The effect of water, brine and ethanol flotation on the quality and shelf life of macadamia kernels 1. Whole kernels

A.I. Ross, R.L. Mason, S. Nottingham, S. Keilar and T. Kowitz.

Whole macadamia kernels were immersed in water (specific gravity 1.00 g/cm³), brine (SG 1.02 g/cm³) and ethanol solution (SG 0.97 g/cm³) for 30 or 60 s, re-dried to 1.0 – 1.5% moisture (wet basis) and stored under vacuum for 0, 4 and 12 months. Immersion in water had no effect on the quality or shelf life of kernels, as measured by sensory evaluation and analysis of the kernel oil. Immersion in brine and ethanol solutions changed the flavour of kernels, but had no effect on shelf life or kernel oil stability over 12 months storage. Water flotation to separate kernels based on differences in oil content is therefore feasible, but microbiological concerns need to be investigated.

Mature macadamia (*Macadamia integrifolia*) nuts contain up to 75% oil by weight, which is the highest oil content of any nut (Mason & McConachie 1994). In terms of eating quality, the oil content of macadamia kernels is the single most influential factor, and therefore the kernels may be graded into classes of eating quality based on the amount of oil that each kernel contains.

Grading operations relating to oil content of nuts have primarily been based on differences in specific gravity (SG) and such systems are by no means a recent development. Early studies determined that there was a high correlation between the specific gravity of the kernels and the amount of oil that they contained (Ripperton & others 1938). Later research further demonstrated the relationship between specific gravity of raw kernels and the eating quality of roasted kernels, thereby justifying the specific gravity system as an index of kernel quality (Mason & Wills 1983). The use of specific gravity has also proven effective for sorting and separating macadamia kernels from shells following cracking (Liang 1977).

Flotation in water, salt or ethanol solutions (of fixed SG) is the physical process through which macadamia kernels and shells are separated and/or graded (Liang 1977, Farmer & Cavaletto 1983, Mason & Wills 1983). The use of solutions of varying SG based on water, salt or ethanol, enables effective separation of kernels with different oil contents. However, commercially only water and salt solutions are used to separate and grade macadamia kernels. This method is relatively fast and simple, yet still effective in grading/separating; it improves recovery of kernel pieces and may also exert a cleaning effect (Liang 1977, Mason & McConachie 1994).

The Australian macadamia industry uses its reputation for producing a high quality product as a marketing advantage over other nations which have access to cheaper labour. However, despite the greater control over quality that the flotation process would provide, macadamia processors in Australia are reluctant to implement flotation as a method of grading. Concerns for the reliability of SG as a guide to quality as well as the uncertain effect of water flotation on the storage stability of kernels have impeded acceptance of the process by the Australian industry (Mason & Wills 1983, Luttig & others 1998). However, flotation grading is conducted on a commercial basis in countries such as Costa Rica and South Africa (Lee 1998 pers comm).

Studies in Hawaii have shown that immersing kernels in brine not only causes them to absorb moisture, but also causes slight flavour deterioration during extended storage (Liang 1977, Farmer & Cavaletto 1983). Investigations in South Africa have indicated that wet processed nuts become rancid faster than those that are dry processed (Luttig & others 1998). However, rancidity measurements were based on oxidative stability alone, and no sensory evaluation was performed to relate rancidity levels to consumer acceptance.

In response to concerns within the Australian macadamia industry, the objectives of this study were to assess the impact of water, brine and ethanol solution flotation on the shelf life of raw *M. integrifolia* whole kernels. Chemical stability of the kernel oil and sensory descriptors of the kernel were measured as indices of rancidity and eating quality.

Materials and methods

Bulk quantities (20 kg) of *M. integrifolia* whole kernels were purchased from a local supplier. A representative sample (2 g) was taken in triplicate, and the moisture content determined using a modified Association of Official Analytical Chemists (AOAC) Method 40.1.04 (Hilrich 1990), operating the vacuum oven at 75°C and -75 kPa pressure until constant mass was reached.

