold Storage Breakdown

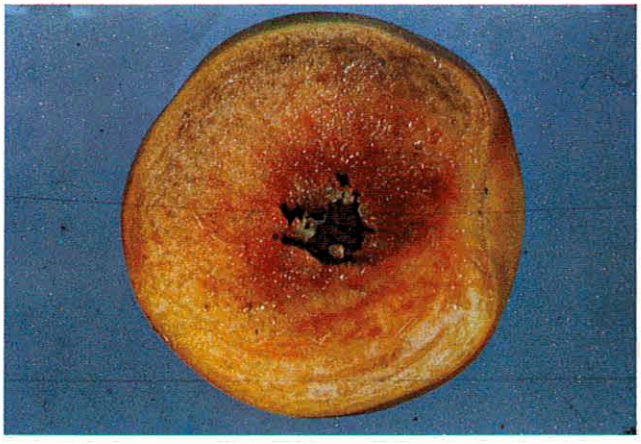
If we discount fungal wastage, the cool storage life of plums is terminated by failure to ripen normally after removal to temperatures at which fruit fresh from the trees would ripen. Abnormal ripening may be due not only to over-storage but also to unsuitable ripening temperatures. While the optimum ripening temperature is about 20° C, plums will ripen satisfactorily, though slowly, at lower temperatures. The minimum temperature for normal ripening varies with variety and may be as low as 5°.

Cold storage breakdown and abnormal ripening have varying symptoms. Normal deep skin and flesh colour and normal juiciness do not develop. Commonly the flesh becomes injected and discoloured (Fig. 90), often with a gelatinous texture; this condition may develop further to 'bladderiness', the fruit becoming a watery shapeless mass held in the skin. Alternatively, the fruit may become spongy and dry and the flesh very pale in colour, or the flesh may become mealy. As is common following injury or death of cells the flesh of over-stored plums is frequently discoloured brown; the tissues around the stone and the vasculars are usually affected first. The colour may be distinctly greyish and the flesh either firm or softening (Fig. 91).

Symptoms vary with variety and maturity, the less mature fruit usually becoming mealy and discoloured rather than gelatinous or 'bladdery' as is common with fruit picked when more mature.

As with peaches, cool wet seasons are unfavourable to keeping quality. Plums keep best when stored either at −1° C continuously or at −1° for 2–3 weeks and then at the lowest ripening temperature, commonly 7°.

90 Cold storage breakdown.



91 Cold storage breakdown.

Freezing Injury

After thawing, plums which have been frozen develop water-soaked injected areas of flesh where the cells have been disrupted by freezing and the intercellular spaces are consequently suffused with leaked cell sap (Fig. 92). As with frozen pears and apples (Supp. VI, Figs. 21–24), freezing injury may show externally as water-soaked areas on the skin. Likewise, affected tissue tends to dry and become discoloured so that the injury is difficult to distinguish from cold storage breakdown.

The freezing point of plums and other stone fruits is higher in cool, wet seasons than in warm, dry seasons because of differences in the levels of soluble solids in the juice. These are higher in fruit maturing in warm dry weather.

Therefore in cool wet seasons the storage temperature should be raised to −0·5° C or even 0° to avoid freezing.

PAPAWS

Ripe Rot

Ripening and ripened papaws and other tropical fruits such as bananas and mangoes commonly develop ripe rots which show as numerous sunken, soft, discoloured spots which enlarge and coalesce and affect the underlying flesh (Fig. 93). The fruit may show a sparse growth of fungal mycelium and dark, pinpoint, spore-producing bodies will appear later on.

These spots of ripe rot are caused by multiple latent infections of fungi, commonly anthracnose (*Gloeosporium* spp.) and other organisms such as *Botryodiplodia.*

Infection takes place during the growth of the fruit on the plant. The fungal spore germinates on the wet fruit surface, and the fungus penetrates the fruit and goes into a resting stage until the fruit commences to ripen and lose its resistance to the pathogen.

The disease may be controlled by frequent fungicidal spraying during the growth of the fruit but such a course is rarely economic.

As the infection is latent, post-harvest treatment with a fungicide is of little value. However, heat treatment of unripe fruit by dipping in hot water for 20 min, starting at a temperature of 50° C and dropping to a temperature of 45°, will kill many of the infections and delay the growth of others so that the development of ripe rots is greatly delayed. Treated fruit ripens normally but more rapidly than untreated fruit.

92

Freezing injury.

93

Ripe rot.

MARKET AND STORAGE DISEASES OF FRUIT

Fruit Rots of Bananas

Bananas, in common with mangoes, papaws, avocados and some other tropical fruits, are very subject to fruit rots when ripening. They are mainly the result of infections, during growth of the fruit, by the anthracnose fungus *Gloeosporium* (*Colletotrichum*), usually *G. musarum,* but other species may be involved. These infections remain latent until the fruit starts to ripen and its resistance is lowered; at this stage the fungus becomes active and sunken anthracnose spots and rots develop (Fig. 94).

