Final Report for HDC

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Project Leader	Kerry Burton
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Project Co-ordinator:	Peter Woad Blue Prince Mushrooms Poling Arundel West Sussex BN18 9P4
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The Use of Calcium Chloride in the irrigation water to improve Mushroom Quality (M37)

CONTENTS

PRACTICAL SECTION FOR GROWERS

Background

Quality is one of the main factors influencing the competitiveness of mushroom industry. Any treatments which leads to improved quality has the potential of benefiting the industry. The white colour of mushroom is one of the main factors determining mushroom quality. It has been reported in USA that watering with calcium chloride solutions conserves the white colour of mushrooms. It is not known (previous to this project) whether this technique will have benefits for the British industry. American grown mushrooms are not as high in quality as mushrooms grown in Britain.

This project compared the quality of mushrooms irrigated with five concentrations of calcium chloride solution (0.1, 0.2, 0.3, 0.4 and 0.5%) with water irrigated mushrooms. Two types of water were used: de-mineralised water (virtually calcium free) and tap water (containing 0.004% calcium). This mushroom strain used was A15. The mushrooms were grown as per standard operational practices of HRI except after casing and thereafter throughout the crop the different watering treatments were applied. Mushrooms were harvested from the first three flushes and quality assessments were made on them as:-

(a) mushroom colour (degree of discolouration, redness and yellowness) at the time of harvest, during postharvest storage and after bruising,

(b) rate of cap opening (development) after harvest and

(c) weight-loss after harvest.

Summary of results

- The overall yield of mushrooms was unaffected by calcium chloride irrigation, however the flushing pattern was slightly delayed by the calcium chloride treatment.

- Calcium chloride irrigated mushrooms were whiter at the time of harvest than water irrigated mushrooms. This effect was greatest at the higher calcium chloride concentrations (0.4% and 0.5%). At the end of the storage period, there was little differences in whiteness between the calcium chloride or water irrigated mushroom. It should be noted that the improvement in whiteness caused by calcium chloride was measured by a sophisticated machine but was not seen by many observers. The mushrooms grown in this experiment were of exceptionally good quality. It is possible that calcium chloride would have a more noticeable effect on poorer quality mushrooms.

- Analysis of the colour of mushrooms reveals that they are very slightly reddish in colour and a little more yellowish in colour. Calcium chloride irrigated mushrooms were less coloured (red and yellow) than water irrigated mushrooms.

- Mushrooms from the different watering treatments were given a controlled bruising treatments and the colour of the bruise was measured 4 hours later. The bruises of the mushrooms treated with calcium chloride (concentrations 0.4% and 0.5%) were less discoloured that the water treated mushrooms. This result was visible to human observation.

- Calcium chloride irrigation caused the harvested mushrooms to open out (cap development) faster than for water irrigation.

- Calcium chloride irrigation led to less weight-loss from harvested mushrooms than water irrigated mushrooms.

The benefits of calcium chloride irrigation are (1) improved colour (but this is barely noticeable with good quality mushrooms), (2) less discolouration as a result of bruising and (3) reduced postharvest weight-loss.

The disadvantages of calcium chloride use are (1) increased cap opening (postharvest), and (2) change in current farm practice involving possibly increased management and labour costs.

SCIENCE SECTION

Introduction

It has been reported that watering mushroom beds with a diluted calcium chloride solution has a beneficial effect on mushroom quality (Solomon, Beelman and Bartley, 1991; Miklus and Beelman; 1996). A weak solution (0.3%) of this inexpensive chemical used as irrigation water, has been shown to improve the whiteness of mushrooms at the time of harvest and subsequently during postharvest storage. This treatment is widely practised in farms in North America as a result of studies of Professor Bob Beelman of Pennsylvania State University but hardly at all in Britain. Calcium is considered to be the 'active' part of the solution. More recently, the beneficial effects of calcium chloride on American mushrooms have been described as principally having the effect of reducing the extent of bruising-induced discolouration (Kukura and Beelman, 1998; Kukura, Beelman, Peiffer and Walsh, 1998).