Three solutions (10 L each) of controlled SG were prepared and contained in stainless steel buckets for flotation of the kernels. Solution 1 was tap water (SG 1.00 g/cm³). Solution 2 was made by adding 285 g sodium chloride to 10 L of tap water (SG 1.02 g/cm³). Solution 3 was made by adding 1973 g of 95% ethanol

Richard Mason (corresponding author) is Associate Professor, Food Science and Technology and Alexander Ross, Steven Keilar and Timothy Kowitz are students, at School of Land and Food Sciences, The University of Queensland, Gatton, Queensland 4343, Australia. Stephen Nottingham is a sensory specialist at The Centre for Food Technology, Queensland Department of Primary Industries, 19 Hercules Street, Hamilton, Queensland 4007, Australia

to 10 L tap water (SG 0.97 g/cm³). The specific gravity of each solution was measured using a hydrometer and adjusted if necessary. The temperature of each solution was maintained at 22°C.

The effects of immersing the kernels in each of the three solutions were evaluated at each of three dipping times (0, 30 and 60 s). Kernels were immersed and withdrawn from each solution using a wire mesh basket. No attempt was made to separate kernels of different specific gravity. The kernels were not rinsed following flotation, in order to simulate a worst-case scenario. After surface moisture had been removed by means of an electric hair dryer, all kernels were re-dried to 1.0 – 1.5% moisture (wet basis) in an oven at 40°C and atmospheric pressure.

The amount of moisture absorbed by kernels immersed in water was measured by taking a representative sample (25 – 30 g) after removal of surface moisture, and determining moisture content as previously described.

After re-drying, each treatment was divided into three equal parts (240 g) which were packed into lacquered cans and sealed under a partial vacuum of -50 kPa for assessment unstored and after 4 and 12 months storage under ambient conditions. A partial vacuum was used so that some oxygen was present to enable oxidative changes to occur and so simulate a worst-case scenario.

Oil extraction

The oil was extracted from the macadamia kernels by cold pressing. Samples were ground in a stainless steel coffee grinder, wrapped in two-ply Chinese silk and inserted into a stainless steel cylinder followed by a rigid plastic plunger. The samples were then cold pressed within the cylinder using a hand operated hydraulic Carver laboratory press for 15 minutes to a maximum pressure of 70 000 kPa. Expressed oil, clarified as it passed through the two-ply silk and small holes in the stainless steel cylinder, was collected in a small plastic vessel. New silk was used for each sample. Oil was then transferred into McCartney bottles and frozen at -20°C until analysed.

Oil samples were thawed immediately prior to chemical analysis. Peroxide value (PV) was determined using the AOAC Official Method 965.33 (Cunniff 1995), except that titrations were performed using 0.01N $Na_2S_2O_3$ in a microburette instead of the stated 0.1N $Na_2S_2O_3$. Free fatty acid (FFA) content was measured using the AOAC Official Method 940.28 (Cunniff 1995), except that oil was titrated with 0.1N NaOH in a microburette, instead of the specified 0.25N NaOH. All chemical analyses were performed in triplicate.

Colour measurement of kernels

The colour of kernels from each treatment was assessed using a Minolta Chroma Meter CR-200. Only the L value was measured as this gives an indication of the brightness of the kernels, the aspect most likely to be affected by any cleaning effect of flotation. All measurements were done in triplicate across the surface of five kernels selected at random from each sample.

Sensory evaluation of kernels

A panel of 12 trained macadamia tasters was used to assess hardness, characteristic macadamia flavour intensity, rancid flavour intensity, 'other flavour' intensity, sweetness and overall quality of kernels from each treatment. Sensory attributes were rated on a 100 point graphic line scale on which 0 was the lowest rating and 100 the highest, using a standard rating procedure (Standards Association of Australia 1998). Tasters were encouraged to make comments on any sample where relevant. Tasting sessions were conducted once a week with three samples presented at each session and five sessions conducted each day. Data was collected using an integrated sensory software system (Compusense 4.3, Compusense Inc., Canada). Tasters sat in individual booths that were illuminated with white light (daylight equivalent), and purified water at room temperature was freely available for palate cleansing.

Three different batches of nuts from the same commercial supplier were considered as blocks. Sensory analysis samples were presented three at a time according to a partially balanced incomplete block design. The mean scores from the 12 panellists were analysed as a three (solutions) by two immersions (30 s and 60 s) factorial plus control (undipped) at each storage time.

Chemical analysis data were also statistically analysed using the model above.

Where a significant ($P<0.05$) F ratio was found in the analysis of variance (ANOVA) then pairwise comparisons were made using Fishers LSD.

Results and discussion

Moisture uptake

The initial moisture content of the whole kernels was 0.68% (wet basis). After dipping in water for 30 s and 60 s, the moisture content increased to 2.13% and 2.34% respectively. In a commercial situation, re-drying to a moisture content of <1.5% would be essential to maintain quality. This practice is currently part of the commercial operations in South Africa (Lee 1998 pers comm).