94 Black end and anthracnose.

95 Cushion rot.

A single fruit may carry a large number of infections so that the anthracnose spots may be very numerous; the flecking of very ripe bananas is due to anthracnose (Fig. 94, centre fruit). Wound infections can also occur especially as the fruit approaches maturity. In bananas, black end of single fruits (Fig. 94, top fruit) and cushion rot or crown rot of 'hands' (Fig. 95) develop from infections at knife cuts and broken stems occurring when the bunches are dissected for packing. Fruit rots may also be caused by infection of wounds by a similar fungus, *Botryodiplodia theobromae.*

Anthracnose and the wound infections, unless greatly advanced, do not affect the pulp so that the fruit is edible although it is unsightly. Advanced lesions may develop pinkish, shiny masses of spores.

Control of anthracnose in the plantation is difficult as infection can occur at any stage of the growth of the fruit.

Effective control is now possible by the use after harvest of the newer semi-systemic fungicides such as benzimidazole. As soon as possible after the hands are cut from the bunches or dissected into 'clusters' or 'singles', the fruit should be dipped in a suspension of the fungicide. Treatment by dipping in 250–500 ppm w/v of thiabendazole or thiophanate methyl for a few seconds is recommended; spraying is less effective. When the fruit is packed in bags of polyethylene film to lengthen its post-harvest life the higher concentrations of the fungicides are recommended.

Sanitation in the plantation and packing shed is an important aspect of control; trash and bunch and fruit debris should be regularly removed. Because of the importance of wound infections after harvest the fruit should be handled carefully. Washing, which is generally necessary, should be done only with clean water or water containing chlorine.

Squirter

Squirter is a soft, almost watery, rot of the pulp of bananas, usually commencing at the stem end, and showing externally as a pale, water-soaked appearance of the peel. It is caused by the fungus *Nigrospora sphaerica* (Fig. 96). The common name is derived from the fact that in an advanced rot the rotted pulp may squirt out when the fruit is handled.

The disease is a wound infection and was serious in fruit harvested in the winter in New South Wales until treatment of the fruit with a fungicide was made compulsory. Salicylanilide used to be required but now complete control is obtained with the treatments recommended for control of anthracnose and black end.

Squirter is not a problem in fruit grown in the summer or in tropical areas.

Further reading

Scott, K. J., and Roberts, E. A. (1967). Control in bananas of black end rot caused by *Gloeosporium musarum*. *Aust. J. Exp. Agric. Anim. Husb.* **7**, 283–6.
Allen, R. N. (1970). Plantation and market diseases of banana fruit. *Agric. Gaz. N.S.W.* **81**, 332–7.

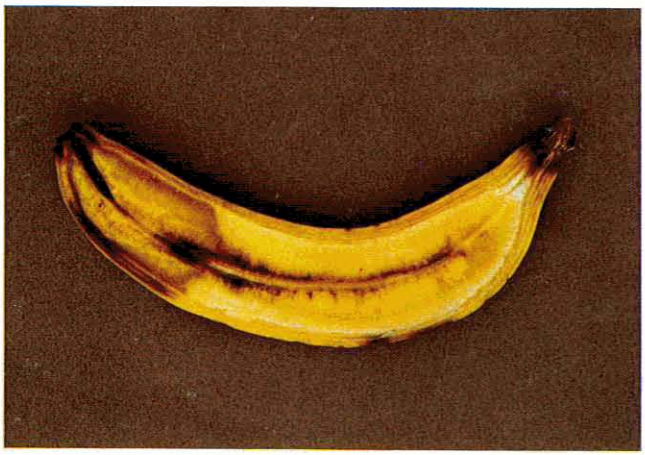
Anthracnose of Mango

Anthracnose can be serious during the ripening of mangoes causing unsightly blemishes and loss of fruit. The lesions are typically dark and relatively dry; pinkish pustules of spore masses are often seen (Fig. 97).

Infection occurs during the growth of the fruit, but unfortunately the fungicides effective against anthracnose in bananas have little effect on the disease in mangoes, papaws and avocados, apparently because they have a thicker cuticle. It can be reduced by close attention to sanitation and careful handling. However, it can be controlled by immersing the fruit after harvest in water at 50–52 °C for 15 min or 55 °C for 5–6 min. Although the treatment may hasten ripening it is not damaging to most varieties. Addition of a fungicide such as TBZ may lower the effective temperature and make the treatment easier and safer.

Further reading

Smoot, J. J., and Segall, R. H. (1963). Hot water as a post-harvest control of mango anthracnose. *Plant Dis. Rep.* **47**(8), 739–42.
Akamine, E. K. (1967). History of the hot water treatment of papayas. *Hawaii Farm Sci.* **16**(3), 4–6.



