INTERNAL BROWNING IN 'FUJI'

What have we learnt since 2015?

"In physiological disorders you get an alignment of stresses," says **Dr Ian Crouch**, director of research at ExperiCo. "All the factors just line up—like dominoes." When certain growing conditions and postharvest practices combine, one falling domino can trigger a disaster. ***Words by Anna Mouton***

In 2015, 'Fuji' apples shipped to Asia developed severe internal browning—up to 80% in some batches. Ever since, researchers in the fruit industry set out to find why this happened, and how to prevent future occurences.

GETTING TO KNOW INTERNAL BROWNING

The clue is in the name: internal browning refers to brown discolouration of fruit flesh. The peel is undamaged. Internal browning is not the only disorder to cause browning, but the brown areas remain firm. In other physiological disorders, the flesh becomes soft. 'Cripps Pink' clones and 'Fuji' apples have been most affected by internal browning in South Africa.

'Fuji' has been grown locally since the mid-1990s. "And right back then, when Unifruco Product Development was looking at the cultivar, they found that, even though it tasted wonderful, it had browning issues," recalls Crouch. Even so, 'Fuji' was a success and orchards have increased fifteenfold between 1995 and 2017. No surprise then that the losses of 2015 prompted a concerted research effort.

Crouch describes a multipronged attack. The first step was to share pictures and a description of the disorder to an international network of postharvest scientists. Feedback soon pointed to carbon dioxide as a potential cause of internal browning. "One of the people who really made an impact on us was Professor Emeritus Michael Reid, from the University of California, Davis," says Crouch. The industry subsequently brought Reid to South Africa as a technical expert.

Crouch also conducted a literature review. "We firmly believe that the cheapest research is somebody else's," states Crouch. "I read all the articles I could find on internal browning." Available research confirmed the role of carbon dioxide (CO_2) injury. Hortgro published a summary of the literature review, including guidelines for control, in a Fresh Notes (see QR code on next page).

CO_2: NOT JUST A GREENHOUSE GAS

So how does carbon dioxide cause browning? "Any ripening fruit produces CO_2," explains Crouch, "and if that CO_2 can't leave the fruit, it leads to leaking of phenolics in the cells and that gives browning. Factors that prevent normal diffusion of CO_2 out of the fruit promote browning." Ethylene contributes to browning by increasing respiration and therefore CO_2 production. Ethylene may also indirectly affect the leakiness of cell membranes to phenolics.

"Normally when we talk carbon dioxide damage, we're thinking of buildup in controlled atmosphere storage or in bags," says Crouch. "What we didn't realise is that, even in the orchard, there are all kinds of factors that also prevent diffusion of CO_2—like the density, peel and size-volume ratio of the fruit.

"We put together projects linked to some of the hypotheses around CO_2. But we can't reproduce all of the dominoes," adds Crouch. "You can't make a fruit do something that it's not programmed to do. That's always a problem in research."

Experiments showed that exposure to extreme CO_2 levels immediately after harvest can produce internal browning. Apples from different orchards vary in their re-

"WHEN CERTAIN GROWING CONDITIONS AND POSTHARVEST PRACTICES COMBINE, ONE FALLING DOMINO CAN TRIGGER A DISASTER."

sponse with some more susceptible than others. "The idea was to rank orchards according to this simple test," clarifies Crouch, "to see if we could link the predicted risk to actual development of internal browning in storage.

"But we only got low levels of browning during storage, so it was difficult to show a correlation." Preharvest risk factors identified so far include suboptimal harvest maturity, harvest after 180 days post bloom and previous occurrence of internal browning in an orchard.

KEEPING THOSE BROWNING BLUES AWAY

At harvest, fruit should be moved to the cold store as soon as possible—but not cooled too quickly! Fruit harvested on a warm day can undergo severe stress during rapid cooling. "A darker fruit like a 'Pink Lady' will be hotter than ambient," Crouch points out. Reduce stress by using step-down cooling. Start storage at 2,5˚C and low humidity, followed by gradual cooling over seven days.

"Even if you're going to put fruit in controlled atmosphere, don't do it immediately," advises Crouch. "Give it a couple of weeks to acclimatise. Cooling is one stress and controlled atmosphere is another. So it's like a domino effect with all these stresses on top of preharvest stresses—we don't even know what all of those are."

Long-term storage under regular atmosphere increases the prevalence of internal browning. Browning may occur as early as three weeks into storage, so fruit stored under regular atmosphere should be packed no later than three weeks post harvest.

Keeping CO_2 levels to a minimum—ideally less than 0,5%—is essential for controlled atmosphere storage. This is most critical during the first four to eight weeks. Note that late-harvested fruit is not suitable for controlled atmosphere storage.

CO_2 buildup in packaging and during transport must be avoided. Increase the re-cooling period from two to five days and use delivery air not colder than –1˚C.

The guidelines for control have recently been updated and include best practices for both internal browning and lenticel breakdown in 'Fuji' apples.

CRACKING UNDER PRESSURE

"The problem with research is that it's very difficult to predict when you're going to have the same problem," observes Crouch. Internal browning has receded since 2015, hampering efforts to understand the disorder.

New research suggests that markets affect internal browning. Crouch wonders whether better cold-chain management on the receiving end is one reason why browning has decreased. "Maybe they're now trying to look after the fruit better when it arrives."

