

Some Characteristics of Internal Ring-cracking in Apples

LINUS U. OPARA¹

Abstract

The problem of fruit skin cracking and splitting occurs in many apple cultivars. Evidence from gross morphological and anatomical examination of the internal structures of 6 apple cultivars showed that 'Gala' and 'Fuji' apples had internal ring-cracking (IRC) which occurred at the fruit-stem joint. Ring-cracking occurred in fruit with splitting and in fruit without splitting. This paper describes some of the physical characteristics of these internal ring-cracks.

Introduction

Fruit damage by pre-harvest cracking and splitting occurs in several important apple cultivars such as 'Cox's Orange Pippin', 'Fuji', 'Gala', and strains of 'Gala' apple such as 'Royal Gala' and 'Regal Gala' (5). In some fruit, the damage can be confined to the cuticle (skin-cracking, cuticular cracking, checking) or extending below the skin deep into the flesh (splitting). In 'Gala', 'Royal Gala' and 'Fuji' apples, a type of splitting called stem-end splitting (SES) originates in the stem-cavity and extends longitudinally toward the cheek. The problem of SES has been reported in New Zealand (4), the United States (2), and by apple growers in South America (1). Fruit with SES is down-graded and classed as unsound. The origin and exact causes of SES are not known and there are no reliable management practices to control the problem. During preliminary studies in the 1991/92 apple season on the origin of SES, we observed that 'Gala' apples with SES had internal ring-cracking (IRC) (4). A ring-crack is not visible externally and occurs near the fruit-stem joint in a plane parallel to the stem-calyx axis. This paper reports the results of a 2-year

investigation on some of the physical characteristics of IRC.

Materials and Method

Six apple cultivars were chosen to include those susceptible to SES ('Fuji' and 'Gala'), skin-cracking and checking ('Cox's Orange Pippin' and 'Fuji'), and those resistant to skin-cracking and SES ('Braeburn', 'Granny Smith', and 'Delicious'). Both the resistant and susceptible cultivars were selected from a commercial orchard in Hastings, New Zealand, with an historical incidence of fruit cracking and splitting. During the 1992/93 and 1993/94 apple seasons, a total sample of 400 apples of each cultivar was picked at commercial maturity and assessed within 24 hours of harvest as follows: (i) individual fruit were visually examined under bright light for the presence of cracks and splits, and (ii) each fruit was cut longitudinally into four equal parts and examined for the presence of any internal gross morphological defects. Some fruit with cracks, splits, or any internal defects was recorded (data not shown) and photographed.

Results and Discussion

Stem-end splitting occurred in 'Fuji', 'Gala' and 'Royal Gala' apples (Figure 1 and Table 1). Examination of cut fruit surfaces showed that every fruit of 'Fuji', 'Gala', and 'Royal Gala' which had SES also had an internal ring-crack (IRC) which originated near the fruit-stem joint (Fig. 2). Some fruit had IRC without SES (Table 1). IRCs occurred 1-2 mm above the fruit-stem joint and propagated along the equa-

¹Department of Agricultural Engineering & Centre for Postharvest and Refrigeration Research, Massey University, Private Bag 11-222, Palmerston North, New Zealand.

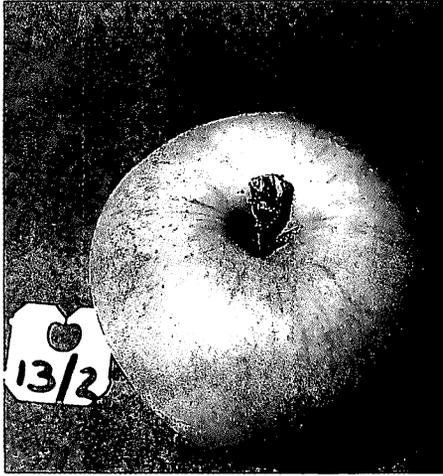


Figure 1. Stem-end splits in 'Gala' apple.

torial axis into the fruit flesh. The size of an IRC varied from a small arc to a full ring circumscribing the fruit stem (Fig.2). Large ring-crack openings can measure up to 3 mm in the stem-calyx axis at the skin surface and propagate 8 mm in length into the flesh. Fruit tissue affected by IRC had a brown discoloration which indicated the completion of enzymatic reaction characteristic of stress damaged apple tissue (3). These observations were consistent during both the 1992/93 and 1993/4 seasons. The fact that all SES fruit had IRC suggests a possible relationship between the presence of IRC and the development of SES in 'Fuji,' 'Gala,'

Table 1. Incidence (%) of stem-end splitting and internal ring-cracking in 'Fuji,' 'Gala,' 'Royal Gala,' and skin-cracking in 'Cox's Orange Pippin' apples.

