The effect of water, brine and ethanol flotation on the quality and shelf life of macadamia kernels
2. Kernel pieces

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Raw macadamia kernel pieces were immersed in water (specific gravity 1.00 g/cm³), brine (SG 1.02 g/cm³) or ethanol solution (SG 0.97 g/cm³) for 30 or 60 s, then re-dried to below 1.5% moisture (wet basis) and stored under vacuum for 0, 4 and 12 months. Flotation in water had no effect on the quality or shelf life of the kernel pieces over 12 months storage, as measured by sensory evaluation of the kernels and chemical analysis of the kernel oil. Immersion in a salt solution caused unacceptable changes in quality during storage, increasing as storage time increased. Flotation in dilute ethanol also caused unacceptable quality changes during storage. Therefore, only flotation of macadamia kernel pieces in water can be recommended for commercial operations. Microbiological concerns with such a process still need to be addressed.

Previous research has shown that flotation in water was effective in grading whole macadamia kernels, and there was no adverse effect on their quality or shelf life as long as the kernels were rapidly re-dried to 1.5% kernel moisture content after flotation (Ross & others 2002).

The use of specific gravity (SG) may also be effective for sorting and separating macadamia kernels and kernel pieces from shells following cracking (Liang 1977, Maree 1998 pers comm). This aspect of the flotation process is also of interest to processors as removal of kernel from shell after cracking using current practices is time consuming and inefficient. Recovery of the maximum amount of saleable product is extremely important with a high value commodity such as macadamia nuts.

Flotation separation is relatively fast and simple and has been shown to improve recovery of kernel pieces (Liang 1977, Mason & McConachie 1994). Even though water flotation had no effect on the quality or shelf life of whole kernels, the greater surface area to volume ratio of pieces warranted a separate investigation into this style of product.

Therefore, the objectives of this study were to assess the impact of the water flotation on the shelf life of raw *Macadamia integrifolia* kernel pieces. Chemical stability of the kernel oil and sensory descriptors of the kernel were measured as indices of rancidity and eating quality.

Materials and methods

The materials and methods and statistical design used for this research are identical to those used by Ross & others (2002), except *M. integrifolia* kernel pieces (Style 4) were used for all treatments. The particle size of these pieces ranged from 10–13 mm.

Results and discussion

Moisture uptake

The initial moisture content of the pieces was 0.6% wet basis. After flotation in water for 30 and 60 s, the moisture content increased to 2.76% and 2.90% respectively. In a commercial situation, re-drying to a moisture content of <1.5% would be essential to maintain quality. Visual observations during flotation showed that much shell and kernel dust were washed from the pieces and left suspended in the solution.

Sensory evaluation

Flotation in water: Sensory evaluations of the macadamia kernel pieces immersed in water and stored for 0, 4 and 12 months are shown in Table 1.

Immersing macadamia kernel pieces in water had a negligible effect on the sensory characteristics of the kernel pieces. A significant decrease ($P<0.05$) in hardness occurred for kernel pieces dipped for 30 s and stored for 12 months compared to pieces not dipped. There was also a significant ($P<0.05$) decrease in 'other flavour' between pieces dipped for 30 s and those dipped for 60 s. There was no other significant treatment effect on the sensory characteristics.

These results indicate that grading macadamia kernel pieces in water (SG = 1.00) would not affect their quality or shelf life provided the conditions were controlled so that the residence time in the water was minimal and that the pieces were rapidly re-dried to below 1.5% moisture content (wet basis). However, this project did not investigate the microbiological aspects of the flotation process and previous work has indicated that this is a potential problem unless the solution is changed regularly or treated to reduce the level of contamination (Luttig & others 1998). Microbial contamination is more likely in separating kernel pieces than whole kernels because of the smaller particle size as well as more macadamia dust and fines being present.

Flotation in salt solution: Sensory evaluations of the macadamia kernel pieces dipped in the salt solution and stored for 0, 4 and 12 months are shown in Table 2.

Macadamia kernel pieces showed a significant increase ($P<0.05$) in 'other flavour' after flotation in the salt solution for both 30 s and 60 s. This was probably due to absorption of salt, especially since the pieces were not rinsed after dipping. There were no other significant treatment effects for unstored kernel pieces.

Macadamia kernel pieces immersed in the salt solution for 30 and 60 s and stored for four months experienced a significant decrease ($P<0.05$) in macadamia flavour, compared to pieces not dipped. This was also probably due to absorption of salt from the flotation solution masking the characteristic macadamia flavour in the unrinsed kernel pieces. There was also a significant decrease ($P<0.05$) in

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overall quality between undipped pieces and those that had been dipped for 30 s, but no significant difference in overall quality between the undipped pieces and those dipped for 60 s.

