

Gentle or intense grape crushing?

Crushing releases juice from grapes and increases the speed of skin extraction. Classically, this process was performed by foot treading but the process started to be mechanised in the early 19th century. Quite vigorous crushing equipment has sometime been used, but relatively gentle overlapping lobe roller crushers are now widely used (when crushing is performed at all). Recently there has been some renewed interest in different and more intense crushing equipment because of the potential for enhanced colour extraction or reduced skin contact time in red wine production. **Simon Nordestgaard**, from The Australian Wine Research Institute, reports on the evolution of grape crushing equipment and some of the new crushers being proposed that operate on different principles as well as research questions that remain.

THE CURRENT STANDARD

Crushing between pairs of rubberised overlapping lobe rollers spinning at the same speed is the current industry standard method (Figure 1). The roller gap is adjustable and one roller in each pair is spring-loaded to try and prevent any hard objects in the harvest from damaging the device. A safety switch is also sometimes fitted for this reason.

The crusher is most commonly integrated underneath a destemmer but independent crushing units are also available to allow for sorting between destemming and crushing. Crushers underneath destemmers are usually mounted on rails or hinges so that they can be moved out of service if a winemaker wishes to destem without explicitly crushing.

Destemmers themselves will of course result in some crushing effect, as will must pumps. For information on recent developments in gentler destemmers, see Nordestgaard (2015).

ROLLER CRUSHER EVOLUTION

Roller crushers were introduced in the early 19th century. Key challenges were trying to crush grapes without crushing

the seeds and stems and getting the material to efficiently feed between the rollers and not just slip/bridge across the top of them. Some designs used rollers spinning at different speeds to aid feeding and enhance crushing via a stripping effect (Figure 2a). Other designs featured rollers spinning at the same speed with overlapping lobes to enhance grip and feeding, not dissimilar to modern designs (Figure 2b).

In the early 20th century, differential speed roller crushers were most common, sometimes with speed ratios as high as 3:1. Rollers then also typically featured helical grooves on at least one roller and an easily adjustable roller gap. One roller in each pair was also sometimes spring-loaded to allow hard objects in the harvest to pass (Figure 3). To enhance feeding and maximise capacity per roller length, some manufacturers also introduced conical rollers (Figure 4).

Simple single roller crushers that crush grapes against a plate were also sometimes used (Figure 5a). In the late 19th century a design was introduced with blades that moved in and out of the roller to feed and crush the grapes against the plate (Figure 5b).

The degree of crushing could be controlled by adjusting the ▶

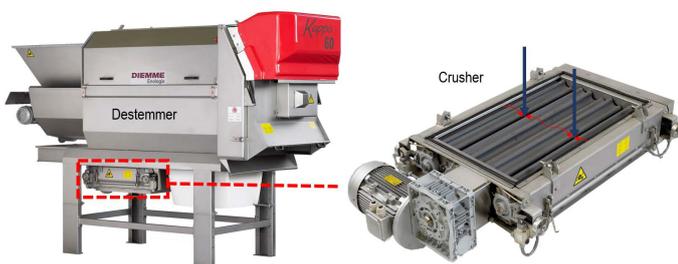


Figure 1. Standard rotary destemmer with a close-up of the associated overlapping lobe roller crusher (lower throughput crushers have one instead of two pairs of rollers)

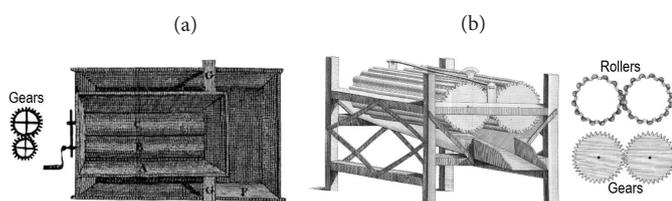


Figure 2. Early 19th century roller crushers: (a) Guerin differential speed roller crusher, image c. 1819, (b) Lomeni same speed overlapping lobe roller crusher (hopper/cover removed), image c. 1825

