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The effect of mechanical dehuskers on the quality of macadamia kernels when dehusking macadamia fruit at differing harvest moisture contents

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ABSTRACT

Dehusking to remove the fibrous husk of the macadamia fruit following abscission is an essential first step in postharvest handling of macadamia nuts. Commercial dehusking uses machines, causing trauma for nuts. Mechanical dehusking of macadamia fruit at “field” (mean harvest) moisture content causes shoulder damage but the effect on kernel quality of dehusking fruit that has dried while on the ground between harvest rounds to “low harvest” moisture content is not known. We dehusked macadamia fruit by hand and with two mechanical dehuskers at field moisture content (23%) and at low harvest moisture content (10-12%) after ambient drying for three weeks. After-roast-darkening (dark, reject kernels), shoulder damage and weight of pieces increased while whole kernel was reduced when dehusking at low harvest moisture content compared with dehusking at field moisture content. There were only minor differences between mechanical dehuskers for kernel damage and no difference between dehuskers for dark roasted kernel. Kernel quality of macadamia is more affected by slow, ambient drying than the type of dehusker used. Improving harvest management by reducing time between harvest rounds is more important to macadamia kernel quality than the type of dehusker used.

Key words: Macadamia; dehusking; whole kernel; shoulder damage; after-roast-darkening; delayed harvest
1. Introduction

*Macadamia integrifolia* Maiden and Betche, *M. tetraphylla* L.A.S. Johnson (Proteaceae) and their hybrids are cultivated for their edible kernels in Australia, Hawaii, South Africa and other countries such as Brazil, Kenya, Malawi and China (Trueman, 2013). Both species are indigenous to subtropical coastal rainforests of the east coast of Australia (Gross, 1995). The fibrous husk of freshly harvested macadamia fruit constitutes 40-45% of the fruit weight (Cavaletto, 1983).

Macadamia harvest management is critical for maintaining kernel quality. Macadamia fruit is usually harvested from the ground after natural abscission although Etaphon® can be used to enhance abscission when that is advantageous for harvest management (Richardson and Dawson, 1993; Trueman et al. 2002). The first step in postharvest processing is dehusking, the removal of the fibrous husk to release nuts (Mason and McConachie, 1994; Trueman et al., 2000; Walton and Wallace, 2005a). The mean harvest (“field”) moisture content of macadamia nuts can range from 25% down to 16% (wet basis) (Hansen and Gough, 1977; Wall and Gentry, 2007; Walton and Wallace, 2008). As these are means of nuts both freshly abscised and those which have been on the ground for up to five weeks, some nuts would be of much lower moisture content than 17%, e.g., 10-12% (“low harvest” moisture content). Dehusking is performed commercially by mechanical dehuskers, preferably within one day of harvesting (O’Hare et al., 2004). Many machines have been developed for dehusking, but despite the stresses
applied to the fruit during this essential operation there has been limited research on the effect of mechanical dehuskers on macadamia kernel quality.

Physical damage to kernels may result from postharvest handling of macadamias, such as shoulder damage, breakage into pieces, bruising, production of dust and excessive browning at roasting (Walton and Wallace, 2008, 2010). Mechanical dehuskers squeeze the fruit to remove the fibrous husk, e.g., a new dehusker was evaluated by Luan and Ling (1983) for dehusking efficiency and number of cracked nuts. Mechanical dehuskers cause 'shoulder damage' to the kernel when dehusking fruit at field moisture content (Walton and Wallace, 2004a) however, the effect on kernel quality of dehusking at low harvest moisture content (e.g. 10-12%) is not known, nor the effect on quality of dehusking different cultivars. Other studies have found that macadamia nuts at low and intermediate moisture contents (3%, 7% and 10%) are more susceptible to damage from postharvest handling such as shoulder damage, bruising and surface mottling (Walton and Wallace, 2008, 2010). Cellular damage in macadamia is associated with after-roast-darkening of kernels, a postharvest disorder whereby apparently normal kernels become excessively dark after roasting (Albertson et al., 2005, 2006).

There is limited information available on the effects of different dehuskers on kernel quality parameters other than shoulder damage, such as percentage of whole kernel recovered and breakage into pieces. Importantly, the effects of mechanical dehusking on roasting quality including after-roast-darkening have not been reported.

