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A REVIEW OF THE METEOROLOGICAL CAUSES OF SUNBURN INJURY ON THE SURFACE OF APPLE FRUIT (*Malus domestica* BORKH)

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A B S T R A C T

Sunburn of apple fruit is a surface injury caused by solar radiation that in the initial phase results in a light corky layer, golden or bronze discolouration, and other injuries to the epidermal tissue on the surface exposed to the sun. According to the definition of Retig and Kedar (1967), sunburn is a physiological injury that significantly affects fruit quality. Meteorological elements, the variety and the physiological condition of the plant may all play a role in sunburn. The damage occurs mainly in the surface and sub-surface layers.

American apple growers divide the phenomenon into three types: "sunburn", "sunscald" and "delayed sunscald". Previously, Walker (1952, 1957) had used "sunscald" to describe all injuries caused by solar radiation.

On the basis of cause, Schrader et al. (2001) proposed two main types of sunburn injuries. The first is "sunburn necrosis", necrosis of the epidermal and sub-epidermal cells caused by heat. This phenomenon causes spotting on the sunlit side of the fruit. The second type is "sunburn browning", which causes yellowish or brownish patches on the sunlit side of the fruit. Schrader et al. (2001) also determined the physiological reasons for the two phenomena. Sunburn necrosis happens when the fruit surface reaches 52±1ºC, which damages the permeability of cell membranes. Sunburn browning happens when the fruit surface reaches 46º to 49º C, but sunlight also plays a decisive role in its formation. In sunburn browning, the membranes of the surface cells are injured to a lesser degree (Schrader et al., 2001; 2003).

Keywords: apple fruit, sunburn, FST (fruit surface temperature), meteorological elements.

INTRODUCTION

Sunburn of apple fruit is a surface injury caused by solar radiation that in the initial phase results in a light corky layer, golden or bronze discolouration, and other injuries to the epidermal tissue on the surface exposed to the sun. According to the definition of Retig and Kedar (1967), sunburn is a physiolo

gical injury that significantly affects fruit quality. Meteorological elements, the variety and the physiological condition of the plant may all play a role in sunburn. The damage occurs mainly in the surface and sub-surface layers.

Plant pathogens such as *Alternaria tenuis, Physalospora obtusa, Monilinia fructicola (=Monilia fructicola), Monilinia laxa (=Monilia laxa), Monilinia fructigena (=Monilia fructigena), Glomerella cingulata*, and *Venturia inaequalis* can infect the fruit through the injured epidermal tissue, making it unmarketable (Holb, 2002; Leeuwen et al., 2000, 2002). Therefore, sunburn can cause serious economic loss in apple plantations (Brooks and Fisher, 1926; Ware, 1932; Meyer, 1932; Whittaker and McDonald, 1941; Moore and Rogers, 1942; Barber and Sharpe, 1971; Bergh et al., 1980; Simpson et al., 1988; Warner, 1997; Schrader et al., 2001).

Barber and Sharpe (1971) studied sunburn injuries in pepper and pumpkin fruits and distinguished three types: ‘heat injury sunscald’; ‘ultra-violet radiation sunscald’; and ‘photo-dynamic sunscald of heated tissues’. American apple growers also distinguish three types: "sunburn", "sunscald" and "delayed sunscald". Previously, Walker (1952, 1957) had used "sunscald" to describe all injuries caused by solar radiation.

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"Sunburn" and "sunscald" are used interchangeably in common usage. The American Phytopathological Society defines sunburn as a fruit injury caused by solar radiation, and sunscald as a injury caused by frost (Jones and Aldwinckle, 1990).

In Hungary and Slovakia, Vanek and Szőke (1988) found that solar radiation caused serious sunburn in apples and grapes. They predicted that sunburn damage will increase in the coming years because of increasing UV radiation and global warming.

Sunburn can drastically reduce yield and fruit quality. Arndt (1992) found that sunburn can cause a 50% reduction in the yield of “Jonagold”, a variety which is sensitive to sunburn. Discolorations on the surface of the fruit, even when present at the beginning of the ripening process, may lead to surface scarring, which can affect colour, taste, storage properties, and the overall marketability of the fruit. Schrader et al. (2001) report that several million dollars are lost each year on apple plantations in America.