Visual observations during flotation showed that much shell and kernel dust were washed from the nuts and left suspended in the flotation solution.

Sensory evaluation

Flotation in water: Sensory evaluations of the whole raw macadamia kernels immersed in water and stored for 0, 4 and 12 months are shown in Table 1. When whole raw macadamia kernels were immersed in water for up to 60 s there was little effect on the quality of the kernels initially or at either of the storage times.

However, there was an obvious effect of storage on quality not influenced by the flotation control since the control also decreased in quality with time. The only parameters affected in the unstored nuts were hardness and sweetness. While these changes were significant ($P<0.05$), in practical terms they were small. There were no significant effects ($P>0.05$) of the water flotation on the quality of whole macadamia kernels stored for either 4 months or 12 months.

These results indicate that flotation in water has a minimal effect on the quality and shelf life of raw macadamia kernels. Grading of macadamia kernels on the basis of specific gravity (1.00) could be performed provided the residence time in the water was minimal and the kernels were rapidly re-dried to below 1.5% kernel moisture content (wet basis).

It should be noted that this project did not investigate the microbiological aspects of the flotation process, and previous work indicates that this is a potential problem unless the solution is changed regularly or treated to reduce the level of contamination (Luttig & others 1998).

Flotation in salt solution: Sensory evaluations of the whole macadamia kernels immersed in the salt solution and stored for 0, 4 and 12 months are shown in Table 2.

Whole macadamia kernels immersed in the salt solution and not stored showed a significant decrease in hardness and macadamia flavour at both flotation times ($P<0.05$) compared to the undipped kernels. Overall quality was not affected by flotation in the salt solution for 30 s but was rated significantly lower ($P<0.05$) for kernels immersed for 60 s than for undipped kernels. 'Other flavour' was significantly higher ($P<0.05$) for kernels dipped for 30 s and 60 s compared to the undipped control. There was no significant effect ($P>0.05$) of flotation in the salt solution on either rancidity or sweetness of the unstored kernels. Kernels dipped in the salt solution and stored for 4 months showed similar results to the kernels not stored except that the overall quality of kernels immersed for 30 s was significantly lower ($P<0.05$) than that of the undipped

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

Dipping time(s)	Hardness	Macadamia flavour	Other flavour	Rancidity	Sweetness	Overall quality
UNSTORED	*	*	*	NS	*	*
0	59.7 a	61.7 a	8.0 a	5.1	16.2 a	67.3 a
30	53.7 b	59.4 a	6.5 a	4.7	21.5 b	63.4 a
60	55.7 b	60.0 a	10.5 a	4.2	17.1 a	65.8 a
LSD	3.4	3.4	5.1	3.8	4.0	5.3
STORED 4 MONTHS	NS	*	*	NS	NS	*
0	58.1	56.7 a	14.2 a	5.9	17.1	63.5 a
30	57.5	58.0 a	11.5 a	4.9	17.6	64.6 a
60	57.3	53.9 a	15.4 a	5.5	16.0	61.3 a
LSD	2.2	4.2	6.8	4.5	3.1	4.4
STORED 12 MONTHS	NS	NS	NS	NS	NS	*
0	59.8	47.3	25.1	25.4	17.4	48.7 a
30	58.0	43.5	27.8	31.6	17.8	44.4 a
60	57.1	44.3	25.9	30.7	14.1	44.3 a
LSD	2.4	4.9	5.6	5.9	3.4	4.8

* 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 whole raw macadamia kernels immersed in salt solution for 0, 30 and 60 s

Dipping time(s)	Hardness	Macadamia flavour	Other flavour	Rancidity	Sweetness	Overall quality
UNSTORED	*	*	*	NS	*	*
0	59.7 a	61.7 a	8.0 a	5.1	16.2 a	67.3 a
30	53.7 b	56.7 b	16.5 b	3.5	14.9 a	63.4 ab
60	55.7 b	52.4 c	19.2 b	4.1	12.2 a	58.1 b
LSD	3.4	3.4	5.1	3.8	4.0	5.3
STORED 4 MONTHS	NS	*	*	NS	NS	*
0	58.1	56.7 a	14.2 a	5.9	17.1	63.5 a
30	56.3	50.6 b	23.4 b	7.7	17.6	57.8 b
60	55.9	54.4 ab	18.2 ab	6.3	17.6	60.0 ab
LSD	2.2	4.2	6.8	4.5	3.1	4.4
STORED 12 MONTHS	NS	NS	NS	NS	NS	*
0	59.8	47.3	25.1	25.4	17.4	48.7 a
30	58.0	43.1	26.2	30.6	16.2	45.4 a
60	57.3	43.5	26.0	31.2	16.4	44.2 a
LSD	2.4	4.9	5.6	5.9	3.4	4.8