The aims of this study were to compare the effect of different mechanical dehuskers on kernel damage when dehusking at low harvest moisture content
and at field moisture content. We compared two mechanical dehuskers and used hand dehusking as a control. Because moisture content of nuts during postharvest handling has a critical impact on damage, we compared dehusking of macadamias (1) at low harvest moisture content (10%) after partial drying on the ground using two cultivars, HAES 344 and HAES 741; and (2) both immediately after harvest at field moisture content (23%) and at low harvest moisture content after partial drying on the ground using cultivar HAES 344 only. These cultivars are used because they are two of the most widely planted macadamias. Cultivar HAES 344 only was used for the second trial to reduce variables and simplify analysis. Partial drying on the ground simulates commercial practice when harvest is delayed and fruit may remain on the ground for extended periods. Our hypotheses are 1) that kernels from fruit mechanically dehusked at low harvest moisture content are more likely to be damaged than those dehusked at normal field moisture content and 2) that mechanical dehuskers cause damage to kernels, predisposing them to after-roast-darkening.

2. Material and methods

2.1. Effects of mechanical dehuskers on raw kernel quality

2.1.1. Experiment 1: effects of mechanical dehuskers when dehusking at low harvest moisture content

We compared the effect of two mechanical dehuskers and a hand dehusked control on the quality of raw macadamia kernel using fruit at low harvest moisture content (~10%). Hand dehusking does not put pressure on or squeeze the fruits and so it can be used as a control to test the effects of mechanical dehuskers. Fruit of cultivars HAES 344 and HAES 741 was
sampled from the ground at Warawee Plantation, Wolvi, South Eastern Queensland, Australia (26°9.63’S, 152°48.65’E). There were three treatments:

1) Hand dehusking, (control), using aviation snips to gently remove the husk;

2) Mechanical dehusking with a scroll-type mechanical dehusker, widely used in the macadamia industry, which employs rollers with metal spiral scrolls working fruit against spring loaded fingers and 3) Mechanical dehusking with an “Admac” dehusker, which squeezes fruit between an auger fitted with strips of rubber and an outer longitudinally-barred metal cage. All moisture contents are calculated on a wet basis.

A bulk sample was obtained from 10 trees and this sample was sub-sampled for 10 replicates of 50 fruit for each dehusker treatment. Fruit was dried partially at ambient outdoor temperature (~ 18 - 21°C max.) before dehusking by spreading the fruit in a single layer on a concrete slab. The slab received mild sunlight in the afternoon but was protected from rain by a roof. This was intended to simulate slow drying of fruit on the orchard floor post-abscission when harvest is delayed, to eliminate the confounding effect of rainfall and to produce nuts at low harvest moisture content. When nuts had dried to ~10% moisture content (approximately three weeks of drying) they were dehusked by the above three methods, then nuts dried to 3% moisture content for cracking as described in Walton and Wallace (2009). Kernels were assessed for whole kernel weight (whole kernel weight as % of sound kernel weight), shoulder damage (whole kernels with shoulder damage as % of whole kernel number), weight of pieces (as % weight of sound kernel), dustiness (dusty whole kernels as % of whole kernel number) and oiliness (oily whole kernels as % of whole kernel number). 'Sound kernel' refers to
kernels free from mould, insect damage, discolouration and immaturity.

‘Shoulder damage’ refers to torn areas of kernel in the apical (micropylar) hemisphere of the kernel that was formerly in contact with the white enamel region of the shell. A kernel was considered to have shoulder damage if an area of tissue greater than 3mm diameter was removed. Kernels with greater than one eighth missing were excluded from the whole kernel count. Pieces were smaller than halves, but with a diameter greater than 5mm. Pieces <5mm diameter were not recorded because of the small weights involved.

Dustiness refers to a visible dusty coating on the surface of the kernel that was confirmed by touch. Oiliness refers to a darker, ‘oily’ appearance of the nut than is normal. This was confirmed by rubbing the apparently oily surface gently on white paper; if the kernel left a mark on the paper the kernel was deemed oily.

2.1.2. Experiment 2: dehusking fruit at both field and low harvest moisture contents

We compared the effect of two mechanical dehuskers and a hand dehusked control on the kernel quality of both raw and roasted macadamia when dehusking at field and low harvest moisture contents. The three dehusker treatments for both moisture contents of this experiment were the same as for experiment 1: hand dehusking (control), a scroll type dehusker and an “Admac” dehusker.