This treatment is inexpensive and it has the potential of making improvements in mushroom quality. The proposed research is designed to establish whether the use of added calcium will be beneficial in Britain. It is uncertain whether calcium chloride irrigation will be advantageous in the UK because of the different materials used in mushroom culture and that British mushrooms are already of much better quality and whiter than those from USA. This project examines whether calcium chloride irrigation can improve the whiteness of British mushroom and, if so, what is the optimal concentration. Any techniques which can improve mushroom quality is a benefit to growers. A technique such as calcium chloride irrigation, which is very cheap in terms of capital, running costs and labour, is of potential benefit to British growers.

Materials and Methods

Mushrooms

A crop of mushrooms (strain A15) was grown on HRI formula III compost on the HRI mushroom unit using Standard Operational Practice (SOP) (Willoughby and Gaze). The only exception to the SOP was that mushroom trays were watered with one of seven solutions as outlined below. Two stacks of four trays were watered with each solution from the point of casing through to airing and cropping. The trays were placed in the growing room in two randomised blocks.

Mushrooms were cropped from the first three flushes. For each flush, mushrooms were harvested from each treatment stack (i.e. 7 treatments x 2 blocks = 14 harvested samples). Yield was recorded from each stack of 4 trays.

Watering Treatments

Seven different solutions were made and stored in 90 l. plastic dustbins in the growing room. The watering rate and frequency was as per the HRI Standard Operational Practice. The seven treatments were:-

1. De-ionised water (essentially calcium free).
2. Tap water (0.004% calcium)
3. 0.1% calcium chloride
4. 0.2% calcium chloride
5. 0.3% calcium chloride
6. 0.4% calcium chloride
7. 0.5% calcium chloride

Mushroom Storage

Mushrooms were harvested from the trays as per commercial practice and weighed. On the peak cropping days from each flush, mushrooms were harvested from each stack and used for experimentation. A batch of 36 mushrooms was selected from each of the 14 stacks (7 treatments x 2 blocks). The mushrooms were selected to be clean, white, blemish-free buttons (stage 2 by the Hammond and Nichols (1976) developmental scale). These mushrooms were then sub-divided into 6 sub-batches of six mushrooms. One of these batches was used for quality assessment shortly afterwards (day 0), the remaining 5 sub-batches were placed in a controlled environment store (18ºC, 90-95% relative humidity). Each day afterwards a sub-batch of six mushrooms from each of the 14 stacks was removed from the store for quality assessment.

Mushroom Quality Assessment

To ascertain whether the calcium chloride treatments are beneficial to mushroom quality, assessments of quality were made as colour (at the time of harvest, during postharvest storage and after bruising), rate of development (cap opening) and weight loss.
Mushroom Colour:- The colour of each mushroom was measured once at the top of the cap and at four positions around the side. Colour was measured using a Minolta meter (model 503i) which measures colour in three forms, L, a and b. 'L' refers to the (whiteness or darkness of a colour). For statistical reasons, L is mathematically transformed to $\log_{10}$ (100-L) which is referred to as the degree of discolouration. The higher the figure means the more discolouration. 'a' and 'b' are known as opponent colour scales. 'a' when positive is the amount of red colour, and when negative is the amount of green colour. 'b' when positive is the amount of yellowness and when negative is the amount of blueness.

Mushroom Bruising

At the same time as this project was being undertaken, a second HDC project (M 19a) was taking place to test the validity of a mushroom bruisometer. The chosen bruisometer design (Bruisometer Two) was used to inflict a control amount of mechanical damage on mushrooms from the seven watering treatments from flushes two and three. Ten mushrooms per treatment per flush were subjected to a 195g weight via the 5mm probe twice. The colour of the bruise region was measured 4 hours later using the Minolta meter.

Rate of Maturation

The test mushrooms were selected to be clean white button mushrooms, stage 2 in the Hammond and Nichols (1976) developmental scale. The rate of maturation/development or rate of cap opening was assessed by examining the harvested mushrooms daily and assessing their development using the Hammond and Nichols developmental scale. Diagrams showing mushrooms at the different stages of the development can be seen in Graph 5.