Year	'Fuji'	'Gala'	Royal 'Gala'	'Cox's Orange Pippin'
1992/93	3.9	11.1	6.4	1.2
	7.2*	15.9	10.8	—
1993/94	2.3	6.6	2.8	1.6
	5.4	9.8	4.1	—
Mean	3.1	8.9	4.6	1.4
	6.3	12.9	7.5	—

*Numbers in bold represent the incidence of internal ring-cracking.

and 'Royal Gala' apples. No IRC or SES occurred in 'Braeburn,' 'Cox's Orange Pippin,' 'Delicious,' and 'Granny Smith' apples (photo not shown).

Skin-cracking occurred only in 'Cox's Orange Pippin' apples (Figure 3 and Table 1), and mainly at the calyx-end but some occurred near the fruit cheek. Skin-cracks also occurred on parts of the fruit with blemishes such as sunburn while others occurred on parts of fruit without any physical defect. There was no stem-end splitting in 'Cox's Orange Pippin' and no fruit cracking or splitting occurred in the crack-resistant cultivars ('Braeburn,' 'Granny Smith,' and 'Delicious'). The occurrence of IRC only in 'Fuji,' 'Gala,' and 'Royal Gala' apples indicates that



Figure 2. Small (a) and large (b) internal ring-crack in 'Gala' apple.

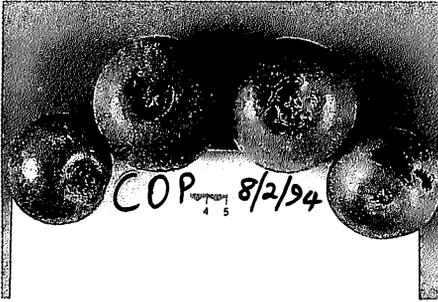


Figure 3. Skin-cracks in 'Cox's Orange Pippin' apples.

SES in these cultivars develops by a mechanism different from skin-cracking and other types of cracking and splitting in apples. The higher incidence of IRC than SES in all cultivars and years (Table 1) also indicates that IRC occurs before the development of SES, and cultivars such as 'Gala' which had higher incidence of IRC also had higher incidence of SES. Further research is required to determine the period of onset of IRC and the mechanism by which SES develops from IRC.

Often in the literature it is difficult to differentiate the types of cracking or splitting occurring especially when the term cracking or splitting is used

generically (5). Knowledge of the physical characteristics of each type of cracking provides a useful method to distinguish them and thereby facilitate an understanding of the underlying mechanisms. This paper has described the presence of internal ring-cracking at the stem-end of apple cultivars susceptible to stem-end splitting. It is recommended that the type of splitting shown in Figure 1 be referred to as stem-end splitting to distinguish it from other types of fruit cracking and splitting in apples. Further work is required to elucidate the relationships between formation of internal ring-cracking and development of stem-end splitting.

References

1. Enriquez, C. H. 1995. Personal communication. Apple Grower, Mono Azul S. A. Neuquen -Argentina.
2. Greene, D. W. and Autio, W. R. 1993. Evaluation of red coloring strains of Gala. Univ. Mass. Coop. Ext. Fruit Notes, pp. 15-19.
3. Miller, A. R. 1992. Physiology, biochemistry and detection of bruising (mechanical stress) in fruits and vegetables. *Postharvest News & Information* 3(3):53-58.
4. Opara, L. U. 1993. A study of stem-end splitting in apples. Ph.D. Thesis. Department of Agricultural Engineering, Massey University New Zealand. 263 pages.
5. Opara, L. U., Studman, C.J. and Banks, N.H. 1996. Fruit skin splitting and cracking in apple. *Horticultural Reviews* 18: in press.

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Peach to Nectarine and Everything Between

W. B. SHERMAN

The glabrous nectarine is well established as recessive to pubescent peach as it segregates 1:3 in the F₂ generation. Fogle and Faust (1975) were the first to suggest different nectarine alleles when they showed three different ultra structure surfaces with the scanning electron microscope and presented evidence for their inheritance. Surfaces were traced to 'Flaming Gold,' 'Quetta,'

and 'Lipiatt.' Fogle & Faust suggested that the restriction in parentage of U.S. peach and nectarine germplasm may explain lack of even greater variation.