More detailed knowledge of the process of sunburn can help in the determination of the roles plant variety and climatic factors play in sunburn. This information can be used to decrease sunburn losses in fruit plantations by determining optimal direction and spacing of rows, irrigation, and canopy shape and structure. With proper agro-technical methods, the frequency and severity of sunburn in apple plantations can be reduced (Meheriuk et al., 1994).

Description of symptoms of injuries caused by solar radiation

"Sunburn" causes a golden-bronze discolouration on the sunlit side of the fruit, detracting from its appearance. It does not usually cause serious damage to the epidermal tissue, and rarely affects the sub-epidermal tissue at all. Sunburn occurs when apples which have been growing in the shade are suddenly exposed to strong sunlight. Sunburn is most often observed on fruits on the south and south-western sides of the tree. Sunburn can be observed on apples which have fallen from the tree, and even on fruit in crates if they have been exposed to strong sunlight for a long time. Brown, hard, sagging patches with a bright surface and a spongy internal structure appear on apples during storage, or even on apples which are still on the trees. These patches are called "delayed sunscald", and are entry points for fungi such as *Alternaria* spp. (Barber and Sharpe, 1971; Bergh et al., 1980; Simpson et al., 1988; Holb, 2002, Leeuwen et al., 2000, 2002).

Severe sunburn alters the cuticle even more, and damages both the epidermal and sub-epidermal tissues. Cell walls get thicker. Intercellular phenols increase, and the structures of plastids and thylakoids change (Barber and Sharpe, 1971; Andrews and Johnson, 1996, 1997).

The meteorological causes of sunburn and conditions under which it forms

Other factors besides solar radiation play a role in the formation of sunburn. According to Barber and Sharpe (1971), these include: solar absorptivity, interception of solar energy, temperature tolerance, specific photostability, tolerance to ultraviolet radiation, degree of adaptation, and sensitisation to the environment. Sunburn occurs mainly where air temperature and the number of sunny hours are high during the ripening period. Sunburn also occurs when cool or mild weather is abruptly followed by hot, sunny weather. If the weather changes gradually, the plant can acclimatise itself, and sunscald is less likely to occur. Concurrent water stress can intensify the damage (Brooks and Fisher, 1926; Ware, 1932; Meyer, 1932; Whittaker and McDonald, 1941; Moore and Rogers, 1942; Barber and Sharpe, 1971).

In grapes, according to the Smart and Sinclair (1976), sunscald formation is affected by wind direction and speed, and by the intensity of turbulence. Sunscald occurs particularly when the sunlight overheats fruits, especially those on the south or south-western side of the tree. Tissue injury leads to scar formation. Radiation flux density and wind velocity are the environmental parameters which have the most impact on fruit temperature. Fruit size, fruit albedo, transpiration, and long-wave radiation also affect fruit temperature by playing a role in heat exchange across the exposed surface. Other variables which play a role are: absorbed radiation flux density, heat conductivity of the fruit, and coefficient of convective heat exchange (Smart and Sinclair, 1976). The coefficient of convective heat exchange can be calculated from wind speed using the formula of Nobel (1975), who developed the formula for grapes, which have a small surface area and a high heat conductivity. When applying this formula to apples, which are larger and have a low heat conductivity, there may be some problem due to the fact that the fruit is not homogeneous.

Weather conditions can cause sunburn in as little as a few days, especially if the fruit is in a sensitive stage of development. Because of solar radiation and the other factors mentioned above, the surface temperature on the sunlit side of the fruit can be as much as 18ºC higher than ambient air temperature, and 8-9ºC higher than fruit on the shaded side of the tree (Meheriuk et al., 1994). When a cool night is followed by a very hot day, anthocyanin synthesis strongly decreases, which contributes to sunburn. According to Arndt (1992), sunburn is more frequent when temperatures during July, August and September are higher than 28-32ºC. Brooks and Fisher (1926) reported that sunburn injury can occur if the temperature of the surface exposed to sunlight is only 14ºC higher than air temperature. In their opinion, sunburn is caused by heat, not by solar radiation. On the other hand, Rabinowitch et al. (1974) found that, in tomatoes, sunburn is caused by both heat and visible light.

Uneven distribution of light and temperature triggers a series of biochemical processes on the surface and in the flesh of the fruit, and alters water balance in the fruit.

