WHEN PUSH COMES TO SHOVE: REDUCE SUSCEPTIBILITY TO BRUISING

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SUMMARY

Bruising is a common cause of mushroom discolouration leading to a reduction in quality and loss of marketable fresh product. Although mushrooms are prone to bruising because of their innate structure and biomechanics, some cultural practices have been shown to reduce the susceptibility of mushrooms to bruising. By analysing the interaction of casing moisture and composition, room humidity and flush number, growers may be able to make small agronomic changes which will reduce the susceptibility of their mushrooms to bruising. With 97% of Australian-produced mushrooms sold in the highly competitive fresh market, any reduction in discolouration will reap benefits.

INTRODUCTION

For mushrooms in the fresh market, quality is determined by colour, texture, cleanliness, maturity and flavour. Of these, the most important is colour. Any sign of discolouration will determine whether or not customers purchase mushrooms from the store and it is also the reason for the majority of supermarket rejections.

To be acceptable, white button mushrooms must be uniformly white and free from any signs of browning, which is obvious against the white background of the mushroom. Browning is perceived by the customer as a sign of age and microbial spoilage and therefore low quality and undesirable product. It takes only a few discoloured mushrooms (**Fig. 1**) to downgrade a whole box in the eyes of a potential purchaser.

Browning occurs when three mushroom cell components – tyrosinase, a phenolic substrate and oxygen – are combined. A chain of biochemical reactions takes place, resulting in the production of melanin, a dark brown pigment. Under normal conditions, these compounds are separated by membranes into different compartments within the mushroom cell. But when the cell structure is broken down, the three compounds mix and the browning process, called melanisation, begins.

For a full description of this process, take a look back at the technical note written earlier this year in the *Australian Mushrooms Journal*.

Browning is caused by senescence, the natural physiological deterioration that begins immediately after harvest.

Figure 1 Bruising-induced browning on harvested mushrooms

Browning may also occur as a disease symptom, such as brown blotch caused by *Pseudomonas tolaasii*, but browning is most commonly caused by bruising resulting from mechanical damage during harvesting, packing and transport.

BRUISING

Bruising occurs in most horticultural crops but because mushrooms are very fragile and lack the protective waxy cuticle and thick skin of other fruits and vegetables, they are highly susceptible to bruising.

Bruisability is not related to texture or firmness but is an upshot of the mushroom cap structure and how the hyphal cells are arranged. In cross-section, the mushroom cap is composed of three distinct zones (**Fig. 2**).

On the outside is the very thin 'skin' layer, a lattice network of hyphal cells designed to withstand lightweight impact and to be flexible as the mushroom cap expands. Immediately beneath is a zone of low-density, loosely packed hyphae containing large air spaces which assist in absorbing low energy impacts, while the third layer, which makes up the bulk of the mushroom cap, comprises densely packed mushroom hyphae.

Bruising, as described by Burton (2013), occurs when a 'slip-shear' force (a downward force with a sideways movement) is applied to the surface of the mushroom. The outer skin cells are pushed into the loosely packed layer below with a downward force or impact and then the cells of the second layer are ruptured as a sideways motion slides them across the unyielding dense tissue below. The phenolic substrate and tyrosinase inside the ruptured cells are released and react with oxygen, resulting in browning.

Because the cells in the outer layers of the cap contain the greatest concentrations of phenol and tyrosinase in the mushroom, mechanical damage to the skin and outer layers results in a rapid, intense and obvious brown bruise. Mushrooms may be subjected to 'slip-shear' forces by pickers during harvesting, when they rub against each other during transport, when they are squashed into a box beneath a lid and when the boxes are badly stacked in the back of a truck.

REDUCING SUSCEPTIBILITY TO BRUISING

Susceptibility to bruising varies between crops and even within a crop. Some mushrooms can bruise at the slightest touch while others seem almost bullet proof. Because mushrooms of the same crop are of the same strain, they are genetically identical. The variability in bruisability cannot therefore be related to genetic differences.