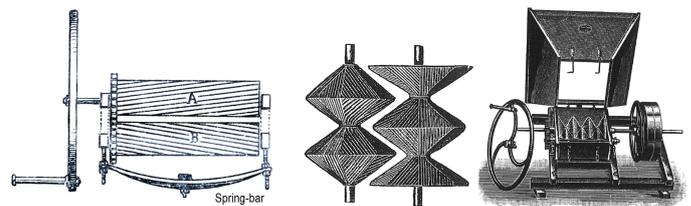


Figure 3. Spring-loaded roller crusher, image c. 1905

Figure 4. Conical roller crusher, images c. 1930

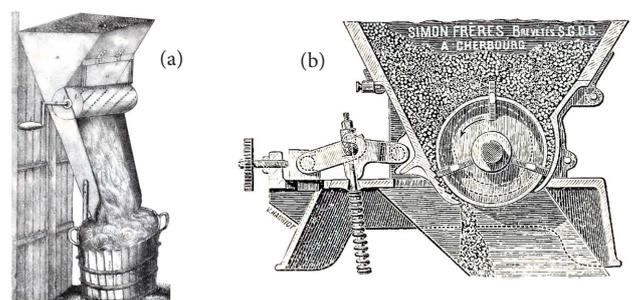


Figure 5. Single roller-plate crushers: (a) Acher/Thiebaut de Berneaud crusher with nails in the roller, image c. 1829, (b) Simon Frères crusher, with reciprocating blades in roller, image c. 1895

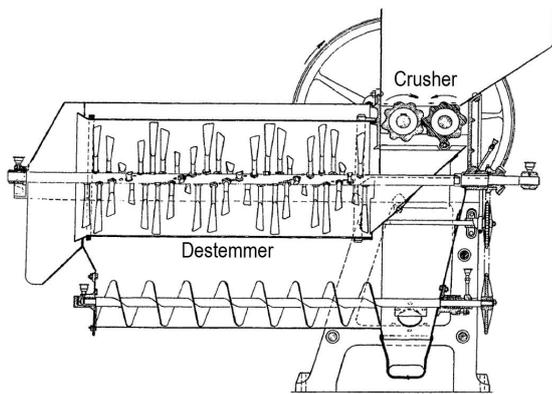


Figure 6. Celestin Coq roller crusher-destemmer, image c. 1950s



Figure 7. Modern hobby-scale differential speed roller crusher

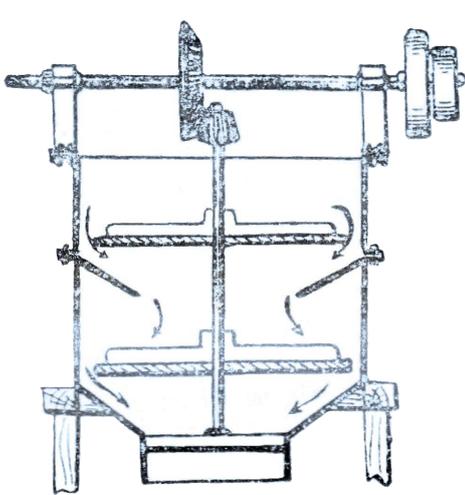


Figure 8. Paul centrifugal crusher, image c. 1905



Figure 9. Bagshaw horizontal centrifugal beater crusher-destemmer

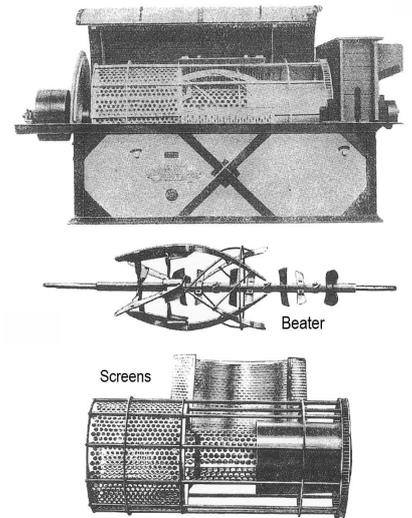


Figure 10. Garolla horizontal centrifugal beater crusher-destemmer, image c. 1940s

position of the plate. The plate was also spring-loaded to allow hard objects to pass.