Rabinowitch et al. (1974, 1986) reported that solar irradiation is essential for sunburn to occur. Schrader et al (2003) found that UV-B radiation plays a bigger role than visible light. Schrader et al. (2001) found that sunburn necrosis can be experimentally induced by high fruit surface temperatures without direct sunlight

The temperature of fruit in the orchard can be significantly higher than air temperature (Schroeder, 1965). Thorpe (1974) studied ‘Cox’s Orange Pippin’ apples in a hedgerow orchard on a cloudless day. Air temperature was 27°C, and wind speed was less than 1 m s^{-1}. The surfaces of apples exposed to full sunlight (630 ±30 Wm^{-2}) were 13-14°C warmer than the air, and the unexposed surfaces were 3°C warmer than the air. Apples growing in the shade, where the short wave flux was about 120 Wm^{-2}, were 1.5-2°C warmer than the air (Thorpe, 1974).

Schrader et al. (2003) emphasise the importance of fruit surface temperature in causing sunburn. They found a high correlation between fruit surface temperature and maximum daily air temperature ($r = 0.9$), the mean of hourly air temperatures (between 11:00 and 17:00 hours), and solar radiation ($r = 0.65$). They found an inverse correlation between maximum fruit surface temperature (between 11:00 and 17:00 hours) and mean wind velocity ($r = -0.24$) and mean relative humidity ($r = -0.66$).

Reducing the occurrence of sunburn by agro-technical methods

By applying agro-technical methods, we can protect fruit from heat and radiation without adversely affecting the development of intense, variety-specific fruit colour. During summer pruning, care must be taken so that the fruits are not exposed to intense sunlight. Overhead sprinkling at canopy level will cool the fruit surface, but increases the risk of diseases such as apple scab and fire blight.

There is no way to prevent or minimise delayed sunscald when fruit is already in cold storage. Washing with diphenylamine does not help. Careful sorting during storage helps reduce damage due to *Alternaria* rot (Meheriuk et al.,1994).

REFERENCES

Andrews P.K., Johnson J.R. 1996. Physiology of sunburn development in apples. GOOD FRUIT GROWER 47(12): 32-36.

Andrews P.K., Johnson J.R. 1997. Anatomical changes and antioxidant levels in the peel of sunscald damaged apple fruit. PLANT PHYSIOL. 114(3): 103.

Arndt H. 1992. Apple shading to reduce heat damage. TREE FRUIT LEADER Vol. 1.

Barber H.N., Sharpe P.J.H. 1971. Genetics and physiology of sunscald fruits. AGRIC. METEOROL. 8: 175-192.

Bergh O., Franken J., Zyl E.J., Kloppers Van F., Dempers A. 1980. Sunburn on apples – Preliminary results of an investigation conduced during the 1978/79 season. DECIDUOUS FRUIT GROWER 30 (1): 8-22.

Brooks C., Fisher D.F. 1926. Some high-temperature effects in apples: contrasts in the two sides of an apple. J. AGR. RES. 32(1): 1-23.

Holb I. 2002. Az alma ventúriás varasodása: biológia, előrejelzés és védekezés. Szaktudás Kiadó Ház, Budapest, pp. 144.

Jones, A.L., Aldwinckle H.S. 1990. Compendium of apple and pear diseases. American Phytopathological Society, St. Paul, USA.

Leeuwen, Van, G.C.M., Stein A., Holb I.J., Jeger M.J. 2000. Yield loss in apple caused by *Monilia fructigena* (Aderh. & Ruhl.) honey, and spatio-temporal dynamics of disease development. EUR. J. PLANT PATH. 106: 519-528.

Leeuwen, Van, G.C.M., Holb I.J., Jeger M.J. 2002 Factors affecting mummification and sporulation of pome fruit infected by *Monilia fructigena* in Dutch orchards. PLANT PATH. 51: 787-793.

Meheriuk M., Prange R.K., Lidster P.D., Porritt W.W. (eds.) 1994. Postharvested disorders of apples and pears. Communications Branch, Agriculture Canada, Ottawa, Ont K1A 0C7, pp. 31-32.

Merzlyak, M.N., Solovchenko A., Chivkunova O.B. 2002. Patterns of pigment changes in apple fruits during adaptation to high sunlight and sunscald development. PLANT PHYSIOL. BIOCHEM. 40: 679-684.

Meyer A. 1932. Comparative temperatures of apples. PROC. AM. SOC. HORT. SCI. 28: 566-567.

