C S I R O   P U B L I S H I N G

Australian Journal of Experimental Agriculture

Volume 39, 1999

… a journal publishing papers (in the soil, plant and animal sciences) at the cutting edge of applied agricultural research

www.publish.csiro.au/journals/ajea

All enquiries and manuscripts should be directed to
Australian Journal of Experimental Agriculture
CSIRO PUBLISHING
PO Box 1139 (150 Oxford St)
Collingwood
Vic. 3066
Australia

Telephone: 61 3 9662 7614
Facsimile: 61 3 9662 7611
Email: chris.anderson@publish.csiro.au
lalina.muir@publish.csiro.au

CSIRO

Published by
CSIRO PUBLISHING
in co-operation with the
Standing Committee on Agriculture and Resource Management (SCARM)

Effect of preharvest bagging and of embryo abortion on calcium levels in 'Kensington Pride' mango fruit

D. R. Beasley[A], *D. C. Joyce*[BD] *and P. J. Hofman*[C]

[A] School of Land and Food, The University of Queensland, Gatton College, Qld 4345, Australia.
[B] Postharvest Horticulture Group, Silsoe College, Cranfield University, Silsoe, Bedfordshire MK45 4DT, United Kingdom.
[C] Horticulture Postharvest Group, Department of Primary Industries, 19 Hercules Street, Hamilton, Qld 4007, Australia.
[D] Author for correspondence; e-mail: d.joyce@cranfield.ac.uk

Summary. Bagging mango fruit during their development on the tree can reduce insect and disease damage. However, it is also possible that bagging can interfere with transpiration and associated calcium accumulation. Low calcium concentrations have been correlated with poor mango fruit quality. This study was conducted to evaluate the influence of bagging at various stages of fruit development on calcium concentration and postharvest quality of 'Kensington Pride' mangoes. Fruits were bagged at 41, 25 or 9 days before harvest. No statistically significant differences in either skin or flesh calcium concentration were found between the bagged (plastic or paper) and unbagged fruits. Postharvest weight loss was enhanced and shelf life reduced in the 'plastic bagged' fruits. In an ancillary study, calcium concentrations in 'Kensington Pride' nubbins (seedless fruit) were compared with those in seeded fruit, since it has been shown with apple fruit that greater seededness is positively correlated with increased flesh calcium concentrations. Conversely, however, calcium concentrations in the flesh of mango nubbins were found to be significantly higher (0.80 mg/g dry weight) than those in seeded fruit (0.58 mg/g dry weight) of similar size.

Introduction

Strong correlations between good quality and high tissue calcium concentrations have been established for a number of fruit crops (Bramlage *et al*. 1990). Calcium is relatively immobile and is translocated almost entirely in the transpiration stream (Bangerth 1979). Developing fruit usually accumulate most calcium during the early stages of growth (Bangerth 1979). Early accumulation may be due to the comparatively large surface area to volume ratio of small fruit (Clark and Smith 1988), the lack of a well developed cuticle, and the presence of functional stomata (Dietz *et al*. 1988).

Bagging fruit during their development has been practiced for the control of insects (Bentley and Viveros 1992) and diseases (Johnson *et al*. 1994). Fruit bagging may also enhance fruit appearance by providing protection from temperature extremes and from abrasion (Homes 1984; Kitagawa *et al*. 1992). However, fruit bagging may have a potentially detrimental influence on fruit quality by inhibiting the transpiration-based flux of xylem mobile calcium into fruit.

The presence and number of seeds is another factor that can affect calcium accumulation by multi-seeded fruit. Bramlage *et al*. (1990) found that increased seed number in apple was correlated with higher fruit calcium concentration, possibly because auxins are produced in seeds (Bangerth 1976). Calcium movement into a particular plant organ may be induced by indole-3-acetic acid (IAA) export from that organ. For example, avocado fruit are believed to be poor IAA exporters, and are therefore considered to provide a weak sink for calcium (Cutting and Bower 1990). Auxins and auxin transport inhibitors have been shown to increase and decrease, respectively, calcium accumulation in apple and avocado fruit (Cutting and Bower 1990).