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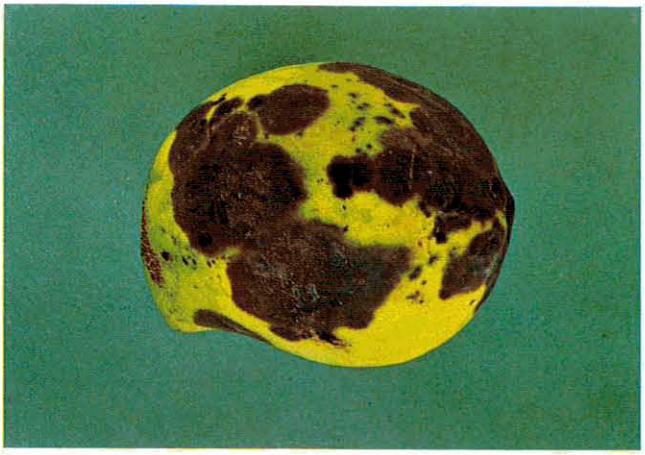
Squirter.



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Anthracnose.

MARKET AND STORAGE DISEASES OF FRUIT

Chilling Damage to Bananas

Although all fruits are damaged by freezing, some fruits, expecially bananas and other tropical fruits, may be damaged by exposure to temperatures considerably above their freezing point.

The lowest temperature at which green bananas can be safely held to delay ripening is about 12 °C, below this they become chilled and injury to the peel results. Certain cells of the peel are killed and the dead cells darken to give the peel a smoky or dull yellow appearance after ripening, although the pulp is unaffected. When chilling is more severe, the peel of the green fruit develops a grey to black discoloration with a steaky appearance which darkens as the fruit ripens (Fig. 98). A characteristic symptom of even slight chilling is darkening of the vascular bundles of the peel, as seen in section (Fig. 99). Exposure of green fruit to a temperature of 10 °C for 12 h or so is usually enough to cause slight dulling of the colour of the peel when ripe.

Chilling lowers the resistance of the fruit to infection, and anthracnose and other fruit rots may develop on chilled fruit before it starts to ripen. The degree of chilling depends not only on the temperature and duration of exposure, but also on the nature of the fruit. Bananas grown under more tropical conditions are more susceptible and in New South Wales winter fruit is more resistant to chilling than summer fruit.

The peel of ripe fruit darkens rapidly and severely when exposed to cold.

98 Chilling.

99 Chilling (section).

Bruising of Bananas

Bruising and other mechanical damage to the green fruit which cause disfiguring blemishes, increased fruit rots, more rapid ripening, and more rapid weight loss from the fruit are a serious marketing problem for the industry. Few growers and packers realize the need for careful handling of green fruit because damage by rough handling usually does not become obvious until the fruit ripens, when it shows as brown to black blemishes (Fig. 100). Bruising of green fruit may extend to the pulp which breaks down locally during ripening.

Considerable damage, particularly bruising, is caused by overtight packing. In transport and handling, injury is caused by abrasive movement of the fruit against the box or carton or another fruit. This injury can be greatly reduced by the use of polyethylene film bag or sheet box liners which reduce friction. Water loss is much more rapid from damaged peel; much of the consequent unsightly darkening of mechanical injuries can be prevented by reducing water loss by packing in polyethylene film.

EDB Injury in Bananas

Ethylene dibromide (EDB) is used for the quarantine fumigation of various fruits against fruit flies, but treatment may damage the skin and/or have adverse effects on the ripening of bananas. This injury may be confused with chilling injury.

Slight injury to green fruit causes a slight grey discoloration of the peel and more severe injury is darker, often brown to black and shiny, and more extensive (Fig. 101).

Injury is caused by the darkening by oxidation of leucoanthocyanidins in killed cells of the peel. Injury and killing of cells by other chemicals may produce similar symptoms.

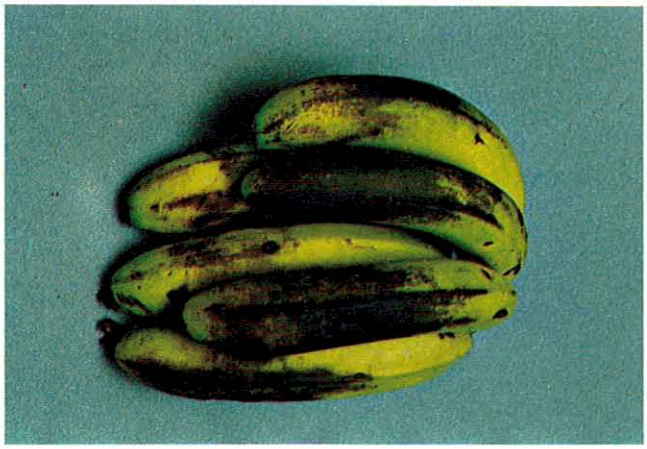
Doses of EDB of 15 g per m^3 at 2-hourly intervals or more have been found to cause injury to the peel, while lower doses have hastened ripening.

Further reading

Farooqi, W. A., and Hall, E. G. (1972). Effects of ethylene dibromide on the respiration and ripening of bananas (*Musa cavendishii* L.). *Nucleus* (*Karachi*) **9**(3–4), 22–8.

100

Bruising.



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EDB injury

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