North of England Potato Day,
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Managing The Risk Of
Bruising
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The Cost Of Bruising & Damage

- Bruising is a significant factor affecting the competitiveness of the GB potato industry and is the biggest single cause of consumer complaint.
- Estimated that bruising is costing £26 million across the potato industry each year!
- Equivalent to each grower losing £200/ha.
How Can Bruising Be Managed?

• Back to basics approach, understanding the biochemical, physical and physiological factors affecting susceptibility of potatoes to damage and bruising.
• Need to understand the agronomy of potatoes
• Need practical risk assessment tools
Cell Structure

Plasma Membrane

Vacuole
Why Does Bruising Occur?

Impact damage → Cell disruption → Tyrosine (AA) → PPO (enzyme) → Amino compounds → Melanin → Visual bruise

Factor is high energy form of oxygen $\text{O}_2^-$ (super oxide)

Vacuole contains substrate tyrosine

Bruising only occurs in cells containing starch granules

The biochemical process that generates **blackspot pigments** is initiated when a mechanical impact such as that occurring when potatoes are harvested causes internal disruption of the membrane surrounding the vacuole and other cellular compartments. Oxidation of tyrosine by the enzyme polyphenol oxidase in the presence of molecular oxygen.
Blackspot Bruising
– Simple Chemistry

• Integrity (strength and permeability) of membranes between enzymes (PPO contained in plasma membranes) and the substrate (mainly tyrosine, contained in the vacuole) is crucial to prevent contact and thereby colorimetric reaction.

• **Permeability increases with cells age**; may be cause of blackspot increasing during the season.

• **Intensity of colour development is more to do with the number of cells crushed** rather than the concentration of tyrosine in each cell.

• **Deterioration of intracellular membranes** may occur for some time after initial impact.
Physical Aspects of Bruising

- Tissue strength (failure stress)
  - strength of cell walls
- Tissue stiffness (elasticity)
  - elasticity and ability to resist strain.
- Small changes in elasticity of tissue have a large influence on bruising by changing the height a tuber can be dropped before cell damage occurs.
  - Slight reductions in hydration (2 to 3% mass loss) can reduce turgor enough to double the bruise threshold.
Turgor Pressure

- Turgor Pressure is a force exerted outward on a plant cell wall by the water contained in the cell vacuole.
- Vacuoles are essentially enclosed compartments which are filled with water containing inorganic and organic molecules including enzymes in solution.
Where The Turgor Story Started

But they never produced any data to support their hypothesis!

Source: Thornton, Smittle & Petterson (1973)
Tissues fully inflated (Classic cv Atlantic split): shock wave transmission very rapid, tissue splits along planes of weakness between cell walls.

Tissues partially dehydrated, shock waves dissipates more sideways, cells deform slightly, thereby “cushioning” contents from force.

Tissues severely dehydrated, shockwave transmission slow, *tuber will spread a given impact load over a larger area, but place peak shear stress deeper, more lateral spread of energy, internal membranes rupture* causing intimate mixing of PPO and Tyrosine.
Susceptibility To Damage At Harvest

• Potato damage at harvest can take various forms.
• Extensive year to year & site to site variability in bruising incidence
• Certain predisposing factors can influence the susceptibility of the crop and therefore the amount of damage.
Damage Properties

Source: adapted from Hughes 1980

Impact

- Tuber Firmness
- Skin strength & adhesion to flesh
- Internal tissue strength
- Starch & membrane properties
- Tyrosine & phenolase

Deformation

- No skin breakage
- Skin breakage

Friction

- Skin breakage & removal

Internal tissue strength

- Cell wall fracture

Starch & membrane properties

- Membrane damage
- Pigment formation (melanin)

Tyrosine & phenolase

- Blackspot

Type of Damage

- Internal fissures & crushing
- Splitting & cracking
- Scuffing
Different Bruise Types
Source: Baritelle et al 2000

- **Blackspot** typically showing no visible cell separation, although the cells are often damaged, typical blue-black discolouration;
- **Internal crush damage** where there is obvious cell wall or cell separation in addition to blue-black discolouration;
- **White spot** which is similar to a crush, except that damaged tissues are not discoloured;
- **Internal shatter** where tissue has sheared and where damage to cells results in discolouration;
- **External shatter** where tissue failure extends to the skin and discolouration is brown because air enters the shatter and dries tissue before complete oxidation occurs;
- **External cracking**, which is mostly the result of cell separation, with little or no tissue discolouration.
Potato Damage

Increasing Drop Height

50-1000 mm

Bruise
Shatter Bruise
Cracked/split

0 20 40 60 80 100
Biochemically, Tubers May Not Blackspot Bruise Early In The Season (cv Lady Rosetta, irrigated, 2004 CUF)
In Potatoes Which Show Some Resistance To Bruising What Is Different?