Weight-loss

The sub-batches of third flush mushrooms were weighed shortly after harvest and then re-weighed daily until the end of the storage period. Weight-loss was calculated as percentage of original weight lost.

Experiment Design and Statistical Analysis

The experiment consists of seven watering treatments replicated as two blocks. Mushrooms were harvested and tested from the first three flushes. Mushroom colour was measured on both the top and the sides (these two regions have distinct colour characteristics).

The experiments were statistically analysed by analysis of variance. This analysis looked for differences between the two water treatments (de-ionised and tap water); if no differences were found, the results were combined and averaged. If the effect (or non-effect) of calcium chloride was the same for all flushes then the results averaged between flushes are presented. Similarly, if the colour effects of calcium chloride irrigation are the same for mushroom tops and sides then the average results are presented, to aid interpretation.

RESULTS

The effect of calcium chloride irrigation on mushroom yield

There was no significant effect of calcium chloride irrigation on mushroom yields. The average yields per treatment are given in Table 1. The statistical indicator for indicating statistic differences (the Least Significant Difference) is 19.4 (at 5% level). This figure is higher than any of the differences between the means in Table 1 and so there is no *statistical* difference between them.

Table 1

	Mushroom Yield (kg/tonne compost)						
Treatment	1 De-mineralised	2 Tap Water	3 01.%	4 0.2%	5 0.3%	6 0.4%	7 0.5%
Yield (kg/tonne)	236	222	244	235	242	247	232

There was, however, strong statistical evidence (0.1% significance) that calcium chloride treatments cause a delay in cropping within each flush. Graph 1 shows the average daily yields (expressed as Kg per tonne of compost) of the combined water treatments (demineralised and tap water) and the combined calcium chloride treatments (0.1 - 0.5%).

Conclusion:

Calcium chloride irrigation does not affect overall yield. However, the flushing pattern was delayed by a day or so by the calcium chloride.

The effect of calcium chloride irrigation on colour

- Degree of Discolouration:

  The degree of discolouration of mushrooms increases with time after harvest (0.1% significance) i.e. they become darker. Calcium chloride treatment makes the mushrooms whiter i.e. a lower degree of discolouration (1% significance). However, the effect of calcium chloride is not uniform over time. The improvement in colour of calcium chloride is greatest at the time of harvest and then declines during postharvest storage. The higher concentrations of calcium chloride used (0.4% and 0.5%) resulted in the whitest mushrooms at the time of harvest but this difference was lost after 5 days storage.

  Graph 2 shows the effect of calcium chloride irrigation on mushroom degree of discolouration. The results of tap water and demineralised water are shown as a single average line as there was no significant difference between them.

Conclusion:

Calcium chloride irrigation leads to mushrooms with a lower degree of discolouration at the time of harvest compared with water irrigated mushrooms. However, this difference is lost as the mushrooms of all treatments become similarly discoloured during postharvest storage.

- The effect of calcium chloride treatment on cap red colour ('a'):

The average 'a' value measured for all the mushrooms from all treatments was 0.891. This figure is positive and therefore is a measure of redness. However, the figure is very close to zero which for an opponent colour scale ('a' or 'b') means that the mushrooms were barely red at all. For completeness we are reporting these data but readers should be aware that the 'a' value has little impact on the human perception of mushroom colour.

The 'a' value or redness of mushrooms increases after harvest during the 5-day storage period (0.1% significance). Calcium chloride causes the mushrooms to be less red i.e. lower 'a' value (0.1% significance). This effect was observed only on the mushrooms from the first and second flushes. Graph 3 shows the redness of the mushrooms (averaged over the three flushes) from the five calcium chloride treatments and the combined water treatments over the 5 day storage period.

Conclusion:

Redness represents a small part of the colour of mushrooms. Calcium chloride treatment gives the mushrooms a lower 'a' value or redness.

- The effect of calcium chloride treatment on cap yellowness ('b' value):

The average value for 'b' from all of the data collected was 11.44. This figure being positive therefore refers to yellowness. It is of sufficient value to say that mushrooms have a yellow hue although they are not distinctly yellow.