In the mid-20th century, overlapping lobe roller crushers overtook differential speed roller crushers as the most common crusher design. Their good feeding capability and therefore high throughput was probably a major factor, as was their gentleness on stems.

Notably, destemming was not as common as it is now, and when performed it was more likely to occur after rather than before crushing (e.g. Figure 6) so the gentleness of crushers on stems was very important.

Crusher rollers at the time also often did not have rubber surfaces that could limit damage to stems and seeds (despite rubber being used on some roller crushers as early as the 1850s).

While no longer common in commercial scale winemaking, differential speed roller crushers are still common in hobby-scale winemaking (Figure 7). The speed differential is 1.3:1 in the model shown and there are paddles above the rollers to assist feeding.

CENTRIFUGAL CRUSHERS

The increasing use of engines/motors instead of hand-power in the late 19th century likely both emphasised the throughput limitations of some roller crusher designs and facilitated the development of alternative high throughput crusher designs.

In France, the engineer P. Paul developed a vertical centrifugal crusher (Figure 8) in which bunches of grapes fell onto a grooved fast rotating tray and were consequently thrown against the tank wall and crushed.

The material was then funnelled to another rotating tray

where it underwent a second crushing.

A diagram in one textbook implies that a version of the Paul device may have also existed without the second crushing stage. In the early 20th century the Paul crusher appears to have been used in many wineries in the south of France and Algeria.

(Algeria may no longer be an important wine producer, but in the first half of the 20th century French Algeria was the world's fourth largest wine producer and largest wine exporter.)

Horizontal centrifugal beater devices that both crush and destem were introduced in the mid to late 19th century by companies like Bagshaw in Australia and Garolla in Italy. The Bagshaw crusher-destemmer has a beater that crushes and destems as it rotates in a single fixed screen (Figure 9).

The crushed grapes fall through the screen while the stems are conveyed along and out the end of the screen. It is not dissimilar to rotary destemmers used today, except that the beater was designed to explicitly crush the grapes as well as to destem them.

In centrifugal beater devices, depending on beater design and speed, crushing is caused by some combination of wedging of grapes between the beater and screens, and direct impact on the grapes as they are hit by the beater and projected into the screen.

The Garolla crusher-destemmer (Figure 10) features two concentric cylindrical screens that rotate slowly. The fast-rotating beater has elements in the inner screen to destem the grapes and elements between the screens to vigorously crush the destemmed grapes.

The inner cylindrical screen only extends for part of the length of the outer screen and the detached stems are exposed

to a final beating in the outer screen to recover adhering juice before they exit.

In the USA, it appears that the term 'Garolla' came to be used as a generic term to describe all horizontal centrifugal crusher-destemmers, even when they were made by other companies and featured only one instead of two screens (e.g. Figure 11).

Vertical centrifugal beater crusher-destemmers were developed in the 1930s in France and Algeria (Figure 12). Grape bunches are fed from the top and are destemmed and crushed by the central rotating beater as they fall. The crushed grapes leave the bottom of the screen.

The stems are conveyed upwards with adhering juice being removed by the outer beaters in the process. Several variations on this design were later developed. For example, some models featured sections in the outer screen that could be opened so stems would fall through with the crushed grape and therefore crushing could be performed without destemming when desired.

In another variation, grapes were fed via a port closer to the bottom and crushing and destemming were all performed in the annulus between an inner drum and the outer screen (Figure 13). Feeding from near the bottom rather than from the top was advantageous because the crusher-destemmer could be directly fed from the grape reception hopper on the same level without the crusher-destemmer needing to be in a pit or the harvest having to be elevated.