* 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 ($P>0.05$).

control. There was no significant change in any of the characteristics measured for whole macadamia kernels dipped in the salt solution and stored for 12 months. This result may be due to the fact that kernels from all treatments had developed a substantial level of rancidity or 'other flavour' that may have masked other characteristics. However, it is important to note that there was no effect of any of the flotation treatments on rancidity.

These results indicate that dipping whole kernels in a salt solution as part of a grading process is likely to have an adverse effect on the flavour of the raw kernels. A similar study also indicated that flotation separation using salt solutions caused slight flavour deterioration over 12 months storage, and the rate of deterioration was greatest for unrinsed, brine-separated kernels (Farmer & Cavaletto 1983). As kernels in this trial were not rinsed after flotation in order to simulate the worst-case scenario in a commercial operation, this may have contributed to the loss of macadamia flavour and an increase in the 'other flavour' because of the residual salt on the surface of the nuts. Rinsing after flotation is likely to reduce these effects but may increase the amount of moisture absorbed by the kernels. However, the small differences in moisture uptake between kernels dipped for 30 s and those dipped for 60 s indicates that this is unlikely. In commercial processing where roasting and salting of macadamia kernels would normally follow flotation, residual salt on the surface of the kernels may not present a significant problem. The changes in texture of the unstored kernels, while statistically significant, were small in practical terms. While there was a substantial loss in quality during storage for 12 months, this does not appear to be affected by the flotation treatments.

Flotation in ethanol solution: Sensory evaluations of the whole macadamia kernels immersed in the ethanol solution and stored for 0, 4 and 12 months are shown in Table 3.

Immersing whole macadamia kernels in the ethanol solution substantially affected the quality of the kernels initially and after storage. The hardness, macadamia flavour and overall quality of the kernels were all rated significantly lower ($P<0.05$) after flotation compared to the control for the unstored kernels. Kernels stored for 4 months showed similar effects except that there was no decrease in the hardness. There was also a significant increase ($P<0.05$) in 'other flavour' as a result of immersing kernels for 60 s in the ethanol solution for both the unstored kernels and those stored for 4 months. There was no significant ($P>0.05$) effect of the flotation process on the rancidity of kernels from any treatment. However, the level of rancidity in kernels stored for 12 months was considerably higher than that of unstored kernels and those stored for 4 months. This again indicates that storage time is having a greater effect on rancidity than the flotation process. It would also appear that the high level of rancidity in the kernels stored for 12 months has masked the effect of the ethanol solution in reducing macadamia flavour and increasing 'other flavour' as observed at the other storage times.

These results indicate that grading macadamia kernels in ethanol solutions should not be recommended owing to the substantial decrease in quality resulting from this process. Also, logistical issues in terms of solvent storage and disposal, as well as a substantial cost factor associated with the amount of ethanol required to reduce the specific gravity to the required level (SG= 0.97), would not justify its use in a commercial situation.

Chemical analysis

Free fatty acids: The free fatty acid contents of the oils from kernels immersed in the various solutions and stored for 0, 4 and 12 months are shown in Table 4. None of the flotation treatments had any effect on the fatty acid content of the oil from unstored kernels or those stored for 4 months. However, the oil from kernels

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

Dipping time(s)	Hardness	Macadamia flavour	Other flavour	Rancidity	Sweetness	Overall quality
UNSTORED	*	*	*	NS	*	*
0	59.7 a	61.7 a	8.0 a	5.1	16.2 ab	67.3 a
30	57.2 ab	56.2 b	10.6 a	4.8	19.8 a	64.0 a
60	55.3 b	55.0 c	17.7 b	5.4	15.5 b	58.3 b
LSD	3.4	3.4	5.1	3.8	4.0	5.3
STORED 4 MONTHS	NS	*	*	NS	NS	*
0	58.1	56.7 a	14.2 a	5.9	17.1	63.5 a
30	55.4	51.8 b	18.8 a	9.2	15.1	58.5 b
60	56.2	49.1 b	25.9 b	12.0	14.5	54.4 b
LSD	2.2	4.2	6.8	4.5	3.1	4.4
STORED 12 MONTHS	NS	NS	NS	NS	NS	*
0	59.8	47.3	25.1	25.4	17.4	48.7 a
30	58.0	44.2	29.6	27.9	17.5	45.4 a
60	58.5	43.8	30.0	29.6	17.0	44.8 a
LSD	2.4	4.9	5.6	5.9	3.4	4.8