Kerry Burton, then of Horticulture Research International, Wellesbourne, United Kingdom undertook extensive studies on mushroom bruising, inventing a 'bruisometer' to repeatedly and consistently apply a known force to mushrooms to inflict a reproducible bruise. With the 'bruisometer' he was able to investigate what influence growing conditions, both environmental and agronomic, play in the susceptibility of mushrooms to bruising.

Burton (2002a) discovered that the flush number, casing moisture and room humidity all play highly significant roles in increasing resistance to bruising (**Table 1**).

First flush mushrooms growing on wet casing bruise less than first flush mushrooms growing on medium or dry casing. For second flush mushrooms, the casing water content does not affect bruising susceptibility. But third flush mushrooms growing on dry casing bruise less than third flush mushrooms growing on medium casing. These mushrooms in turn bruise less than third flush mushrooms growing on wet casing.

In terms of room humidity, first and second flush mushrooms growing in high humidity (92%) bruise less than first and second flush mushrooms growing in low humidity (85%). Neither high nor low humidity affect the bruisability of third flush mushrooms.

Three further cultural factors exert a minor influence on bruising susceptibility. The composition of the casing has a small but significant

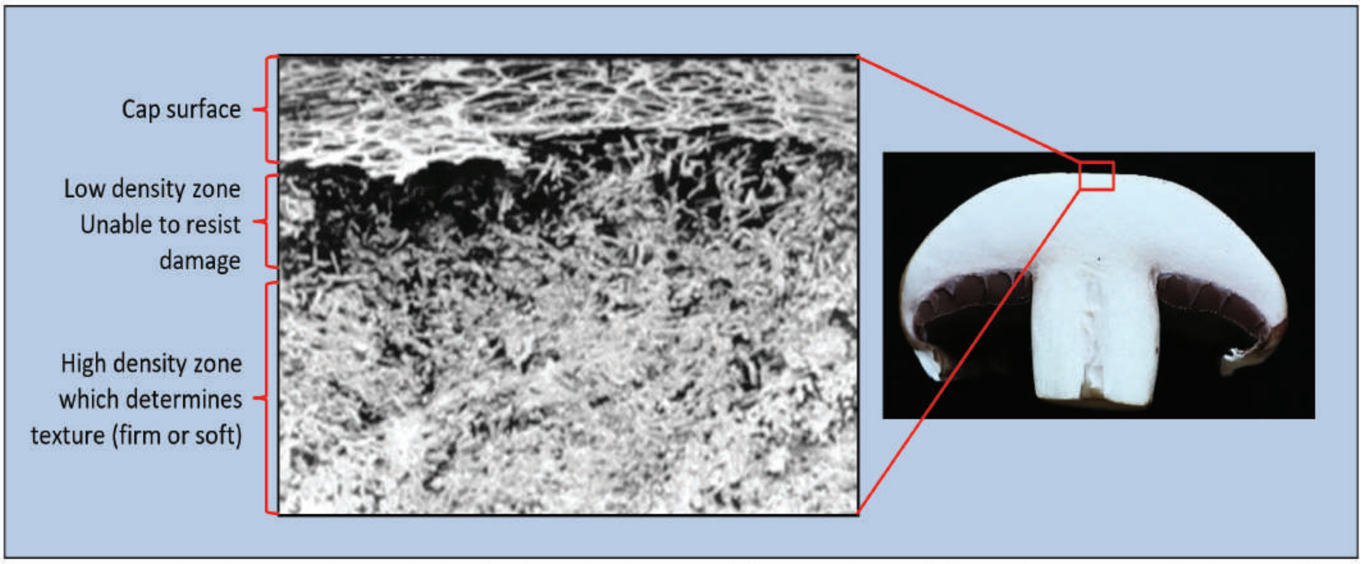

Figure 2 A scanning electron micrograph showing how the structure of the upper layers of the mushroom cap make it vulnerable to mechanical damage and bruising. *Figure adapted from Burton (2013)*