**Tyrosine:** The relative proportions of free and protein bound tyrosine are genetically determined and affect the susceptibility to bruising:

- Lower concentration at apical end where black spot is lower than stem end
- Young tubers have less tyrosine and less blackspot bruising
- In *Solanum hjertingii* - a resistant wild potato, tyrosine levels are lower than in susceptible lines
Pre-Planting Checklist

Planning pre planting will help ensure that risks are minimised:

• Has separation been done to the correct depth?
• Has the right size of clod/stone been removed?
• Has the bed been left too fine?
• Have following operations produce clod?
• Have following operations produced stone?
• Have the correct tractor wheel spacing for the rows and size of tyres for the operation been used?
Potato Soil Profile
Ridge Compaction
By Tyres

450 mm radial tyres will bulge to 490 mm & cause compaction of ridge wall

NB: on 1.8m bed planter @ 13.6 or 340 mm tyre is about right but can pair drills thus 16.9 or 420mm a compromise

Separator @ 16.9 or 420mm (sometimes 18.4 or 450mm)
Deep Ridger @ 26.0 or 650mm or duals
What Other Factors Are Linked To Bruising Sensitivity?
## Variety Risk Assessment

**Source NIAB 2010**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Dry Matter</th>
<th>Resistance to Damage</th>
<th>Resistance to Bruising</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markies</td>
<td>21.0</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td><strong>M Piper</strong></td>
<td>21.7</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td><strong>Lady Rosetta</strong></td>
<td>25.0</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Hermes</td>
<td>22.0</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Pentland Dell</td>
<td>21.8</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Estima</td>
<td>19.1</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Marfona</strong></td>
<td>17.2</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Saturna</td>
<td>23.0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Russet Burbank</td>
<td>21.8</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
Bruising Sensitivity

• Variety, tuber mass (size) and shape
  – Small radii of curvature tend to damage more.
• Impact surface characteristics & impact orientation.
• Planting date & physiological age
  – Older tubers have larger tyrosine pool
  – Higher DM tubers have larger cells that are more sensitive.
  – SG is responsible for less than 30 % of the differences between varieties in bruising frequency
• Nutrition
  – Nitrogen - High nitrogen delays maturity
  – Potassium - >2.5% of DM
• Temperature of tubers <12°C
• Soil type & irrigation
• Turgor - firmness affecting degree of impact deformation
## Bruising In Relation To Temperature

Source: N=200 ADAS 1982

<table>
<thead>
<tr>
<th>Temp °C</th>
<th>Slight</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0 – 9.9</td>
<td>36.5</td>
<td>16.4</td>
</tr>
<tr>
<td>10.0 – 11.9</td>
<td>52.4</td>
<td>16.4</td>
</tr>
<tr>
<td>12.0 – 13.9</td>
<td>20.9</td>
<td>7.9</td>
</tr>
<tr>
<td>14.0 – 15.9</td>
<td>21.3</td>
<td>9.3</td>
</tr>
<tr>
<td>16.0 – 17.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&gt;18.0</td>
<td>27.25</td>
<td>20.25</td>
</tr>
</tbody>
</table>
Growth Of Roots

- Root longevity & turnover: senescence trigger for roots occurs at an earlier time to that of the crop canopy.
  - Growth of tubers removes assimilate from fibrous root system and roots start to degenerate earlier than the crop canopy.
Tuber Re-hydration Depends On:

• Stage of crop growth
• Absolute SMD
• Evaporative demand at time of re-wetting
  – Tubers may not re-hydrate if high evaporative stress around onset of senescence
  – Evaporative demand earlier in the season
  – If roots die, tubers cannot be re-hydrated!
  – Often takes more than one 15-18 mm irrigation event to re-hydrate tubers!
Main Factors That Can Be Managed

• N fertiliser.
• K fertiliser.
• Lifting date and maturity
  • low temperature and delayed harvest are linked to elevated tyrosine content.
• Soil moisture deficit before and at desiccation
• Assess crops before lifting/handling
• Gentle handling & tuber size
• Impacts and position of impacts
Potatoes Are Less Likely To Bruise If:

- More turgid tubers
- Small sized tubers
  or under these conditions:
  - Higher soil potash
  - Higher handling temperatures
  - Silty soil or clay loam provided no clods
  - Short storage period
  - Adequate soil moisture at desiccation and harvest
Potatoes Are More Likely To Bruise If:

- Less turgid tubers
- Large sized tubers

or under these conditions:

- Lower soil potash
- Lower handling temperatures
- Dry sandy soil or cloddy soils
- Long storage period
Haulm Destruction

- Allows skins to set
- Disease control - especially tuber blight
- Reduced volume of haulm for harvesting
  - Haulm should be left in a state for ease of harvesting
- NOT TANGLED AND NOT TOO SHORT
- Any haulm going into harvester will increase damage levels
  - flailing is required somewhere in sequence
Effects of Moisture On Skin Set