Moore M.H., Rogers W.S. 1942. Sun scald of fruits. EAST MALLING RES. STA. REPT., pp. 50-53.

Nobel P.S. 1975. Effective thickness and resistance of the air boundary layer adjacent to spherical plant parts. J. EXP. BOT. 26: 120-130.

Rabinowitch H.D., Kedar N., Budowski P. 1974. Induction of sunscald damage in tomatoes under natural and controlled condition. SCI. HORT. 2: 265-272.

Rabinowitch H.D., Ben-David B., Friedmann M. 1986. Light is essential for sunscald induction in cucumber and pepper fruits, whereas heat conditioning provides protection. SCI. HORT. 29: 21-29.

Reay P.F., Lancaster J.E. 2001. Accumulation of anthocyanins and quercetin glycosides in Gala and Royal Gala apple fruit skin with UV-B–Visible irradiation: modifying effects of fruit maturity, fruit side, and temperature. SCI. HORT. 90: 57-68.

Retig N., Kedar N.1967. The effect of stage maturity on heat absorption and sunscald of detached tomato fruit. ISRAEL J. AGR. RES. 17: 77-83.

Schrader L.A., Zhang J., Duplaga W.K. 2001. Two types of sunburn in apple caused by high fruit surface (peel) temperature. Online. Plant Health Prog. doi: 10.1094/PHP-2001-1004-01-RS.

Schrader L.A., Zhang J., Sun J. 2003. Environmental Stresses that Cause Sunburn of Apple. ACTA HORT. (in press).

Schroeder C.A. 1965. Temperature relationships in fruit tissues under extreme conditions. PROC. AM. SOC. HORT. SCI. 87: 199-203.

Simpson J., Rom C.R., Patterson M. 1988. Causes and possible controls of sunburn on apples. THE GOOD FRUIT GROWER 39(2): 16-17.

Smart R.E., Sinclair T.R. 1976. Solar heating of grape berries and other spherical fruits. AGRIC. METEOR. 17: 241-256.

Thorpe M.R. 1974. Radiant heating of apples. J. APPL. ECOL. 11: 755-760.

Vanek G., SZŐKE L. 1998. Napperzselés (infravörös sugárzás) és a napsugárzás (UV sugárzás) tünetei szőlőn. INTEGRÁLT TERMESZTÉS A KERTÉSZETBEN 19: 71-76.

Walker J.C. 1952. Diseases of vegetable crops. McGraw-Hill, New-York, N.Y., pp. 529.

Walker J.C. 1957. Plant Pathology. McGraw-Hill, New-York, N.Y., pp. 707.

Ware W.M. 1932. High temperature injury on the growing apple. GARDNERS CHRON. 92: 287-288.

Warner G. 1997. Sunburn is a hot topic in orchards of Washington. THE GOOD FRUIT GROWER 48(13): 22-23.

Whittaker E.C., McDonalds S.L.D. 1941. Prevention of sunscald of deciduous fruit trees in hot climates. AGR. GAZ. N. S. WALES 52: 231-233.

PRZEGLĄD WPŁYWU CZYNNIKÓW METOOROLOGICZNYCH NA USZODZENIE SKÓRKI JABŁEK PRZEZ OPARZELIZNĘ SŁONECZNĄ

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STRESZCZENIE

Oparzelizna słoneczna jest uszkodzeniem skórki owocu spowodowanym promieniowaniem słonecznym. W miejscach zbyt silnego promieniowania słonecznego uszkodzona skórka przybiera kolor biały, żółtawy lub brązowy.

Uszkadzana jest przede wszystkim powierzchni owocu. Według definicji podanej przez Rediga i Kadara (1967) oparzelizna słoneczna jest uszkodzeniem istotnie wpływającym na jakość owoców. Występowanie uszkodzeń uzależnione jest od przebiegu pogody, kondycji roślin oraz podatności poszczególnych odmian. Uszkodzenia mogą mieć różny stopień nasilenia – od wystąpienia przebarwień aż po nekrozy. Nekrozy występują w przypadku nagrzania powierzchni owocu do temperatury 52±1°C, przebarwienia natomiast, gdy temperatura skórki w miejscu nasłonecznienia osiąga poziom 46-49°C.

Słowa kluczowe: jabłka, oparzelizna, czynnki metorologiczne