Fruit of cultivar HAES 344 was sampled from the ground at Sahara Farms at Glasshouse Mountains, South Eastern Queensland (26°53.44’S, 152°56.16’E). There were 10 replicates of 50 fruit per dehusker treatment per moisture content. Fruit for the dehusker treatments at field moisture content
was dehusked immediately following harvest when the nut-in-shell moisture content was 23%. Fruit for the dehusker treatments at low harvest moisture content was dried for three weeks on the ground under a roof at ambient outdoor temperatures (~18 - 21°C max.) to ~12% (11.8%) nut moisture content to simulate slow drying of fruit on the orchard floor post-abscission, then dehusked. Following dehusking, nuts were dried to 3% moisture content before cracking. Kernel quality was assessed as described for experiment 1.

2.1.3. Statistical analysis, raw kernel

Parametric data for whole kernel, shoulder damage, weight of pieces, dustiness and oiliness were initially analysed by SPSS statistics (IBM, Chicago) using a factorial ANOVA with dehusker, cultivar and dehusker*cultivar as factors for Experiment 1, or dehusker, moisture content, and dehusker* moisture content as factors for Experiment 2. Due to significant interactions between factors in these experiments, all data were subsequently analysed using a series of one way ANOVAs with each cultivar and dehusker combination as treatments for experiment 1, and each moisture content and dehusker combination as treatments for experiment 2. Where significant differences were detected, means were compared using Duncan’s multiple range test.

2.2. Effects of mechanical dehuskers on roasted kernel quality

2.2.1. Roasting methods

An evaluation of the effect of mechanical dehusking at high and intermediate moisture contents on roasted kernel quality was conducted on kernels from Experiment 2. Ten whole kernels were selected at random from each replicate of all treatments. Samples were dried to 1.5% moisture content before
roasting (De La Cruz et al., 1966). Samples were air roasted in a Memmert
fan-forced laboratory oven (Memmert Gmbh & Co. KG, Schwabach,
Germany) for 20 min at 130°C. Roasted samples were examined for colour,
mottled colour and surface damage. The darker portion of the kernel (that is in
contact with the tannin layer of the shell before cracking) was not used to
determine colour and mottled colour as the darker surface tends to mask
colour changes due to roasting. However, for surface damage the whole of
the kernel was assessed. As a standard for colour evaluation, a Taubmans
Colour Concepts colour swatch No.44 (Taubman’s Paints, Regents Park,
Sydney, Australia) was used to grade kernels. The colours were assigned
ranks by comparison with the colour swatch as follows: Abbot White=1,
Annabelle=2, Pixie=3, Momento=4, Paxton=5, progressing from lightest to
darkest colour. For mottled colour and surface damage, kernels were ranked
from 1 to 3, representing minimal, moderate, and severe mottling respectively.
For surface damage kernels were ranked from 1 to 3, representing minimal,
moderate and severe surface damage respectively.

2.2.2. Statistical analysis, roasted kernel

Total kernels in each category for each replicate and treatment for colour,
mottled colour and surface damage were counted and converted to
percentages. For colour, rank 5 (very dark,) and rank 4 (dark kernels) colour
counts were combined because kernels in these two ranks are dark enough to
be rejected during commercial grading. Percentages for severe mottled colour
and severe surface damage (rank 3) were analysed for significant difference
as these were the only ranks with obvious visual loss of quality.
Data for rank 4 and 5 combined dark roasted kernels, rank 3 severe mottled
colour and rank 3 severe surface damage did not meet the assumptions for
parametric tests, therefore data were analysed by Kruskall-Wallis and Mann-
Whitney tests, and where significant difference ($P<0.05$) was found a Sidak-
Bonferroni correction factor was applied to determine the appropriate level of
significance (Abdi, 2010).