- If wet, lenticels open - gaseous balance in tuber unfavourable for suberisation
- Similarly, if soil is dry, suberisation does not occur - can be poor adhesion between skin and flesh
- Tuber in field requires RH between 30’s and 70’s, where lenticels are active and open, to achieve adequate skin set.
- Don’t assume +14-21 days haulm destruction that skin is set.
Maturity & Biphasic Bruising With Time

source: Fraser Milne
The page contains a section titled "Prediction of Bruising." The content includes the following points:

- Use bruise barrels together with hot box.
- Hotbox setup: 15-24h @ 34-36°C and 95-98%RH
- Manual peeling to assess level of bruising.
  - Variation between samples can be enormous.
  - Re-test at least daily and regularly review results.
- Pre-harvest guide, as well as post-harvest QC.
- Significant time investment that needs accuracy and purpose.
Hot Box- Beginners Mistakes

• Completely sealing the hot box.
  – Keytones produced

• The tubers need to be assessed immediately they are taken out of the hotbox.

• Operating the hot box at too high a temperature.

• Assuming that hot box results accurately reflect the level of bruising seen in the crop as a whole.
## Damage & Bruising Prevention Factors

<table>
<thead>
<tr>
<th>Which factors increase</th>
<th>Damage</th>
<th>Bruising</th>
</tr>
</thead>
</table>
| **The crop**           | Low dry matter  
Loose skin  
High water turgor | High dry matter  
Set skin  
Low water turgor | **Bold sample**  
Cold temp (below 8°C) |
| **The soil**           | Sharp stones/flints  
Very wet soil | Large stones & clods | **Dry soil**  
Stones & clods |
| **Harvester Operation**| Lifting share depth too shallow  
Web rods too close in wet soil | | Topper blade impact  
Poor haulm removal  
Poor soil retention (web rods too far apart in dry soil)  
Diablo pressure too high  
Haulm roller gap & position incorrectly set-up  
Excessive cleaning or agitation  
Tyre wall compression damage |
Justification For Attention To Harvester Set Up

Two factors are of paramount importance:

- getting crop out of ground
- minimising tuber damage

Modern harvester are capable of lifting 60 t/hr, thus 1% increase in No. of damaged tubers could reduce saleable tubers by:
  - 0.6t/hr
  - 6t/day
  - £600 per day per harvester
Summary

- Staff training is vital – **DO NOT** solely blame the harvester driver for a bruised crop as it is rarely his fault.
- Monitoring of crop quality into store and liaison with customer to ensure compliance with their requirements.
- Should problems arise, flexibility within the supply chain may be necessary for all to achieve their ultimate goal.
PLEASE THINK ABOUT HEALTH & SAFETY AT ALL TIMES
TOP TEN
DAMAGE REDUCTION AREAS
Position One

Make sure the topper height is set correctly to ensure efficient chopping of the haulm without damage to the crop. Check the blade configuration to suit the row/bed widths.
Position Two

Adjust the pressure of the Diablo on the ridge to allow an even shape and density to be presented into the machine. (Too much weight can cause damage to the crop.)
Position Three

Check share height and pitch adjustment to ensure a clean feed onto the web. Digging depth is adjustable to lift the whole crop without cutting any potatoes but avoiding lifting unnecessary amounts of soil. (If the share is set to low bruising can occur when the potatoes hits the front of the intake web at position 3.)
Position Four

Check intake disc width set to give clean feed into the harvester without cutting any potatoes and avoiding carrying unwanted soil into the machine. Haulm intake wheels can be set to avoid blockages. (Check width of disc to ensure no potatoes are cut, and depth of disc to stop the intake being carried and cutting potatoes with the share)
Position Five

Design of web to give effective sieving of the soil and the bars and rivets. (Exposed rivet heads can cause damage to the crop) protect the crop from...

Hochnocken

Hochnocken
Grimme gives the choice of cascade or hydraulic agitation to increase the sieving capacity when needed but avoiding unnecessary bouncing of the crop. Speed and intensity of the agitation is adjustable according to conditions. (Too much aggression can cause damage to the crop)
Haulm separation that is efficient but gentle. Adjustable configurations and positions to give different degrees of aggression to suit varying crop conditions. Efficient removal of haulm enables the main soil separation system to work at its most efficient and gentle manner. (Set to aggressive may result in damage to the crop)
Position Eight

Choice of soil separation systems to suit different conditions and crops. All systems are adjustable for speed and aggression. (Make sure the separator is set to suit lifting conditions to avoid unnecessary damage.)
The cart elevator has soft pockets and active side panels, which ensure that the crop is not moving within the elevator. Each pocket is like an individual basket of crop, avoiding scuffing.

(This is where damage can occur on harvesters without active side panels)
Position Ten

The fall breaker reduces the drop into the trailer or boxes, minimising possible bruising. Improves the accuracy of delivery when loading directly into boxes.
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