The 'b' value or yellowness of mushrooms increases over time after harvest (0.1% significance). Calcium chloride irrigation made the mushrooms less yellow (0.1% significance). At the time of harvest, the yellowness of the water irrigated or calcium chloride irrigated mushrooms was the same. However, during postharvest storage the water irrigated mushrooms developed more yellowness than the calcium chloride irrigated mushrooms.

Graph 4 shows the effect of calcium chloride or water irrigation on mushroom yellowness over time.

Conclusion:

Calcium chloride has no effect on mushroom yellowness at the time of harvest. However, the water irrigated mushrooms developed more yellowness than the calcium chloride irrigated mushrooms during postharvest storage.

- Overall conclusion of colour taking into account all colour data (degree of discolouration, 'a' and 'b'):

  The experiment has shown that calcium chloride irrigation leads to mushrooms with a lower degree of discolouration, 'a' value (redness) and 'b' value (yellowness). These data were collected using a sophisticated machine, the Minolta meter. Also to be sure of the accuracy of the result, the experiment had a large number of replicates, over 1000 different colour measurements were taken for each calcium chloride concentration or water treatment. As a result we are sure of the statistics and their conclusions. However, the critical question is whether the differences identified could be recognised by the consumer. Trays of harvested mushrooms were shown 'blind' to colleagues at HRI and over half of people could not identify any colour differences. It should be noted that the quality of all the mushrooms used in this experiment was very good. However, the measured colour improvements by calcium chloride should be qualified by noting that these may not be recognisable by consumers (see Photograph 1).

Effect of calcium chloride irrigation on colour of bruised mushrooms

Colour is an important determinant of mushroom quality. Mushrooms can discolour as a result of one of two processes:- (1) Due to ageing (also known as senescence), this process is being examined by measuring the colour during postharvest storage; (2) due to mechanically-induced damage or bruising, this process was also examined as described below.

Since this proposal for work was first submitted to and accepted by HDC, two reports have been published (Kukura and Beelman, 1998 (a) and (b)) which suggests that calcium chloride reduces the effects of bruising. The authors of these reports used the shaking box technique to bruise mushrooms as first described by Noble, Burton and Atley, 1992; and Burton and Noble, 1993. A vastly improved bruising technique, the bruisometer, is currently being developed by HRI, Coventry University and HDC. As some of this development work was taking place at the same time as the calcium chloride experiment, it was decided to investigate the effect of calcium chloride irrigation on bruise colour.

Mushrooms from the second and third flush were given the specified bruisometer treatment across the top of the mushroom cap, and the colour of the bruise was measured 4 hours later.

Results:

The bruising treatment increased each of the colour parameters as compared with the day 0 readings as shown in Table 2.

Table 2. Average colour parameters of mushrooms on day 0, bruised and unbruised.

	Bruised	Unbruised
Degree of Discolouration	1.198	0.9339
'a' (redness)	2.25	0.599
'b' (yellowness)	11.305	7.788

- Degree of discolouration

  On average, the mushrooms which had been irrigated with calcium chloride had a lower degree of discolouration at the bruise region that mushrooms irrigated with water. This effect varied between the different concentrations used (Table 3). However at 0.4% and 0.5% calcium chloride, the degree of discolouration of the bruise was significantly less than the water treated mushrooms.

- 'a' value (redness)

  No significant effects were found for the use of calcium chloride and the 'a' value of the bruise colour (redness).

- 'b' value (yellowness)

  Calcium chloride had a slight effect on the yellowness of the bruise. It caused a lowering of yellowness for the lowest three calcium chloride concentrations of flush 2 compared with water irrigation but no effect on the remaining treatments of flush 2 or flush 3. These data are shown in table 4.

Conclusions:

Overall, calcium chloride lessened colour development after bruising compared with water irrigation. The effect varied between mushrooms of different flushes and between different concentrations of calcium chloride. The difference in bruise colour between water-irrigated and 0.4% or 0.5% calcium chloride irrigated mushrooms could be observed by the human eye. Photograph 2 illustrates the effect of the different irrigation treatments on bruise colour of third flush mushrooms.