The present study was conducted to determine the effect of bagging using paper or plastic bags on calcium accumulation by 'Kensington Pride' mango fruit. 'Kensington Pride' is the most commercially important mango cultivar grown in Queensland (Cull and Lindsay 1995). This cultivar is susceptible to internal disorders

 10.1071/EA98060

thought to be associated with low flesh calcium concentrations (Mead and Winston 1991).

In an earlier study, bagging of 'Sensation' mango fruit 49 days before harvest did not affect their fruit calcium concentrations (Joyce *et al*. 1997). In a more extensive study on 'Keitt' mangoes, fruit calcium concentrations were reduced by bagging at ≤56 days before harvest (Hofman *et al*. 1997). It was considered important to extend this work to 'Kensington Pride', the most commercially important cultivar in Australia. In addition, the hypothesis that 'Kensington Pride' nubbins (fruit with aborted ovules; i.e. no seeds) would have reduced calcium concentrations was tested.

The aim of the present study was to test the hypothesis that bagging would reduce calcium influx into the fruit through an increased vapour pressure within the bag, which would lead to reduced transpiration and calcium accumulation, and possibly increased incidence of physiological disorders.

Materials and methods

Treatments, harvesting and handling

Fruit on 6-year-old mango (*Mangifera indica*) cv. 'Kensington Pride' trees at a farm near Gatton (27°33'S, 152°17'E), Queensland, were bagged with paper or plastic bags 41, 25 or 9 days before harvest. The treatments were: (i) unbagged (control); (ii) opaque white waterproofed paper bag (Japanese-made 'T20' paper bags, 335 by 215 mm; supplied by Palmwoods Farm and Garden Supplies, Palmwoods, Qld); and (iii) opaque white plastic bags (Australian-made polyethylene bags, 295 by 170 mm; manufactured by Beaver Plastics Pty Ltd, Coopers Plains, Qld). Bagging was commenced after the first heavy fruit drop, when the mango fruit had reached the 'golf ball size' stage. The bagging dates were 29 November, 15 December and 31 December. Before each bagging, diameters of 100 randomly selected mango fruit were measured and fruit for bagging were selected from within ± 10% average fruit size. At each time, 15 fruit (5 fruit/treatment) were randomly selected for treatments from each of 12 trees (i.e. 5 x 12 = 60 fruit in total per treatment). Extra mango fruit (30 fruit/treatment) were bagged on each occasion to compensate for potential subsequent fruit drop. Mean ± s.e. fruit weight and cheek to cheek diameter at the first, second and third bagging times were 28.3 ± 1.9 g and 31.3 ± 1.0 mm, 129.6 ± 10.6 g and 52.8 ± 1.2 mm, and 334.3 ± 11.1 g and 71.3 ± 1.3 mm respectively (*n* = 15).

Additional mango fruit were harvested 6 days before commercial harvest on 3 January and later divided, following dissection, into groups with or without seeds. Mean ± s.e. overall fruit weight and cheek to cheek diameter were 135.7 ± 3.1 g and 54.5 ± 0.4 mm respectively (*n* = 44).

All other mango fruit randomly selected from the same trees were harvested on the morning of 9 January. Bags were removed at harvest, and the fruit were transported in <1 h by road to the laboratory in Brisbane. Stalks were then removed from the fruit, which were placed upside down on a wire mesh rack for 30 min to allow sap to drain. Fruit were next dipped in fungicide [0.55 mL Sportak (a.i. 450 g prochloraz/L)/L water] for 2 min, air dried under shade at about 20°C for 30 min, labelled and weighed. The fruit were ripened in a controlled environment room at 25°C and about 70% relative humidity. Fruit were arranged in a completely randomised design within fibreboard mango fruit trays. There were 20 (*n* = 20) individual replicate fruit for each treatment, and the total number of fruit in this experiment was 180 (i.e. 20 replicate fruit x 3 bagging treatments x 3 bagging times).