Macadamia kernel pieces immersed in the salt solution and stored for 12 months underwent significant changes ($P<0.05$) in hardness, macadamia flavour, 'other flavour', rancidity and overall quality. The kernel pieces were softer and had less characteristic macadamia flavour when dipped for 30 and 60 s compared to undipped pieces. Kernel pieces dipped for 30 s were more rancid and had a lower overall quality rating compared to undipped pieces, but there was no difference between kernel pieces dipped for 60 s and the undipped pieces. The 'other flavour' of kernel pieces dipped for 30 s was greater than those dipped for 60 s, but neither flotation time resulted in a significantly increase ($P<0.05$) in the 'other flavour' rating compared with the undipped pieces.

These results indicate that dipping macadamia kernel pieces in a salt solution caused unacceptable changes in quality during storage and the extent of the changes increased as storage time increased. Some of these effects could be minimised if the kernel pieces were rinsed after flotation. However, the increased level of rancidity is a cause for concern. No increase in rancidity was recorded for any treatments associated with flotation of whole macadamia kernels (Ross & others 2002). The increase in rancidity of the kernel pieces is possibly due to the larger exposed surface area compared with whole kernels.

Flotation in ethanol solution: Sensory evaluations of the macadamia kernel pieces dipped in the ethanol solution and stored for 0, 4 and 12 months are shown in Table 3.

There was no effect of flotation in ethanol solution or flotation time on the sensory characteristics of unstored macadamia kernel pieces. However, the hardness, macadamia flavour and overall quality ratings of macadamia pieces dipped in the ethanol solution for 30 and 60 s and stored for 4 months were significantly ($P<0.05$) lower than those of the undipped kernel pieces. Rancidity of the kernel pieces was not affected

Table 1. Sensory evaluation of raw macadamia pieces immersed in water for 0, 30 and 60 s

Dipping time(s)	Hardness	Macadamia flavour	Other flavour	Rancidity	Sweetness	Overall quality
UNSTORED	NS	NS	*	NS	NS	NS
0	54.7	56.7	14.3 a	6.6	19.6	60.8
30	53.0	53.3	15.5 a	8.6	18.8	57.2
60	53.3	53.0	16.0 a	5.7	18.4	55.9
LSD	3.0	7.1	6.6	4.7	6.8	8.3
STORED 4 MONTHS	*	*	NS	NS	NS	*
0	56.7 a	58.9 a	17.3	3.1	20.7	65.3 a
30	55.5 a	57.9 a	13.7	5.9	21.2	65.1 a
60	56.3 a	57.8 a	16.5	3.3	21.1	64.7 a
LSD	1.6	3.4	5.2	3.4	2.4	4.2
STORED 12 MONTHS	*	*	*	*	NS	*
0	57.6 a	57.0 a	16.4 ab	11.2 a	19.7	59.4 a
30	55.3 b	53.9 a	18.0 a	13.6 a	21.9	56.7 a
60	56.8 ab	55.1 a	13.5 b	11.5 a	19.7	59.1 a
LSD	2.0	4.7	4.3	6.6	3.5	4.9

*ANOVA significant ($P<0.05$)
NS ANOVA not significant ($P>0.05$). LSD's are presented as a measure of variability and are also used for pairwise comparisons.
All sensory scores are made according to a 0-100 scale in which 0 is the lowest rating and 100 is the highest rating.
Values within a column followed by the same letter are not significantly different ($P>0.05$).

Table 2. Sensory evaluation of raw macadamia pieces immersed in salt solution for 0, 30 and 60 s

Dipping time(s)	Hardness	Macadamia flavour	Other flavour	Rancidity	Sweetness	Overall quality
UNSTORED	NS	NS	*	NS	NS	NS
0	54.7	56.7	14.3 a	6.6	19.6	60.8
30	50.3	48.2	24.5 b	12.0	12.3	50.2
60	52.8	51.3	23.4 b	6.8	11.2	56.2
LSD	3.0	7.1	6.6	4.7	6.8	8.3
STORED 4 MONTHS	*	*	NS	NS	NS	*
0	56.7 a	59.0 a	17.3	3.1	20.7	65.3 a
30	55.2 a	56.8 b	17.0	5.3	18.3	62.2 b
60	55.2 a	56.4 b	18.9	6.2	20.3	63.6 ab
LSD	1.6	3.4	5.2	3.4	2.4	4.2
STORED 12 MONTHS	*	*	*	*	NS	*
0	57.6 a	57.0 a	16.4 ab	11.2 a	19.7	59.4 a
30	55.2 b	49.1 b	19.9 b	19.9 b	19.3	51.4 b
60	54.8 b	49.8 b	13.8 a	13.8 ab	18.2	54.7 ab
LSD	2.0	4.7	4.3	6.6.	3.5	4.9

*ANOVA significant ($P<0.05$)
NS ANOVA not significant ($P>0.05$). LSD's are presented as a measure of variability and are also used for pairwise comparisons.
All sensory scores are made according to a 0--100 scale in which 0 is the lowest rating and 100 is the highest rating.
Values within a column followed by the same letter are not significantly different ($P>0.05$).

after flotation in ethanol solution and storage for 4 months.