* 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 ($P>0.05$).

stored for 12 months showed a significant increase ($P<0.05$) in fatty acid content for all solutions at each of the dipping times. There was also an obvious increase in free fatty acid content across all treatments with increasing storage time.

However, all free fatty acid levels were within the range (0.10-0.30% oleic acid) considered acceptable for high quality macadamia oil (McConachie 1996). This is not surprising given that all the kernels were re-dried to below 1.5% moisture (wet basis) immediately after flotation. These data support the results from the sensory evaluation of the kernels, which indicated that in most cases, although rancidity increased with storage time, there was little or no effect of flotation time or solution on rancidity development.

Peroxide value: The peroxide values of the oils from kernels immersed in the various solutions and stored for 0, 4 and 12 months are shown in Table 5. None of the flotation treatments had any effect on the peroxide value of the oil from unstored kernels or those stored for 12 months. Generally the peroxide values were below the level of 6.0 meq kg^{-1} oil proposed as being an acceptable level for macadamia oil (McConachie 1996).

However, the oils from kernels immersed in water for both 30 and 60 s, or the salt solution for 30 s and stored for 4 months, showed significant increases ($P<0.05$) in peroxide value. The oil from kernels immersed in ethanol showed a significant increase ($P<0.05$) in peroxide value between kernels dipped for 30 s and those dipped for 60 s. There was no significant difference ($P>0.05$) in peroxide value between the undipped kernels and those dipped for 30 s or 60 s in ethanol solution. Only kernels immersed in water for 30 and 60 s, salt solution for 30 s and ethanol solution for 60 s had peroxide values greater than 6.0 meq kg^{-1} oil.

Peroxide values were generally highest after 4 months storage for each treatment, decreasing again after 12 months storage. Storage at room temperature for 4 months allowed autoxidation to produce peroxides, but the decrease in peroxide value after 12 months storage indicates the decomposition of hydroperoxides to form aldehydes, ketones and hydrocarbons (Lawson 1995). However, as stated above, the sensory assessment did not indicate an effect of flotation time or solution on rancidity development.

The trained taste panel did not detect an increase in rancidity development as a result of the flotation process even though there were some changes in the free fatty acid levels and peroxide values. Results from this work again indicate that there is not a clear relationship between the common tests for either hydrolytic rancidity (free fatty acid content) or oxidative rancidity (peroxide value) and the sensory perception of rancidity in macadamia kernels. This concern has previously been expressed, and indicates the importance of using both subjective and objective methods in determining the presence of rancidity in macadamia nuts (Mason & others 1998).

Colour measurement

The objective colour (L values) of kernels from all treatments are shown in Table 6. While some statistically significant changes were recorded, the changes overall were small and indicate that there was a minimal effect of flotation in improving the brightness of kernels.

Table 4. Free fatty acid content of whole raw macadamia kernels 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 NS	4 months NS	12 months *	unstored NS	4 months NS	12 months *	unstored NS	4 months NS	12 months *
0	0.072	0.106	0.136 a	0.072	0.106	0.136 a	0.072	0.106	0.136 a
30	0.078	0.123	0.174 b	0.076	0.122	0.178 b	0.073	0.123	0.195 b
60	0.072	0.117	0.182 b	0.075	0.117	0.161 b	0.075	0.111	0.181 b
LSD	0.005	0.018	0.026	0.005	0.018	0.026	0.005	0.018	0.026

* 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 whole raw macadamia kernels 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 NS	4 months *	12 months NS	unstored NS	4 months *	12 months NS	unstored NS	4 months *	12 months NS
0	1.71	5.12 a	4.53	1.71	5.12 a	4.53	1.71	5.12 ab	4.53
30	1.75	9.24 b	4.49	1.63	9.24 b	4.40	1.63	3.79 a	5.24
60	1.70	8.25 b	4.75	1.73	4.76 a	4.24	1.53	7.34 b	4.83
LSD	0.23	2.98	1.79	0.23	2.98	1.79	0.23	2.98	1.79

* 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 ($P>0.05$).