Centrifugal crushers and crusher-destemmers of the types above were widely used in large-scale wine production primarily because of their relatively high throughput. Their use declined in the latter part of the 20th century. They provided extensive crushing, resulting in high yields and high colour extraction.

However, the extensive crushing gave more lees and sometimes excessive tannin levels. The vigorous aeration in some devices also cooled the must and fostered fermentation, but could have degraded some flavour compounds or precursors. In the literature, these devices were generally not advocated for anything but low quality mass wine production.

Pacottet (1915) reported that the Paul centrifugal crusher did not damage the seeds or stems but that it gave substantive lees requiring many rackings and that the device had caused serious disappointment when trialled for quality wine production.



Figure 11. Valley horizontal centrifugal beater crusher-destemmer, image c. 1970s

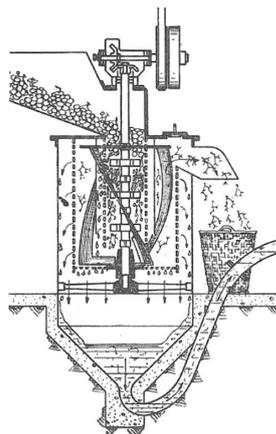


Figure 12. Blachère vertical centrifugal beater crusher-destemmer, image c. 1940s



Figure 13. Vertical centrifugal beater crusher-destemmer with feed on the bottom left, image c. 1970s

Peynaud (1984) advised that centrifugal beater crusher-destemmers should be rejected for quality winemaking and Ribéreau-Gayon et al. (2006) stated that they produced fine suspended solids, imparting vegetal and herbaceous tastes to the wine.

Centrifugal beater crusher-destemmers also resulted in more small fragments of residual stems in the must than standard destemmers (Marteau 1954). ▶

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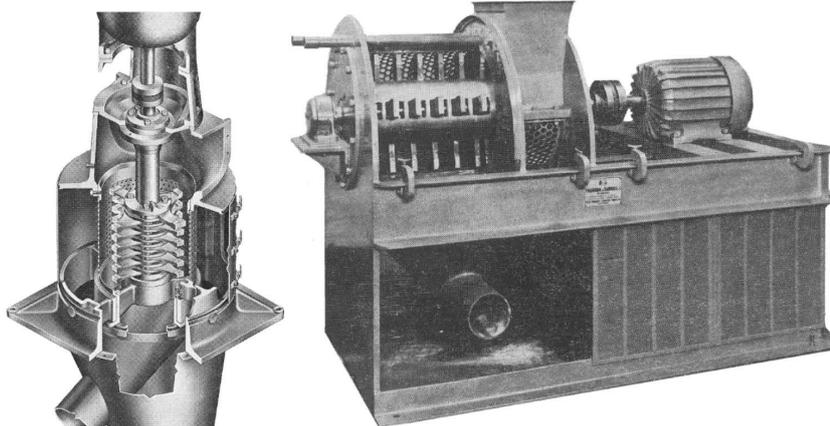
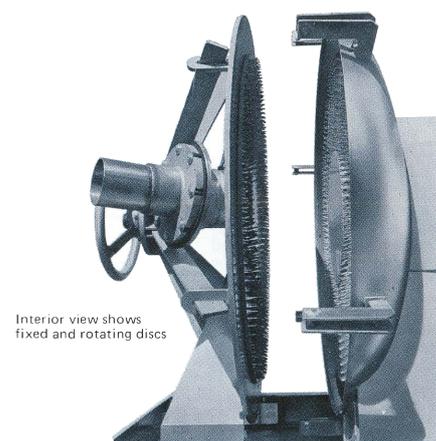


Figure 14. US-designed disintegrators, images c. 1960s



Interior view shows fixed and rotating discs

Figure 15. Pin-mill disintegrator/crusher used for secondary crushing, image c. 1970s



Figure 16. Pellenc Extractiv' centrifugal crusher



Figure 17. Diemme Open Grape differential speed roller crusher (stickers obscure roller surfaces - Diemme is applying for a patent on the roller design)

DISINTEGRATORS AND SECONDARY CRUSHING

In the 1960s and 1970s, some US manufacturers developed disintegrators as alternatives to roller and centrifugal crushers (Figure 14). Amerine et al. (1967, 1970) report that disintegrators were sometimes used to improve the balance in wine from red grapes with low tannin levels.