Assessments

Fruit blush (percentage of surface area affected) and skin blemish (severity ratings: 0, none; 3, slight; 5, moderate; 7, excessive; 9, extreme) were scored after harvest. Dry matter (%) was determined for 5 sample fruit from each of the 3 bagging treatments by oven drying their flesh at 60°C to constant weight.

Five mature green fruit were randomly selected from each treatment for calcium analysis (i.e. 5 replicate fruit x 3 bagging treatments x 3 bagging times = 45 fruit in total). Skin and flesh portions were separated and samples were selected randomly after dicing and mixing the portions. About 10–20 g samples of skin or flesh tissue were oven-dried at 60°C to constant weight, ground to a fine powder, and wet digested with nitric and perchloric acids. Calcium was quantified using a Philips PYE Unicam SP9 atomic absorption spectrophotometer. Calcium concentration was calculated as mg/g dry weight.

Fruit hand firmness was determined daily during ripening using the following rating scale: 1, hard; 3, springy; 5, slightly soft; 7, soft (eating ripe); 9, very soft. Fruit were considered ripe when a firmness rating of 7 was recorded for 3 consecutive days. Objective firmness measurements were carried out for all fruit every second day by measuring fruit deformation (mm) under a 500 g weight applied for 30 s (Macnish *et al*. 1997). Fruit colour was visually assessed using the following scoring scale: 1, 100% green; 3, 75% green; 5, 50% green/yellow; 7, 75% yellow; 9, 100% yellow. The fruit were also weighed every second day to enable calculation of relative weight loss [% initial (at harvest) fresh weight].

Repeated measures ceased when all fruit in each treatment ripened (i.e. achieved a hand firmness score ≥7 for 3 days). Upon ripening, skin shrivelling was scored using the following scale: 1, none; 3, minor; 5, moderate; 7, excessive; 9, severe. Disease and physiological disorders were both rated subjectively using the same 1–9 scale.

Treatment effects on dry matter content (%), skin and flesh calcium concentration (mg/g dry weight) and weight loss (mg/g initial fresh weight . day) were evaluated by ANOVA using Minitab (Version 10). Means were separated using Tukey's multiple range test (*P* = 0.05). Days to ripen (shelf life), skin shrivelling, disease and physiological disorders, were analysed by the Kruskal–Wallis test.

Results and discussion

Fruit characteristics at harvest

Compared with unbagged control fruit, bagging 'Kensington Pride' mango fruit in paper or plastic bags during development had no effect (*P*>0.05) on either dry matter content (overall mean = 13.9 ± 0.52%, *n* = 90) or weight (overall mean = 367.7 ± 4.32 g, *n* = 180) at harvest. This result is similar to that reported by Joyce *et al*. (1997) for 'Sensation' mango bagged 49 days before harvest. In contrast, Johnson *et al*. (1994) found

Table 1. Calcium concentrations (mg/g dry weight) in skin and flesh tissue samples from unbagged (control), paper bagged or plastic bagged 'Kensington Pride' mango fruit which were treated 9, 25 and 41 days before harvest

Factor A (bagging) (n = 30), n.s.; factor B (skin/flesh) (n = 45), P<0.001; factor C (time) (n = 30), n.s.; interaction (A x B), n.s.; interaction (A x C), n.s.; interaction (B x C), n.s.; interaction (A x B x C), n.s.

Row or column means followed by the same letter are not significantly different at P = 0.05

Treatment	Skin	Flesh	Row means
No. of fruit (*n*)	5	5	10
9 days before harvest			
Unbagged	2.88	1.16	2.02a
Paper bag	3.22	0.81	2.02a
Plastic bag	3.15	0.69	1.92a
Column means (*n* = 15)	3.08a	0.89b	
25 days before harvest			
Unbagged	3.29	0.83	2.06a
Paper bag	3.95	1.16	2.55a
Plastic bag	2.73	1.23	1.98a
Column means (*n* = 15)	3.32a	1.07b	
41 days before harvest			
Unbagged	3.90	1.05	2.48a
Paper bag	3.44	0.84	2.14a
Plastic bag	3.01	0.71	1.86a
Column means (*n* = 15)	3.45a	0.87b	