Kernel pieces immersed in the ethanol solution and stored for 12 months were softer, had less macadamia flavour, more other flavour, greater rancidity and had lower overall quality than undipped kernel pieces. This result is similar to the effect of the salt solution described above in that kernel pieces immersed in ethanol were more rancid than undipped kernel pieces. However, whole macadamia kernels dipped in ethanol solution and stored for 12 months did not show an increase in rancidity (Ross & others 2002). This again highlights the adverse effect that the greater surface area of kernel pieces seems to have on stability and shelf life.

Overall, these results confirm those obtained for whole macadamia kernels (Ross & others 2002) and support the conclusion that ethanol solutions should not be used in flotation grading of macadamia kernels.

Chemical analysis

Free fatty acids: The free fatty acid contents of the oils extracted from kernel pieces immersed in the various solutions and stored for 0, 4 and 12 months are shown in Table 4.

There was no significant effect ($P>0.05$) of flotation solution or time on the free fatty acid content of the oil from the kernel pieces, except for unstored kernels dipped in ethanol solution. In this treatment, kernel pieces dipped for 30 and 60 s had significantly higher ($P<0.05$) levels of free fatty acids than the undipped pieces. However, the actual levels were low and in all cases within the acceptable range (0.10-0.30% oleic acid) for high quality oil (McConachie 1996). The fact that free fatty acid levels remained low throughout this trial indicates that as long as the kernels are rapidly re-dried to below 1.5% kernel moisture content, there is little likelihood of hydrolysis occurring.

There was also an obvious increase in free fatty acid content across all treatments with respect to storage time, indicating that storage had a greater effect on hydrolysis than any of the flotation treatments. A similar result was observed for whole macadamia kernels (Ross & others 2002).

Peroxide value: The peroxide values of the oils extracted from kernel pieces immersed in the various solutions and stored for 0, 4 and 12 months are shown in Table 5.

There was no significant effect ($P>0.05$) of flotation solution or time on the peroxide value of the oil from the kernel pieces except for those dipped in water and stored for 12 months, where the peroxide values of kernel pieces dipped in water for 30 and 60 s were significantly ($P<0.05$) higher than those of undipped kernel pieces, indicating a higher level of oxidative rancidity. However, the sensory ratings for rancidity do not support this finding. In most cases the peroxide values were below the limiting peroxide value (6.0 meq peroxide kg^{-1} oil) for high quality macadamia oil (McConachie 1996).

There was also an increase in peroxide value across all treatments with respect to storage time, indicating that storage had a greater effect on oxidative rancidity development than any of the flotation treatments.

Colour measurement: The objective colour (L values) of kernels from all treatments are shown in Table 6. There was no significant ($P>0.05$) effect of any flotation treatment on the objective colour measurements. However, visual assessment of the kernel pieces did indicate that flotation removed much of the small pieces of shell and kernel dust resulting from the cracking process.

This result is in contrast to another study that found that dipping kernels for 1, 2 and 3 minutes in a range of solutions increased the L value and therefore improved the appearance of the kernels (Yow 1992).

Conclusions

Immersing macadamia kernel pieces in water as part of a flotation separation process appears to have little effect on quality or shelf life. While moisture was absorbed, it was easily removed by subsequent re-drying. This result indicates that macadamia kernel pieces could be separated into two grades (SG<1.00 and SG>1.00) provided the residence time in the water was kept to a minimum and they were re-dried rapidly to below 1.5% moisture (wet basis) after separation. Future work should investigate microbiological aspects of the process, including the opportunity to use the grading step as part of an overall strategy for microbiological control. The effect of the flotation process on the quality and shelf life of roasted kernels should also be investigated.