3. Results

3.1. Raw kernel

There was significant shoulder damage ($P<0.05$) from both mechanical
dehusker treatments for both cultivars compared with hand dehusking when
fruit was dehusked at low harvest nut moisture content of 10% (Fig. 1). There
was no difference between mechanical dehuskers for each cultivar. For
cultivar HAES 741 mechanical dehusking increased shoulder damage by ~
12% - 14% over hand dehusking (Fig. 1). The scroll dehusker caused more
shoulder damage to HAES 344 kernels than to HAES 741 kernels, but there
was no difference for the Admac dehusker (Fig. 1). Whole kernel weight,
weight of pieces, dustiness and oiliness were not affected by dehusking in
experiment 1.

Insert Fig. 1

There were significant differences between field moisture content (23%) and
low harvest moisture content (12%) dehusker treatments for whole kernel
(Fig. 2) and weight of pieces (Fig. 3A) ($P<0.05$). However there were no
differences for shoulder damage, oiliness and dustiness. There was a
significant reduction in whole kernel for the low harvest moisture content scroll
dehusker treatment compared with both mechanical dehuskers at field
moisture content (Fig. 2). However, there was no difference between
mechanical dehuskers when dehusking at the same moisture content (Fig. 2).
Weight of pieces increased significantly for all dehusking treatments including
hand dehusking when fruit was dehusked at low harvest moisture content
compared with dehusking at field moisture content (Fig. 3A). The Admac
dehusker generated significantly more pieces than the other treatments.

Insert Fig. 2 & 3

3.2. Roasted kernel
There were significantly more dark kernels for fruit dehusked at low harvest
moisture content (12%) compared with fruit dehusked at field moisture
content using all dehusking methods, including hand dehusking, and many
dark kernels (30 to 60%) were generated \( P<0.05 \), Fig. 3B). However, there
was no difference in dark kernels between the three dehusking methods when
dehusking at either field moisture content or at low harvest moisture content
(Fig. 3B). There were no significant differences in severe mottled colour and
severe surface damage.

4. Discussion
This study showed that dehusking macadamia fruit at low harvest moisture
content following slow, ambient drying on the ground can lead to heavy losses
from dark kernels at roasting, and significant reduction of whole kernel. In
addition, mechanical dehusking can cause significant mechanical damage to
raw kernel in the form of shoulder damage and kernel pieces when dehusking
fruit at low harvest moisture content (for example, 10% to 12%) compared to
dehusking fruit at field moisture content (for example, 20-23%). Specifically,
the scroll type dehusker caused significantly more loss of whole kernel, but
the Admac dehusker generated more pieces.

In commercial macadamia orchards fruit will dry partially while it is on the
ground after abscission and harvest is delayed (Walton and Wallace, 2009),
particularly if there is no rainfall during this time. It is important to harvest
macadamias frequently so that they are dehusked at as high moisture content
as possible to reduce quality loss. Shoulder damage can result from
dehusking at high moisture content (Walton and Wallace, 2005a), but these
results show shoulder damage can also result from dehusking fruit at low
harvest moisture content that is typical of harvest. These results emphasise
the importance of optimal and regular adjustment of mechanical dehuskers to
minimise this damage. Further, there may be justification for research into
improved macadamia dehuskers that cause less damage.

Whole kernel was reduced significantly when dehusking at low harvest
moisture content. The only previous report in the literature of reduction in
whole kernel is following delayed harvest (Walton and Wallace, 2009). The
kernel-breakage mechanism is unclear but appears to be related to reduced
moisture content. Lower moisture content during handling appears to weaken
the bond between the cotyledons of kernels, reducing whole kernel (Walton
and Wallace, 2005b; Walton et al., 2012).

Weight of pieces increased significantly compared with hand dehusking
for all treatments dehusked at low harvest moisture content, with the Admac
machine producing more pieces. Pieces were increased even for hand-
dehusked fruit. This suggests that handling fruit at around 10% moisture content causes damage to kernels even when they are handled with the utmost care. This may indicate some change in or even deterioration of tissue when at low harvest moisture content. Pieces were also increased after five weeks delayed harvest in a previous study (Walton and Wallace, 2009). Pieces are an indicator of surface damage of the kernel. These results emphasise that reduced raw kernel quality in terms of whole kernel, shoulder damage and weight of pieces can be expected when harvest is delayed and nuts are handled at low harvest moisture content. As for other nut crops such as almonds and walnuts, macadamias should be picked up from the orchard floor as soon as possible after abscission to preserve kernel quality (Mason and Wells, 1984; Kader and Thompson, 1992; Mason, 2000).