that bagging 'Keitt' mango fruit 91–112 days before harvest increased dry matter accumulation by 2% relative to unbagged fruit. This difference in response between studies may be attributable to differences in the time of bagging and/or to varietal differences in response to bagging. Time of bagging did, however, influence dry matter accumulation by 'Kensington Pride' mango fruit. Fruit bagged with either paper or plastic bags 41 days before harvest had significantly (P<0.001) lower dry matter (13.2 ± 0.36%, n = 30) than those bagged 9 days before harvest (14.5 ± 0.67%, n = 30). Dry matter of those fruit bagged 25 days before harvest (13.9 ± 0.52%, n = 30) was not significantly (P>0.05) different from fruit bagged at either 41 or 9 days before harvest.

Bagging fruit with either paper or plastic bags significantly (P<0.001) reduced fruit skin blush, compared with unbagged fruit. The area of fruit skin blush on unbagged fruit was 4.10 ± 0.47% (n = 90) compared with 1.59 ± 0.30% (n = 90) and 2.12 ± 0.42% (n = 90) for fruit bagged with paper bags and plastic bags respectively. This result is in agreement with that of Hofman *et al*. (1997), who found that bagging 'Keitt' mango fruit with paper bags 86 or 92 days before harvest also reduced blush. Bagging fruit with plastic bags resulted in a significantly (P = 0.003) greater degree of skin blemish (brown scars similar to those on fruit affected by windrub) than was recorded for either unbagged or paper bagged fruit. The skin blemish score for fruit bagged with plastic was 2.83 ± 0.44 (n = 90), as compared with 1.88 ± 0.35 (n = 90) and 1.99 ± 0.38 (n = 90) for unbagged fruit and for fruit bagged with paper respectively. This result is contradictory to observations reported for 'Sensation' mangoes by Joyce *et al*. (1997). Once again, this difference between studies might be attributable to different varietal characteristics. Notionally, skin blemishes should be reduced by bagging due to avoidance of windrub and exclusion of microbes and insects (Homes 1984; Bentley and Viveros 1992). High humidity around fruit within plastic bags may perhaps have retarded formation of their cuticle, leading to an enhanced susceptibility to physical injury (Joyce *et al*. 1997).

Bagging 'Kensington Pride' mango fruit in either paper or plastic bags did not significantly (P>0.05) affect skin or flesh calcium concentrations (Table 1). However, there was a slight tendency for fruit bagged with plastic bags to have lower calcium concentrations than unbagged fruit, especially in fruit bagged 41 days before harvest. Skin calcium concentrations were about 2–3 times higher than those in the flesh, an observation similar to that reported earlier on 'Sensation' mango fruit (Joyce *et al*. 1997). It was expected that the calcium concentration in mango fruit bagged with plastic bags would be reduced because the fruit were bagged when smaller [as compared with the older (49 days before harvest) 'Sensation' fruit bagged by Joyce *et al*. (1997)], this being closer to when the majority of calcium accumulates (Bangerth 1979). However, the length of time for which the fruit were bagged did not significantly affect calcium concentration in the fruit.

Fruit characteristics during shelf life

Shelf life, as judged by days to ripen, was reduced significantly (P<0.001) as a result of bagging fruit with plastic bags. Unbagged mango fruit had a shelf life of 13.6 ± 0.73 days (n = 60), compared with 11.6 ± 0.63 days (n = 60) for fruit bagged with plastic bags. The shelf life of mango fruit bagged with paper bags (13.7 ± 0.36 days, n = 60) was not significantly different to that of unbagged fruit. Weight loss was significantly (P<0.001) increased by bagging fruit with plastic bags. Fruit bagged with plastic bags had an average weight

Table 2. Calcium concentration (mg/g dry weight) in skin and flesh tissue samples from seeded mango fruit and from nubbins (seedless fruit)

Factor A (fruit type) (n = 10), P = 0.029; factor B (skin/flesh) (n = 10), P<0.001; interaction (A x B), n.s.
Row or column means followed by the same letter are not significantly different at P = 0.05