Immersing macadamia kernel pieces in a salt solution caused unacceptable changes in their quality during storage and the extent of the changes increased as storage time increased. While some of these effects could be minimised if

Table 3. Sensory evaluation of raw macadamia pieces immersed in ethanol solution for 0, 30 and 60 s

Dipping time(s)	Hardness	Macadamia flavour	Other flavour	Rancidity	Sweetness	Overall quality
UNSTORED	NS	NS	*	NS	NS	NS
0	54.7	56.7	14.3 a	6.6	19.6	60.8
30	52.1	52.2	16.6 a	7.4	16.9	54.5
60	51.7	53.0	15.7 a	6.4	18.7	56.8
LSD	3.0	7.1	6.6	4.7	6.8	8.3
STORED 4 MONTHS	*	*	NS	NS	NS	*
0	56.7 a	58.9 a	17.3	3.1	20.7	65.3 a
30	54.6 b	53.4 b	20.6	5.4	19.2	60.4 b
60	53.3 b	54.4 b	19.6	7.1	19.3	59.7 b
LSD	1.6	3.4	5.2	3.4	2.4	4.2
STORED 12 MONTHS	*	*	*	*	NS	*
0	57.6 a	57.0 a	16.4 a	11.2 a	19.7	59.4 a
30	57.0 a	47.1 b	22.4 b	20.1 b	21.5	51.6 b
60	54.9 b	46.5 b	18.4 ab	24.8 b	17.3	50.0 b
LSD	2.0	4.7	4.3	6.6	3.5	4.9

*ANOVA significant ($P<0.05$)
NS ANOVA not significant ($P>0.05$). LSD's are presented as a measure of variability and are also used for pairwise comparisons.
All sensory scores are made according to a 0-100 scale in which 0 is the lowest rating and 100 is the highest rating.
Values within a column followed by the same letter are not significantly different ($P>0.05$).

the kernel pieces were rinsed after flotation, the increased level of rancidity is a cause for concern and indicates that dipping macadamia pieces in a salt solution should not be recommended.

Immersing macadamia kernel pieces in ethanol as part of a commercial grading system should also not be recommended owing to unacceptable quality changes during storage.

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Table 4. Free fatty acid content of raw macadamia pieces immersed in solutions for 0, 30 and 60 s and stored for 0, 4 and 12 months

Dipping time (s)	Free fatty acid content (% oleic acid)								
	Water flotation			Salt flotation			Ethanol flotation		
	unstored	4 months	12 months	unstored	4 months	12 months	unstored	4 months	12 months
	*	NS	NS	*	NS	NS	*	NS	NS
0	0.041 a	0.109	0.183	0.041 a	0.109	0.183	0.041 a	0.109	0.183
30	0.039 a	0.112	0.197	0.039 a	0.094	0.157	0.044 b	0.096	0.169
60	0.039 a	0.141	0.190	0.039 a	0.092	0.159	0.044 b	0.106	0.179
LSD	0.003	0.032	0.029	0.003	0.032	0.029	0.003	0.032	0.029

* ANOVA significant (P<0.05)
NS ANOVA not significant (P>0.05). LSD's are presented as a measure of variability and are also used for pairwise comparisons.
Values within a column followed by the same letter are not significantly different (P>0.05).

Table 5. Peroxide value of raw macadamia pieces immersed in solutions for 0, 30 and 60 s and stored for 0, 4 and 12 months

Dipping time (s)	Peroxide value (meq peroxide kg^{-1} oil)								
	Water flotation			Salt flotation			Ethanol flotation		
	unstored	4 months	12 months	unstored	4 months	12 months	unstored	4 months	12 months
	NS	NS	*	NS	NS	*	NS	NS	*
0	2.76	1.86	3.89 a	2.76	1.86	3.89 a	2.76	1.86	3.89 a
30	2.47	1.13	5.77 b	2.63	2.29	5.01 a	2.83	1.84	7.11 a
60	2.6	1.26	6.74 b	2.9	2.45	4.99 a	2.53	2.43	7.32 a
LSD	0.38	1.00	1.58	0.38	1.00	1.58	0.38	1.00	1.58

* ANOVA significant (P<0.05)
NS ANOVA not significant (P>0.05). LSD's are presented as a measure of variability and are also used for pairwise comparisons.
Values within a column followed by the same letter are not significantly different (P>0.05).

Table 6. Objective colour of raw macadamia pieces immersed in solutions for 0, 30 and 60 s and stored for 0, 4 and 12 months

Dipping time (s)	Colour (L value)								
	Water flotation			Salt flotation			Ethanol flotation		
	unstored	4 months	12 months	unstored	4 months	12 months	unstored	4 months	12 months
	NS	NS	NS	NS	NS	NS	NS	NS	NS
0	72.7	59.2	57.9	72.7	59.2	59.2	72.7	59.2	59.2
30	72.0	57.4	50.1	69.7	59.1	53.7	73.1	61.9	62.2
60	73.6	57.8	57.7	72.2	57.9	54.3	70.3	59.6	63.5
LSD	2.4	9.4	13.3	2.5	9.4	13.3	2.5	9.4	13.3

* ANOVA significant (P<0.05)
NS ANOVA not significant (P>0.05). LSD's are presented as a measure of variability and are also used for pairwise comparisons.
Values within a column followed by the same letter are not significantly different (P>0.05).