Table 1 Environmental and agronomic factors shown to affect mushroom bruisability

Factor	Relative importance	Factor	Relative importance
Water potential of casing	●●●	Compost type	●
Growing room humidity	●●●	Compost depth	—
Casing depth	●●	Flush	●●●
Casing composition (% SBL)	●	Strain	●●●

●●● large influence on bruisability; ●● medium influence on bruisability; ● low influence on bruisability; — no effect on bruisability

Adapted from Burton (2002a)

effect. Mushrooms growing on dry casing composed of 30% sugar beet lime (SBL) bruise less than those grown in 9% SBL. The difference in casing composition does not affect yield.

Burton (2002) further showed that second flush mushrooms growing on a shallow casing (25mm) are less prone to bruising than those growing on a deep casing (55mm), but casing depth has no such effect on first and third flush mushrooms.

Although the depth of compost has no influence on bruisability, less degraded, more 'strawy' composts reduce bruisability compared to darker, more degraded composts.

Finally, the mushroom strain grown is also highly significant and selecting the best strain to be grown is critical to minimise bruising (Burton *et al* 2003). However, strain choice is made on the expression of multiple characteristics which are considered desirable by the grower and not on a single trait such as reduced bruisability. As Burton (2002a) cautioned, changing strain may reduce bruisability and therefore improve quality, but it may also make matters worse!

THE BATTLE AGAINST BRUISING - NON-BROWNING MUSHROOMS ARE NEARLY MARKET-READY

A new gene editing technology has been developed called CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) which has led to the development of non-browning mushrooms. Researchers at Penn State University have identified many of the genes which regulate the browning process and have cut them out of the mushroom genome.

Consequently, the mushroom can no longer produce melanin and does not brown even after slicing. Furthermore, because the scientists have not inserted DNA from another organism, the non-browning mushroom is not considered a genetically modified organism (GMO) by the United States Department of Agriculture and is not subject to the rigorous risk assessment and approval process that transgenic GMOs must go through.

In addition to extending mushroom shelf life, it is hoped that the non-browning mushroom will allow mechanical harvesting systems to be used on mushrooms destined for the fresh market, which is currently handpicked, incurring high labour costs. Robotic harvesters work at up to 400 times the capacity of manual harvesters, but because they severely bruise the mushrooms, mechanically harvested mushrooms are currently fit only for canning and processing.

The researchers have made no comment on the impact of non-browning mushrooms on expression of diseases such as brown blotch.

Without melanin production, the blotch symptom will not be expressed so brown blotch may be a disease of the past. Yet browning is also a defence mechanism, as melanized tissue prevents infection by bacteria. What will happen if *P. tolaasii* is allowed free access to the interior of mushroom caps?

Read about non-browning mushrooms at:

https://agsci.psu.edu/magazine/articles/2016/fall-winter/a-crispr-mushroom

https://news.psu.edu/story/432734/2016/10/19/academics/penn-state-developer-gene-edited-mushroom-wins-best-whats-new

CONCLUSION

The main cultural factors which influence bruising susceptibility are concerned with water (casing moisture, humidity and casing depth).

But because no two farms are identical, it is not possible to offer one singular course of action that will reduce susceptibility to bruising on every farm.

Each farm runs different compost and casing formulations and runs to a unique schedule.

Changing watering patterns to reduce bruising susceptibility may well increase quality, but will also alter pinning times, harvest schedules and other crop management parameters.

Changes must be assessed carefully by individual farms and undertaken with caution.

However, because in Australia 97% of mushrooms produced are supplied to the fresh market, a small reduction in the frequency of bruised mushrooms will bring significant gains in these times of tight margins and intense competition in the marketplace.

FURTHER INFORMATION:

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KEY REFERENCES

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