This study has shown that dehusking at a low harvest moisture content causes significant increase in the numbers of dark kernels at roasting. Dark kernels are only suitable for low-value oil production. After-roast-darkening increased in all dehusker treatments at low harvest moisture content in this study (including hand dehusking), demonstrating that mechanical dehusking was not the cause of dark kernels. These results confirm that delaying harvest leads to loss of both raw and roasted kernel quality (Walton and Wallace, 2009). Any delayed drying of macadamias in-shell such as delayed harvest or during storage on-farm leads to loss of kernel quality (Walton and Wallace 2011, 2013).

The period of slow drying before dehusking in this study can explain the mechanism causing dark kernels at roasting. The nut-in-shell began slow, ambient drying at 23% moisture content and remained at 12% moisture.
content after three weeks drying. Macadamia nut-in-shell should be dried on-farm to 10% over a period of no more than two weeks, then sent to a processor (Mason, 2000). The nuts in the study were above 12% moisture content for a large part of the three weeks of drying. Macadamias are an orthodox seed, tending to germinate immediately at maturity (Doijode, 2001). Macadamias can even begin germination while still hanging on the tree (Jones, 1939) so there can be enzyme-mediated biochemical changes in the seed during slow drying, such as conversion of sucrose to reducing sugars, preparing the seed for germination. After-roast-darkening is a result of the non-enzymatic Maillard Reaction in which reducing sugars such as glucose react with amino acid residues, usually during heating, to produce dark coloured compounds (Belitz et al., 2004; Albertson et al., 2005, 2006). In addition to enzymic activity, reducing sugars can be produced by hydrolysis of sucrose when there is sufficient water available, for example, sucrose levels of walnuts dropped by 22% at the beginning of storage, while glucose increased by 70% (Hadorn et al. 1981). The water available in the macadamia kernels during slow drying (23% reducing to 11.8%) was sufficient for some hydrolysis of the sucrose in macadamias to reducing sugars (Wall and Gentry, 2007). The time factor (three weeks of slow drying) is also an important consideration, providing time for the reactions to progress. Similarly, macadamia nut-in-shell remaining at moderately high moisture content (15%) two weeks after harvest following on-farm grading and storage produced significant numbers of dark kernels at roasting (Walton and Wallace, 2011). These factors explain why all dehusker treatments dehusked at low harvest moisture content after three weeks delay and slow drying, including the hand
dehusked control, produced significantly more dark kernels at roasting than
fruit dehusked at high moisture content (23%) immediately after harvest.

5. Conclusion

These experiments demonstrated that dehusking at low harvest moisture
content (10 – 12%) results in significant loss of macadamia kernel quality in
reduced whole kernel, shoulder damage and kernel breakage to pieces. In
addition, kernels from fruit dehusked at low harvest moisture content after a
period of slow drying developed significant after-roast-darkening. Fruit should
be harvested as soon as possible after abscission, preferably at intervals no
longer than three weeks (Walton and Wallace, 2009). Mechanical dehuskers
had some effects on kernel quality but did not cause after-roast-darkening.

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**Fig. 1.** Shoulder damage (%) for two macadamia cultivars dehusked at low harvest moisture content (10%) using three dehusking methods. Means with different letters are significantly different (Duncans Multiple Range Test, $P < 0.05$). Hand = hand dehusking; Scroll = scroll type mechanical dehusker; Admac = Admac mechanical dehusker.

**Fig. 2.** Percent weight of whole kernel weight for 3 dehusking methods for macadamia fruit of cultivar HAES 344 at field moisture content (23%), and low harvest moisture content (12%). Means with different letters are significantly different (Duncans Multiple Range Test, $P<0.05$). Hand = hand dehusking; Scroll = scroll type mechanical dehusker; Admac = Admac mechanical dehusker.
Fig. 3. Weight of pieces and dark kernels at roasting for macadamia fruit dehusked at field moisture content (23%) and at lower moisture content (12%). Means with different letters are significantly different ($P < 0.05$). A, ANOVA, Duncans Multiple Range Test; B, Kruskall-Wallis test followed by Mann-Whitney U tests with a Sidak-Bonferroni correction factor. Hand = hand dehusking; Scroll = scroll type mechanical dehusker; Admac = Admac mechanical dehusker.