But producers have no reason to relax. Crouch says that cracking is the new problem with 'Fuji' apples—to the extent that some producers are removing trees. "We may be able to solve the browning. The cracking may be something that we can't prevent." **FQ**

WHEN PINK APPLES GO BROWN

The many browning disorders of 'Cripps' Pink' clones

Words by Anna Mouton

"What's amazing about browning in the 'Cripps' Pink' clones is that there are so many kinds," says Dr Elke Crouch, postharvest physiology and technology researcher at Stellenbosch University. "And every single type of browning is different: both in the factors that cause them and how we rectify them."

Browning of the flesh in 'Cripps' Pink' clones fall into five categories: diffuse, radial, combination and bulge browning, and carbon dioxide (CO_2) damage. Diffuse browning is the most common kind in South Africa. "The rest of the world has a problem with radial browning," states Crouch, "and that's difficult to rectify because we don't really know why it occurs."

In diffuse browning the cortex is affected whereas in radial browning it's the vascular tissue. Combination browning shows discolouration of both areas. Browning is not present at harvest—it develops after several months of storage.

GETTING RID OF DIFFUSE BROWNING

Crouch and her colleagues have been researching browning for several years. "We started with postharvest—I think the postharvest work is really important because that's where you can make a big difference.

"You have to harvest at less than 40% starch breakdown. You cannot store long-term if you don't have that. If you harvest over 40% starch breakdown, your chances of getting diffuse browning are really good."

The second critical factor is storage temperature. "It seems like slightly higher storage temperatures actually prevent diffuse browning," explains Crouch. She recommends storage at 2˚C. Application of 1-MCP (1-methylcyclo-

1.

DIFFERENT TYPES OF INTERNAL BROWNING

1. DIFFUSE BROWNING
2. RADIAL BROWNING
3. COMBINATION BROWNING

PHOTOS PROVIDED BY DR ELKE CROUCH

2.

3.

propene or SmartFresh™) will reduce the risk of greasy fruit.

Studies of pre-harvest variables indicate that factors which speed up ripening—such as sandy soils and younger trees—also increase the risk of diffuse browning. "We found that anything that enhances maturity led to more diffuse browning. Or combination browning, because you need diffuse browning to get combination browning," says Crouch. "Radial browning wasn't related to any of those factors."

According to Crouch, the danger of diffuse browning is greater when the season has favoured early ripening. Producers need to be aware of this risk and adjust harvest schedules and storage decisions accordingly.

OTHER SHADES OF BROWNING

Although researchers overseas found harvest maturity to affect radial browning, this was not seen in South African studies. Instead, radial browning seems to be associated with seasonal factors, especially cooler seasons. "I think a lot of people are going to get radial browning this season," warns Crouch. "I already see the claims coming through.

"Radial browning, like diffuse browning, only manifests with longer-term storage—three to four months under controlled atmosphere. And you definitely want to take fruit out after five months if there is a risk of either of these."

Crouch advises non-destructive sorting when radial browning is found on opening a room. In their study, radial browning didn't increase much during shelf-life, so removal of affected fruit prior to export should go a long way toward avoiding claims.

In other countries, radial browning occurs in areas that accumulate more than 1 100 GDD (growing degree days) between full bloom and harvest. In these regions, it manifests during seasons with GDD in the range 1 100 to 1 700. Lower spring temperatures seem to increase later risk of radial browning, perhaps by affecting early cell division and expansion processes.

In contrast, bulge browning occurs when fruit is misshapen and browns on the deformed side. "The theory is that pollination was faulty," says Crouch, "that something went wrong at fruit development." The bulging side of the fruit is weaker and more susceptible to browning. This problem has not attracted much research interest—the prevalence seems low and badly shaped fruit are easily identified and removed during sorting.

CO_2 injury is characterised by small cavities in the cortex. It develops due to incorrect storage practices. "If you don't cool the fruit down properly before you put it under controlled atmosphere," explains Crouch, "then the fruit respires causing carbon dioxide buildup and low oxygen levels. 'Pink Lady' especially doesn't like that and develops carbon dioxide injury." High respiration rates and rising carbon dioxide levels in a cold store indicate a problem and need investigation.

DIGGING DEEPER INTO BROWNING

"There's still a lot of research to be done," stresses Crouch. An ongoing project is looking at long-term—up to nine months—storage. "Nine months and a six-week shipping period and then seven days shelf-life: it's risky and this season was very successful.

"Our last evaluation was toward the end of February this year, of fruit harvested last year in April—almost a year. We had very good results. But we need to repeat it," cautions Crouch. "We need to confirm that it wasn't just a good season."

Orchard effects on browning also require further study. "The orchard differences are huge so there are definitely orchard factors involved in all of these types of browning," says Crouch. "So it's easy to say: 'Harvest at the right time, store correctly' but then one goes back to the orchard factors and you can't really put your finger on the cause."

Crouch is optimistic that diffuse browning in 'Cripps' Pink' clones is controllable. "I think the the problem is not as bad as it was because more people are doing what they're supposed to be doing. But I think we also had a tough season—fruit are generally riper, so maybe things might be popping out. And we had a cool spring, so we are likely to see more radial." **FQ**