Fruit type	Skin	Flesh	Row means
No. of fruit (n)	5	5	10
Seeded	1.67	0.58	1.12b
Nubbin	2.87	0.80	1.83a
Column means (n = 10)	2.27a	0.69b	

loss of 12.9 ± 0.71 mg/g.day (n = 60), compared with 7.36 ± 0.65 (n = 60) and 7.76 ± 0.36 mg/g.day (n = 60) for unbagged fruit and for fruit bagged with paper bags respectively. A similar reduction in shelf life and accelerated water loss of fruit bagged with plastic have been recorded for 'Sensation' mangoes (Joyce *et al*. 1997). It is possible that water-deficit-induced stress increases ethylene production by fruit, which may, in turn, initiate earlier ripening of climacteric fruits such as avocado, bananas and pears (Littmann 1972; Adato and Gazit 1974; Cutting *et al*. 1992).

Fruit characteristics at the end of shelf life

Skin shrivelling was significantly (P<0.001) more pronounced for fruit bagged with plastic bags, and became progressively more severe with longer bagging times. The skin shrivelling score for fruit bagged with plastic bags was 3.32 ± 0.39 (n = 60), compared with 1.29 ± 0.94 and 1.00 ± 0.01 for unbagged fruit and for fruit bagged with paper bags respectively. Similarly, skin shrivelling as a result of bagging 'Sensation' mangoes in plastic bags was reported by Joyce *et al*. (1997). There were no differences (P>0.05) in disease scores among the different treatments (data not shown). However, physiological disorders such as premature ripening and starchy tissue were significantly (P<0.001) reduced by bagging fruit with plastic bags. Physiological disorder scores for unbagged fruit and fruit bagged with paper bags were 2.43 ± 0.32 (n = 60) and 2.69 ± 0.43 (n = 60), respectively; as compared with 1.43 ± 0.15 (n = 60) for fruit bagged with plastic bags. This result was somewhat surprising, since it was initially anticipated that supposedly calcium-deficiency-related mango physiological disorders, such as soft-nose and spongy tissue, would be enhanced by bagging fruit with plastic bags.

Effects of seed presence versus absence

The presence or absence of the seed in otherwise apparently normal mature fruit had very little effect on fruit size (P>0.05). The fresh weights of seeded fruit and of nubbins were 141.0 ± 4.4 g (n = 11) and 134.8 ± 3.8 g (n = 33) respectively. However, dry matter was significantly (P = 0.003) higher in nubbins (15.4 ± 0.79%, n = 5), compared with seeded fruit (11.7 ± 0.41%, n = 5). The calcium concentrations in the skin and flesh of seeded mango fruit were significantly (P = 0.029) lower than those in nubbins (Table 2). This result was unexpected as increased seed number in multi-seeded fruits, such as apple, has been correlated with higher fruit calcium concentration (see Introduction). Higher dry matter content suggests that the nubbins had hung on the tree for a longer period (i.e. were more mature), which might account for their higher calcium concentrations. It is a common observation that nubbins abscise from the parent tree early in the course of their development. Accordingly, our data might be considered to be generally similar to those of Quinlan (1969), who found that, at the same point in time early in the season, shed apple fruit had higher calcium concentrations than retained fruit.

Conclusion

The commercial implication of this research is that bagging 'Kensington Pride' mango fruit within 40 days before harvest in order to reduce damage from insects or disease-causing organisms will not adversely affect calcium accumulation by developing fruits. However, as was found earlier with 'Sensation' mango fruit (Joyce *et al*. 1997), closed plastic bags should be avoided as their use can result in accelerated postharvest water loss and reduced shelf life. Further research is required to determine the temporal dynamics of calcium uptake by developing fruit.

Acknowledgments

The authors thank Bevan Bochman for the supply of fruit. Thanks also to Associate Professor David Simons, Mr Tony Shorter, Mrs Melinda Gosbee, Mrs Lyn Hall, Mrs Kathryn Raymont, Mr John Oweczkin and Ms Pakinee Akkarvessapong for technical assistance and/or advice. Financial support from ACIAR (Project 9313) is gratefully acknowledged.