Malan et al. (1978) trialled the use of a pin-mill disintegrator/crusher as a secondary crushing stage after standard destemming and crushing.

The pin-mill consisted of a static and rotating disc with concentric circles of slanted pins (similar to Figure 15). Material was pumped into the space between the discs (via the pipe on the left) and the treated material exited below.

The pin-mill successfully stripped the pulp from the skins and seeds without damaging the seeds. The envelope effect sometimes seen with overlapping lobe roller crushers where the seed is trapped within the flattened skin was eliminated and there was an enhanced fragmentation of the skins.

The pin-mill resulted in increased free suspended solids that impaired the efficiency of draining of white juice, although final yields were higher after mechanical draining and pressing. Tannin and colour were higher in bottled red wines that had been drained/pressed early and it was concluded that the enhanced extraction speed could be a means of turning fermenters over more quickly.

However, with longer skin contact times (e.g. draining/pressing at 3°Baumé) colour intensity was sometimes lower than the control treatment that had only been crushed in the conventional manner.

Additional small solids generated by the extra crushing could perhaps have had a fining effect on colour that became more prominent as the rate of release of fresh anthocyanins from skins decreased later in the fermentation.

The use of disintegrators as an alternative to existing crushers or as a secondary crushing stage is not mentioned in a later US textbook from the same series cited previously (Amerine et al. 1980) so it appears that interest in these devices dissipated.

RECENT DEVELOPMENTS: IN-LINE STICK BLENDER, PELLENC EXTRACTIV' AND DIEMME OPEN GRAPE

Sparrow (2016) has recently looked again at the use of a secondary crushing device to fragment skins after standard destemming and crushing. In her trials an in-line stick blender type device was used for the secondary crushing operation. Like Malan (1978) the device did not damage seeds.

Wines produced with the technique and early draining/pressing received similar quality scores to control wines that had been produced without secondary crushing with draining/pressing at the normal time.

Around 2012, Pellenc released the Extractiv' grape crusher as an alternative to roller crushers. In the Extractiv' (Figure 16) grapes fall onto a rotating disc and are thrown against the tank wall and are crushed by this action. The crushing method is like that in the old Paul centrifugal crusher (Figure 8) but with only one instead of two centrifugal crushing stages.

The speed and therefore degree of crushing is also probably much more easily manipulated than in the Paul device. The nominal capacity of the Extractiv' is 25 tonnes/hour.

In 2016, Diemme released the Open Grape differential speed roller crusher (Figure 17). Unlike older differential speed devices, the speed differential can be easily adjusted via independent motors and a controller and the company advocates the use of quite low speed differentials.

Diemme gives examples with speed ratios of 1.3:1 and 2:1 in its marketing material. The company advises that it is looking for just enough difference in speed to fold the grape skin back

and expose the inner side of the skin for extraction. The Open Grape uses rubberised rollers with an undisclosed surface pattern to grip the grapes. Diemme offers sizes from a two-roller model with a nominal capacity of 13 tonnes/hour up to a four-roller model with a nominal capacity of 45 tonnes/hour.

Excessive lees and tannic astringency could result if the above designs were to be operated in the extreme manner their historical analogues sometimes were (i.e. high rotating disc or differential roller speeds). But, if they are operated in a milder manner, results may be favourable.

The actual performance for specific devices would need to be determined through independent experiment. The different modes of crushing with these devices likely offers a greater ability to modulate the degree of crushing than is possible with current overlapping lobe roller crushers.

