What breaks a plum's heart?

When plum stones split apart, the financial consequences are enough to break the bank for producers. A study funded by industry and the PHI Programme has made inroads into understanding the broken stone mystery, and giving the industry tools to manage it.

1 Dr Mariana Jooste (left) and MSc student, Imke Kritzinger, collect data from a plum orchard near Stellenbosch.
2 3D computed tomography technology, often used by doctors to perform scans of the human body, has provided valuable insights into the growth stages of different cultivars.

WHEN MORE THAN 10% of the plums in a carton destined for any of the Organisation for Economic Co-operation and Development (OECD) member countries have broken stones, it loses its Class I status.

Aggravating the matter is the fact that the cartons have to be marked as Class II despite the fruit adhering to Class I standards in all other respects. This poses tremendous marketing challenges, since approximately 70% of the total plum volume exported from South Africa is affected by broken stones.

In the 2013 season, approximately 1,6 million of the 11 million cartons of plums exported from South Africa had to be marked as Class II because they exceeded the 10% broken-stone threshold. Some supermarkets in the 34 OECD member countries – currently the most important importers of South African plums – do not accept fruit marked as Class II, while others pay a reduced price. In the 2013 season, Class II plums fetched R5 to R8 per carton less than their Class I counterparts.

The financial and reputational impact of this phenomenon prompted Dr Mariana Jooste, from the Department of Horticultural Science at Stellenbosch University, to find out why plum stones break and if it can be prevented. Working with her was Imke Kritzinger, an MSc Agric student in the Department of Horticultural Science at the university, and Dr Elmi Lötze from the same department.

Objectives and methodology

The three main objectives of the study were the following:

- Determine the effect of growing area and season on the incidence of broken stones;
- Investigate how the growth patterns of susceptible and non-susceptible plum cultivars differ during the season to get a better understanding of the development of the defect; and
- Investigate whether calcium and silicate treatments can reduce stone breakage in Japanese plums.

To answer these questions, Mariana, Elmi and Imke looked at three local plum cultivars, namely 'Laetitia', 'Sapphire' and 'Songold'. "By working out if and how stone breakage is related to climatic conditions or fruit growth patterns, we were hoping to find a way to give early warning to farmers of how much stone breakage they can expect at harvest time," says Mariana.

To determine the impact of climate on stone breakage, 'Laetitia' plums were sampled from two climatically different growing areas, namely Stellenbosch and Robertson.

In the 2013/2014 season, fruit was sampled from three farms per area; in the 2014/2015 season, two more farms per area were included to make the model more robust.

The sampling was done on several different days during the season for each cultivar. On each sampling date, the diameter and length of each fruit were measured using a digital calliper. The plums were then cut open and examined for the presence of broken stones and, in selected cases, individual endo- and