Table 3 – The effect of calcium chloride irrigation on bruise colour (degree of discolouration). The Least Significant Difference (at the 5% level) is 0.05. This figure can be used for comparing the values of the calcium chloride treated mushrooms with water treated mushrooms. Note that for both flushes the values for 0.4% and 0.5% calcium chloride are significantly lower than the water value (i.e. difference is greater than 0.05)

Degree of Discolouration						
		Calcium Chloride (%)				
	Water	0.1	0.2	0.3	0.4	0.5
Second Flush	1.279	1.198	1.239	1.250	1.208	1.221
Third Flush	1.178	1.206	1.167	1.147	1.118	1.103

Table 4 – The effect of calcium chloride irrigation on bruise colour (yellowness of 'b' value). The Least Significant Difference (at the 5% level) is 0.84. This figure can be used for comparing values of the calcium chloride treated mushrooms with water treated mushrooms

Yellowness – 'b'						
		Calcium Chloride (%)				
	Water	0.1	0.2	0.3	0.4	0.5
Second Flush	11.66	9.93	10.77	10.43	11.24	11.98
Third Flush	11.44	11.64	11.85	11.78	11.14	11.33

The effect of calcium chloride irrigation on rate of development

A quality factor recognised by consumers is the rate of maturation or development which means how fast the mushrooms open out. The date of this experiment show that the rate of cap opening increases with increasing flush number i.e. the third flush is the fastest, followed by the second flush and the first flush mushrooms are the slowest in opening out.

However, to simplify the presentation of the results, the date from different flushes are combined and averaged. The rate of development results are presented on the basis of the different irrigation treatments (Graph 5). Increasing the concentration of calcium chloride in the irrigation water leads to a significantly faster rate of development. The highest calcium chloride concentration used had an accelerated development effect similar to the difference between flush 1 and flush 3.

Conclusion:

The use of calcium chloride in the irrigation water leads to a faster cap opening or rate of development. In this aspect therefore calcium chloride has a deleterious effect on quality.

The effect of calcium chloride irrigation on weight-loss

The effect of calcium chloride irrigation on weight-loss of the harvested mushrooms can be observed in Graph 6. The calcium chloride treatments cause a significant reduction of weight-loss compared with the water irrigation treatment. The higher the concentration of calcium chloride led to the lowest weight-loss.

Conclusion:

Calcium chloride irrigation leads to reduced weight-loss of the harvested mushroom. In this respect therefore calcium chloride has a beneficial effect on quality.

CONCLUSIONS

1. Calcium chloride irrigation treatments had no overall effect on mushroom yield, although the flushing pattern was slightly delayed.

2. Calcium chloride irrigated mushrooms were whiter and less coloured than water irrigated mushrooms. However, this difference was not easily discernible to the human eye.

3. Calcium chloride irrigated mushrooms were less discoloured after a controlled bruising treatment than water irrigated mushrooms. This difference could be detected by the human eye.

4. The rate of cap opening or cap development was greater for calcium chloride irrigated mushrooms than those treated with water.

5. Water loss from the harvested mushrooms during storage was less for the calcium chloride irrigated mushrooms than those irrigated with water.

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Photograph 1 – The colour of mushrooms from the seven different watering treatments. The column of five mushrooms above each number were taken from that treatment number (i.e. Tr. 1 – demineralised water; Tr.2 – tap water; Tr.3 – 0.1% calcium chloride; Tr.4 – 0.2% calcium chloride; Tr. 5 – 0.3% calcium chloride; Tr.6 – 0.4% calcium chloride; Tr.7 – 0.5% calcium chloride).

Photograph 2 – The effect of calcium chloride irrigation on bruise colour. Note the colour of the horizontal stripe over the centre of the cap. The column of five mushrooms above each number were taken from that treatment number (i.e. Tr.1 – demineralised water; Tr.2 – tap water; Tr.3 – 0.1% calcium chloride; Tr.4 – 0.2% calcium chloride; Tr.5 0.3% calcium chloride; Tr.6 – 0.4% calcium chloride; Tr.7 – 0.5% calcium chloride).