However, visual assessment of the kernels did indicate that flotation did remove much of the small pieces of shell and kernel dust resulting from cracking.

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

Conclusions

Immersing whole macadamia kernels 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 kernels could be separated into two grades (SG<1.00 and SG>1.00) provided the residence time in water was kept to a minimum and they were re-dried rapidly after separation. Future work should investigate these aspects as well as the opportunity to use the grading step as part of an overall strategy for microbiological control.

Immersing whole macadamia kernels in a salt solution caused a loss in characteristic macadamia flavour and an increase in other flavours. Residual salt may be removed with rinsing or may not even be detrimental to the flavour or quality of macadamia kernels if roasting and salting are later stages in the commercial process. As a commercial grading system is likely to require a salt solution (SG=1.02) to effectively separate reject kernels from acceptable kernels, there is a need to investigate this aspect in more detail.

While dipping macadamia kernels in an ethanol solution did not increase the development of rancidity, the overall quality decreased as a result of the absorption of alcohol flavour and loss of characteristic macadamia flavour. The use of ethanol solutions for commercial grading is therefore not recommended.

Acknowledgements

The authors wish to acknowledge the financial support provided by the Australian Macadamia Society and Horticulture Australia Limited.

References

Cunniff, P (ed). 1995. Official Methods of Analysis of the Association of Official Analytical Chemists International. 16th Edition. Association of Official Analytical Chemists, Arlington, Virginia, USA.

Farmer, EI & Cavaletto, CG. 1983. Floatation Separation of Macadamia Nuts. In Hawaii Macadamia Nut Association Yearbook: 32-35.

Hilrich, K (ed). 1990. Official Methods of Analysis of the Association of Official Analytical Chemists International. 15th edition. Association of Official Analytical Chemists, Arlington, Virginia, USA.

Lawson, H. 1995. Food Oils and Fats: Technology, Utilization and Nutrition. Chapman and Hall, New York.

Lee, P. 1998. Personal Communication via facsimile. SAMAC. Tzaneen, Republic of South Africa.

Liang, T. 1977. A new processing system for maximizing macadamia nut kernel recovery. Transactions of the ASAE 20: 438-43.

Luttig, AC, Lemmer, D & Kruger, FJ. 1998. Maintaining quality during wet and dry processing of South African macadamia kernels. The South African Macadamia Growers' Association Yearbook 6: 95-107.

Mason, RL, Kowitz, TJ, Bowden, RP & Isaacs, AR. 1998. Storage of macadamia nut-in-shell. Horticultural Research and Development Corporation Final Report: HRDC Project MC607. Horticultural Research and Development Corporation, Gordon, NSW.

Mason, RL & McConachie, I. 1994. A Hard Nut to Crack: A review of the Australian macadamia nut industry. Food Aust. 46: 466-71.

Mason, RL & Wills, RBH. 1983. Evaluation of the use of specific gravity as an objective index of the quality of Australian macadamia nuts. Food Tech. Aust. 35: 245-248.

McConachie, I. 1996. Fats and oils as applied to macadamias: a very basic chemistry lesson. Australian Macadamia Society News Bulletin 23: 34.

Ripperton, JC, Moltzau, RH & Edwards, DW. 1938. Methods of evaluating the macadamia nut for commercial use and the variation occurring among seedling plantings in Hawaii. Hawaii Agricultural Experiment Station Bulletin 79: 2-23.

Standards Association of Australia. 1998. Australian Standard AS 2542.2.3: Sensory Analysis of Foods Method 2.3.1, Rating.

Yow, J. 1992. Macadamia nut kernel grading. A fourth year study project submitted to the Faculty of Applied Science, The University of Queensland, Gatton. □

Table 6. Objective colour (L value) of whole raw macadamia kernels 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
0	71.6	71.7 a	73.2 a	71.6	71.7 a	73.2 a	71.6	71.7 a	73.2 a
30	71.0	65.6 b	70.0 b	70.5	68.9 b	72.1 a	69.3	70.0 a	71.8 a
60	72.2	71.0 a	70.0 b	70.8	69.8 ab	72.5 a	68.0	70.8 a	71.3 a
LSD	3.2	2.4	2.0	3.2	2.4	2.0	3.2	2.4	2.0

* 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).