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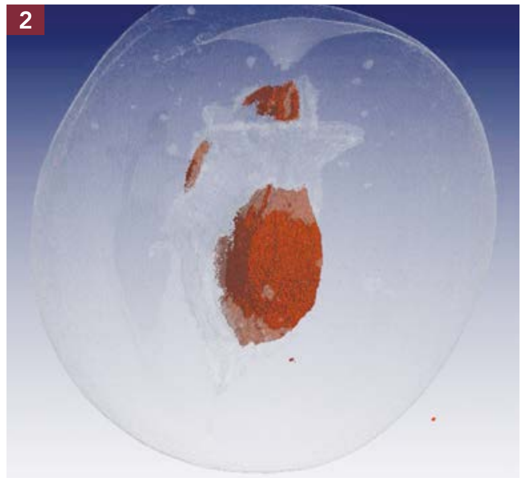
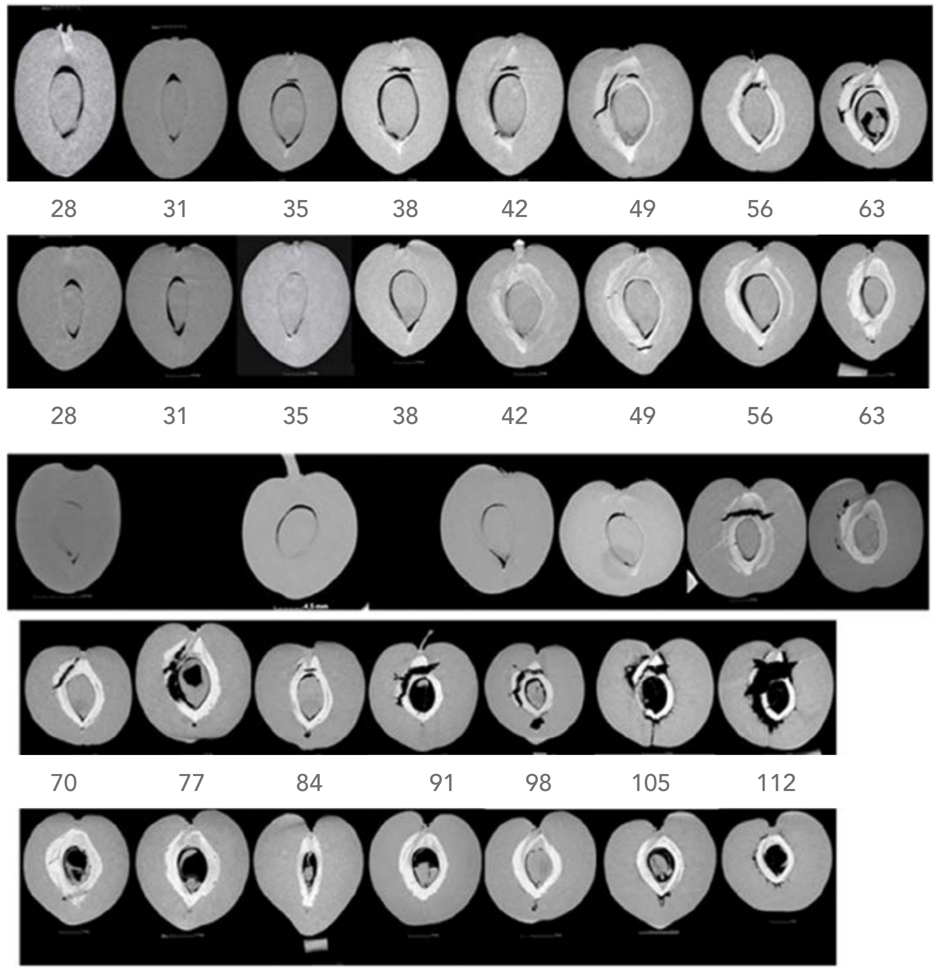


Figure 1

CT-scans showing the progression of endocarp lignification between 'Laetitia' and 'Songold' over the period of stone hardening in the 2013/2014 season and 'Sapphire' in the 2014/2015 season. Lighter colours depict denser areas, whereas darker colours indicate areas of lower density.



> With 3D computed tomography technology, often used by medical doctors to perform scans of the human body, we obtained valuable insights into the heart of the broken stone matter of different cultivars.
>
> Dr Mariana Jooste

PROJECT TITLE
Broken stones in plums

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DURATION
Two years and three months

PHI PROGRAMME & INDUSTRY CONTRIBUTIONS
R195 232 & R115 232

LEAD INSTITUTION
Stellenbosch University (Department of Horticultural Sciences)

BENEFICIARY
The South African stone fruit industry

FOCUS AREA
Pre-harvest physiology influencing post-harvest fruit quality

HUMAN CAPITAL DEVELOPMENT
One MSc student

PUBLICATIONS
One

PRESENTATIONS AND PAPERS
Two

Figure 2
A phloroglucinol-HCl solution, which stains tissue pink in the presence of lignin, was used to indicate stone hardening in 'Laetitia' plums.

mesocarp were weighed to determine their fresh weight.

Temperature and relative humidity loggers were installed in each orchard and measurements were logged every hour throughout the season. The minimum and maximum temperature and relative humidity (RH) were calculated daily. Additionally, the average night temperature and RH, and average day temperature and RH, were calculated.