Other variations in skin surfaces of peach to nectarine are known. 'Masterpiece' nectarine, while first appearing smooth, has a sandpaper feel to the tongue and a similar character has

been observed in seedling nectarines in the University of Florida breeding program by Sharpe and Sherman (unpublished data). The rough fruit skin, described by Okie and Prince (1982) and the cracked fruit exocarp, later described by Werner (1987) were shown and discussed at the 1981 National Peach Breeders Workshop (Sherman, 1981). The rough skin is thought to be different than that of 'Masterpiece.' Recent communication with Okie suggests that this rough skin character is a single recessive gene not allelic to G. The cracked fruit variant sheds its pubescence four weeks after bloom, and this variant may be recessive to peach pubescence. Rene and Annie Montoux-Caillet, private stonefruit breeders in France, have developed peach varieties with extremely short and low density pubescence so that the epidermis appears as a nectarine skin underneath the peach. Because the character appears recessive to peach but dominant to nectarine, and because the character was fixed in a breeding program it may be a simply inherited character in a multiple allelic series. We have six nectarine mutations (I have seen each mother tree with the bud sport intact) from Florida peach genotypes that are heterozygous for nectarine. A recent study of these mutations (unpublished) revealed epidermal ultrastructures resembling two of those described by Fogle and Faust (1975). Crosses between parents having the two types have produced only nectarines, but hybrids were not studied for ultrastructure. One peach parent, Fla. 5-16, produced two nectarine sports which had non-distinguishable epidermal structure but were visually distinguishable in fruit size as verified from fruit of budded trees for each sport (unpublished data). These two sports are probably allelic, but the pleiotropic effects for fruit size differ. Creller and Werner (1996) describe the morphological development of a genotype intermediate be-

tween peach pubescence and glabrous nectarine. They postulate this character is in a multiple allelic series for the pubescence to glabrous locus. If this is true, then in a breeding program, a single allele could be fixed more easily than a quantitative character.

An interesting hypothesis, advanced by Hesse (1975), states that the nectarine is a deletion mutation from peach. Primary evidence is lack of a back mutation from nectarines of sexual origin. Our hypothesis is that the locus resulting in pubescence (peach) to glabrous (nectarine) is part of a regulatory gene with embedded hierarchy and deletions at various rank within the gene. Visualizing the regulatory gene at a locus in a hierarchical manner would allow for seemingly multiple degrees from heavily pubescent to lightly pubescent to glabrous and also for the pleiotropic characters associated with nectarine fruit, such as small size, redder epidermal color, firmer, more dense flesh, rounder shape, higher sugars and acids, and more susceptibility to fruit disease (Wen et al., 1995a, b). The higher in the regulatory order the mutation occurs, the more characters are affected underneath. This idea would be an extension of the findings in *Arabidopsis* (Larkin et al., 1994) or maize (Lloyd et al., 1992) where there were broad pleiotropic effects of a single gene on both pigment and pubescence formation.

Literature Cited

- Creller, M. A. and D. J. Werner. 1996. Characterizing the novel fruit surface morphology of 'Marina' peach using scanning electron microscopy. *J. Amer. Soc. Hort-Sci.* 121: 198-203.
- Fogle, H. W. and M. Faust. 1975. Ultrastructure of nectarine fruit surfaces. *J. Amer. Soc. Hort. Sci.* 100:74-77.
- Hesse C. O. 1975. Peaches. P. 308. In: J. Janick and J. N. Moore (eds.). *Advances in fruit breeding*. Purdue Univ. Press, West Lafayette, IN.
- Larkin, J. C., D. G. Oppenheimer, A. M. Lloyd, E. T. Paparazzi, and M. D. Marks. 1994. Roles of the glabrous 1 and transparent tests

glabra genes in Arabidopsis trichome development. *Plant Cell* 6:1065-1076.

Lloyd, A. M., V. Walbot, and R. W. Davis. 1992. Arabidopsis and Nicotiana anthocyanin production activated by maize regulators R and Cl. *Science* 258:1773-1775.

Okie, W. R. and V. E. Prince. 1982. Surface features of a novel peach x nectarine hybrid. *HortScience* 17:66-67.

Sherman, W. B. 1981. Peach breeders workshop. *Fruit Var. J.* 35:147.

Wen, I., K. E. Koch, and W. B. Sherman. 1995a. Comparing fruit and tree characteristics of two peaches and their nectarine mutants. *J. Amer. Soc. Hort. Sci.* 120:101-106.

Wen, I., W. B. Sherman, and K. E. Koch. 1995b. Heritable pleiotropic effects of the nectarine mutant from peach. *J. Amer. Soc. Hort. Sci.* 120:721-725.

Werner, D. J. 1987. A new fruit variant in peach. *Fruit Var. J.* 40:57-58.

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