OTHER RAPID EXTRACTION TECHNIQUES IN RED WINE PRODUCTION

The new devices above are mainly being marketed for their ability to speed up or enhance the extraction of (stable) colour from red grape skins and therefore allow for faster turnover of red fermenters or more colourful wines. Other tools to achieve more rapid extraction are also available.

The most well-established rapid extraction tool is pre-fermentation heat treatment (see Nordestgaard 2017). Heat treatment results in a rapid extraction of skin colour/anthocyanins and a slower extraction of skin tannins, in contrast to intense crushing where tannin increases proportionally more than colour (Peynaud 1984).

Heat treatment may therefore be a safer technique for avoiding excessive astringency; however, intense crushing does

avoid heating and therefore concerns about possible degradation of some grape flavour components.

Research is also being conducted around the world on other extractive techniques. One example is pulsed electric field (PEF) treatment which involves the application of short high-strength electric pulses to degrade skin cell membranes. However, PEF treatment does not appear to be used commercially for this application at this stage.

TANNINS – JUST MORE OR ARE THEY DIFFERENT?

More intense crushing should generally increase the rate of extraction of tannins from skins. An interesting question is whether tannins extracted in this way are different from those extracted slowly after more mild crushing.

Only a small fraction of the tannins in grape skins ultimately ends up in wine so there is some possibility that different wine tannin composition may result from different types and intensities of crushing.

The sensory properties of tannins may vary depending on their location within skin cells (e.g. cell vacuole or cell wall) and from different skin cells (e.g. closer to the inside or outside of the skin).

More intense crushing could potentially enhance the release of tannins from particular locations. It may also modulate which of the released tannins are removed from solution through effects like the binding of tannins to pulp solids.

Ribéreau-Gayon et al. (2006) seem to be of the opinion that different tannins do result from different crushing methods stating:

- "For example, brutal crushing promotes the extraction of bitter and herbaceous substances. Percolation of must, on the

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contrary, favours supple and full-bodied tannins.” and

- “Energetic crushing increases the diffusion of solid tissue components, but, according to a general rule, the corresponding tissue destruction promotes the extraction of inferior-quality tannins. These tannins impart vegetal and herbaceous tastes to the must and resulting wine. Unfortunately, no measures are currently available to confirm this fact.”

The lack of objective data on the effects of mechanical actions on grapes under winery conditions is an impediment to the optimised design of crushing equipment and more generally to the optimisation of solid-liquid contact during red wine fermentation.

Devices like the Pellenc Extractiv’ and the Diemme Open Grape may provide a good opportunity to study this topic because of their ability to readily manipulate the degree of crushing. Studies might also be aided by performing prior destemming and sorting using one of the new generation of gentle winery destemming and sorting systems to remove effects of incidental grape crushing and residual vegetal matter. Historically, the effects of explicit crushing may have sometimes been convoluted with berry breakage during destemming and/or pumping and stem breakage/inclusion during destemming, crushing and pumping.

CONCLUSIONS

This article summarises the history of mechanised grape crushing. The general trend has been towards relatively gentle overlapping lobe roller crushers (when crushing is performed at all). Devices that crush more intensively have been used for periods but then later discarded for reasons including low throughput, stem damage, excessive lees, drainer/press screen blockages, tannic astringency, and aeration.

Gentle crushing with overlapping lobe roller crushers is the status quo and therefore probably the most conservative approach when crushing mechanically. However, if crushing processes are to be optimised for both quality and productivity, it may be worth experimenting with equipment that works by different principles and pushing the limits a little.

In doing this it is important to keep in mind why similar designs have been rejected historically, and ensure that the new designs do not suffer from the same quality or productivity issues.

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Disclaimer

Readers should undertake their own specific investigations before purchasing equipment or making major process changes. This article should not be interpreted as an endorsement of any of the products described. The dates provided are best estimates based on comments in the available literature – there is always the possibility that some objects are older than specified.

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