References

Adato, I., and Gazit, S. (1974). Water-deficit stress, ethylene production, and ripening in avocado fruits. *Plant Physiology* **53**, 45–6.

Bangerth, F. (1976). A role for auxin transport inhibitors on the calcium content of artificially induced parthenocarpic fruits. *Physiologia Plantarum* **37**, 191–4.

Bangerth, F. (1979). Calcium-related physiological disorders of plants. *Annual Review of Phytopathology* **17**, 97–122.

Bentley, W. J., and Viveros, M. (1992). Brown-bagging Granny Smith apples on trees stops codling moth damage. *California Agriculture* **46**, 30–2.

Bramlage, W. J., Weis, S. A., and Greene, D. W. (1990). Observations on the relationships among seed number, fruit calcium and senescent breakdown in apples. *HortScience* **25**, 351–3.

Clark, C. J., and Smith, G. S. (1988). Seasonal accumulation of mineral nutrients by kiwifruit. 2. Fruit. *New Phytologist* **108**, 399–409.

Cull, B., and Lindsay, P. (1995). 'Fruit Growing in Warm Climates.' 3rd Edn. (Reed Books: Chatswood, NSW.)

Cutting, J. G. M., and Bower, J. P. (1990). Relationship between auxin transport and calcium allocation in vegetative and reproductive flushes in avocado. *Acta Horticulturae* **275**, 469–75.

Cutting, J. G. M., Wolstenholme, B. N., and Hardy, J. (1992). Increasing relative maturity alters the base mineral composition and phenolic concentration of avocado fruit. *Journal of Horticultural Science* **67**, 761–8.

Dietz, T. H., Thimma Raju, K. R., and Joshi, S. S. (1988). Structure and development of cuticle and lenticels in fruits of certain cultivars of mango. *Acta Horticulturae* **231**, 457–60.

Hofman, P. J., Smith, L. G., Joyce, D. C., Johnson, G. I., and Meiberg, G. F. (1997). Bagging of mango (*Mangifera indica* cv. 'Keitt') fruit influences fruit quality and mineral composition. *Postharvest Biology and Technology* **12**, 83–91.

Homes, J. (1984). Paper bags used for growing table grapes. *Horticultural News* **5**, 3–26.

Johnson, G. I., Campbell, T. P., Hofman, P. J., and Meiburg, G. F. (1994). Effect of mango fruit bagging on fruit quality. *In* 'Horticulture Postharvest Group Biennial Review 1994'. (Eds R. McLauchlan, G. Meiburg and J. Bagshaw.) pp. 27–8. (Department of Primary Industries: Brisbane, Qld.)

Joyce, D. C., Beasley, D. R., and Shorter, A. J. (1997). Effect of preharvest bagging on fruit calcium levels, and storage and ripening characteristics of 'Sensation' mangoes. *Australian Journal of Experimental Agriculture* **37**, 383–9.

Kitagawa, H., Manabe, K., and Esguerra, E. B. (1992). Bagging of fruit on the tree to control disease. *Acta Horticulturae* **321**, 871–5.

Littmann, M. D. (1972). Effect of water loss on the ripening of climacteric fruits. *Queensland Journal of Agriculture and Animal Sciences* **29**, 103–13.

Macnish, A. J., Joyce, D. C., and Shorter, A. J. (1997). A simple non-destructive method for laboratory evaluation of fruit firmness. *Australian Journal of Experimental Agriculture* **37**, 709–13.

Mead, A. J., and Winston, E. C. (1991). Description of the disorder 'stem-end cavity', possible causes and suggestions for reducing incidence in packing sheds. *Acta Horticulturae* **291**, 265–71.

Quinlan, J. D. (1969). Chemical composition of developing and shed fruits of Laxton's Fortune apple. *Journal of Horticultural Science* **44**, 97–106.

Received 11 April 1998, accepted 14 January 1999