To determine the difference between the growth patterns of susceptible and non-susceptible cultivars, trials were conducted at Stellenbosch University's experimental farm, Welgevallen. The highly susceptible 'Laetitia' and minimally susceptible 'Songold' cultivars were used in the 2013/2015 season. For the 2014/2015 season, the highly susceptible 'Sapphire' was added.

In both seasons, and for all the cultivars, a complete randomised design was used. Sampling started 28 days after full bloom (dafb) and continued until the first commercial harvest date. Two-hundred plums were sampled once a week from 20 trees per cultivar (10 fruit per tree) to determine the incidence of broken stones. On each sampling date, an additional six fruit per cultivar were used for CT scans.

Imke also used techniques to stain lignin (the organic substance that binds to cellulose fibers as well as hardens and strengthens plants' stone cell walls) to gain insight into why and how the stones actually break. Stone cells, a type of cell with thick cell walls, are laid down very early in fruit development and later turn into the plum's stone, or pit.

The trial to determine the impact of calcium and silicate treatments on stone breakage was also done at the experimental farm; it entailed foliar, post-harvest and root applications.

1 During the study's 27-month duration, Imke Kritzinger analysed more than 25 000 Japanese plums either by dissecting them or performing CT scans to look inside the fruit.

Results and implications

The research, the first of its kind on plums, has provided many interesting results. It has, for instance, shown that the stone of the fruit breaks as soon as it starts hardening. Mariana explains that, as the fruit develops, the growing flesh pulls on the stone and, if the pulling forces are great enough, breaks it apart.

Unlike what is observed with peaches, plum pits do not split in half; they break near the stylar (bloom) end, pedicel end or at the sides of the stone. This does not happen close to harvest, but starts as soon as pits start hardening. Hardening of the stone starts at the stylar end of the fruit and progress towards the stem end, between 28 and 63 days after the tree is in full bloom. The inner lining of the stone starts to harden first, after which lignification continues radially from the inside of the stone towards its sides.

In terms of the differences in growth patterns between susceptible and non-susceptible cultivars, the study found that growth at the stalk end of the fruit is much faster in cultivars that are susceptible to broken stones. As a result, the stones are often broken apart in this area.

Significant differences were also observed in the density of the different parts of the stone (endocarp). Breakage in 'Sapphire' was observed before the stones had started to lignify, indicating that the endocarp was pulled apart by the expanding flesh because it was too soft to withstand the pulling forces. In 'Laetitia', the breaking happens just as hardening and lignification starts.

Cultivars that are prone to stone breakage are likely to have a higher percentage of broken stones after warmer springs as more stone cells – that resist the pulling forces of the flesh – are formed under such conditions.

In cultivars that are not prone to breakage, such as 'Songold', more broken stones can be expected after cooler springs, given that lower temperatures seem to affect the lignification enzymes in non-susceptible cultivars, leading to more dense stones. If this is coupled with rapid fruit growth, the stones will break.

The researchers concluded that environmental factors and cultivation practices that lead to faster fruit growth tend to increase the occurrence of broken stones. For both 'Laetitia' and 'Songold', stone breakage was observed when rapid increases in stone density coincided with rapid increases in fruit growth.

It is clear that both genetics and environmental factors play a role in the development of broken stones in Japanese plums. However, although parameters were identified that could be used to predict the incidence of broken stones at harvest, the study will have to be repeated over more seasons to make the model more robust.

What was established beyond any doubt is that neither calcium nor silicate whether applied as foliar, post-harvest or root treatments, can be recommended to reduce broken stones in plums.

Mariana believes that the study's results will be of great value for the local plum industry when deciding on its marketing strategy for a particular season. "Our model may help to forecast the severity of the defect in some seasons," she says. "It could also support the South African plum breeding programme to select cultivars not susceptible to stone breakage."

The data will furthermore become hugely important in view of the kind of climatic changes expected in plum producing regions over the next few decades.

> "Further research to make our model more robust may help to forecast the severity of this defect and could also support the South African plum breeding programme to select cultivars not susceptible to stone breakage."
>
> **Dr Mariana Jooste**

Figure 3
This chart shows the size of cavities formed in the plum flesh, ranging from 1 (no cavity) to 5 (very large); 6 indicates a split stone, ie, the entire stone had broken in half along the suture.