The quality of macadamia kernels stored in simulated bulk retail dispensers

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Macadamia kernels (raw and roasted, salted) were stored for 36 days under conditions similar to those found in supermarket bulk retail dispensers (21.7°C and 55.5% relative humidity). Samples were removed from storage at regular intervals and assessed for quality by objective (moisture content, peroxide value and free fatty acid level) and subjective (kernel colour grade and sensory evaluation) methods. Between four and eight days, significant ($P<0.05$) changes in quality were evident and it is recommended that both raw and roasted, salted macadamia kernels are not stored for more than eight days in supermarket bulk retail dispensers.

Australia is currently the largest producer of macadamia nuts in the world. Annual production of nuts-in-shell (NIS) increased from 4400 t in 1987 to 38 000 t in 2002 (Lee 2002). Along with the increase in production, the market focus has changed from being predominately export to about 50% local sales (W Prowse pers comm 2001). Macadamia kernels are sold locally at the retail level in bulk dispensers and in portion packs. Bulk retail dispensers vary from open bins to fully enclosed dispensers that are filled from the top and have provision for continuous product removal from the bottom. Portion packs are in the form of cellophane or foil laminate pouches, cans or glass jars and may or may not be gas flushed and/or vacuum-sealed.

A survey of the retail market by Horticulture Australia Limited (HAL) indicated large differences in the quality of macadamia kernels sold at the retail level raising concerns that the industry was at risk of losing consumers because of the poor quality of some of this product (W Prowse pers comm 2001). There are several issues related to this perceived lack of quality and uniformity of product.

Firstly, the industry is endeavoring through its research program to improve the quality of macadamia kernels produced by growers and processors. However, once the product is in the distribution chain the level of control is reduced and poor quality product is seen as a generic problem for the entire industry. Consumers do not differentiate between suppliers when poor quality product is marketed and therefore the high quality image of all macadamia kernels may suffer.

Secondly, there are no objective data that indicate the effect of bulk retail storage on the quality of product sold at the retail level. This lack of information makes it difficult to formulate guidelines that will assist the industry to develop effective procedures to ensure the quality of product will be maintained at the retail level.

Moisture content will affect the quality of macadamia kernels as well as influencing the stability of both NIS and kernel. Mason & others (1998) reported that NIS should be dried to 10% moisture content on-farm and then transported to the processor where they should be further dried to 3.5% NIS moisture content. The final moisture content of the kernel should be 1.5% or lower (Cavaletto 1981). The Australian Macadamia Society Minimum Standards and Guidelines (AMS 2001) and The Southern African Macadamia Grower's Association Quality Assurance Handbook (SAMAC 1998) both recommend that the moisture content of raw and roasted kernels should not exceed 1.5%. Dela Cruz & others (1966) reported good stability of roasted kernels at 1.1% moisture content compared to those at higher moisture levels (1.7% and 2.9%).

The high oil content of macadamia kernels (>69%) (Kaijser & others 2000) contributes to their flavour and texture (Mason & Wills 1983), but also makes macadamia kernels susceptible to rancidity. This problem is likely to be accelerated during retail storage as the kernels are often held at ambient temperature and relative humidity and are also exposed to light that is a catalyst for rancidity development (Sattar & others 1989).

Peroxide value (PV) has been used to predict the stability of macadamia kernels in relation to oxidative rancidity. The AMS Guidelines indicate a maximum PV of 5.0 meq/kg for the oil from raw and roasted kernels while SAMAC recommends a maximum PV of 3.0 meq/kg (SAMAC 1998) for raw kernel. McConachie (1996) proposed that macadamia oil with a PV of 6.0 meq/kg is moderately to completely rancid. Macadamia kernels have a low concentration of polyunsaturated fatty acids and thus the level of peroxides is generally low in unstored kernels (Kaisjer & others 2000).

While free fatty acid (FFA) content is a measure of the hydrolysis of triglycerides in macadamia oil, hydrolytic rancidity is unlikely to occur in the oil as it consists mainly of longer chain fatty acids which do not contribute to the development of rancid flavours and odours (O'Brien 1998). However, FFA are more susceptible to oxidation and hence the measurement is still considered important in relation to the stability of macadamia kernels (Frankel 1998). The AMS Guidelines and SAMAC both recommend a maximum level of 0.5% FFA for the oil from raw kernel. The AMS recommends a maximum FFA level of 0.5% for the oil from roasted kernel. McConachie (1996) reported that the acceptable range of FFA in macadamia oil is 0.1 – 0.3%.

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While no research has been conducted on the storage of macadamia kernels in retail outlets in Australia, surveys of packaged macadamia kernels from retail outlets in South Africa (Lemmer & Kruger 2000, 2001) indicated that the average moisture content of the macadamia kernels sampled was 1.88% (2000) and 1.43% (2001) and that the proportion of samples which exceeded the SAMAC standard of 1.5% moisture content was 70% in 2000 and 30% in 2001. The average PV of the macadamia kernels sampled was 10.5 meq/kg (2000) and 2.3 meq/kg (2001), with 87% and 24% of the samples exceeding the SAMAC standard of 3.0 meq/kg in 2000 and 2001 respectively. These results indicate that the composition of macadamia kernels at the retail level is likely to vary considerably and the eating quality of the product is likely to be adversely affected. However, as no sensory evaluation of the product was conducted, the actual effect of these changes on sensory quality was not measured. It was recommended that proper packaging and storage of kernels below 18°C improves the shelf life.

Given that a large proportion of macadamia kernels are now sold in retail bulk dispensers, the aim of the present trial was to determine the maximum shelf life of raw and roasted, salted macadamia kernels under simulated supermarket conditions.

Materials and methods

Samples of raw and roasted, salted kernels (11.34 kg cartons) used in this study were obtained from two processors in 2000. Two different batches of kernels were obtained from one processor in Queensland and one batch from another processor in New South Wales; a total of three batches for both raw and roasted, salted kernels. All the kernels were Style 4, which are premium half kernels that have a diameter range between 10 and 14 mm (AMS 2001).

The kernels were stored in open plastic trays to simulate a bulk retail display unit and to provide data on the worst case scenario in a commercial situation. The kernels were stored in a controlled environment room at 21.7°C (standard deviation 0.5°C) and a relative humidity (RH) of 55.5% (standard deviation 6.3%). The lighting was automatically controlled to be on for 12 h and off for 12 h. These conditions were based on data from a survey of bulk dispensers in retail outlets conducted in conjunction with the work reported here (Nottingham & others 2001). Samples (about 500 g) were randomly selected for chemical analysis and sensory evaluation over a period of 36 days at intervals of 0, 0.25, 0.5, 1, 2, 3, 4, 8, 16, 23, 29 and 36 days. The samples were vacuum sealed in lacquered cans at a pressure of -60 kPa and kept in a cold room at 2°C until all samples were collected.

Data collected

Moisture content: Kernel moisture content was 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.

Oil extraction: Oil was extracted from kernel samples using a laboratory press (Apex Corporation Ltd, London). Kernel samples were ground using a small food blender (Breville, *'mini-wizz'*), wrapped in pure Chinese silk and inserted into a stainless steel cylinder with a rigid plastic plunger. The wrapped samples were then subjected to 70 000 kPa for 5 min to express the oil through small holes in the cylinder. The expressed oil was clarified as it passed through the silk and collected in a small plastic vessel. New silk was used for each sample.

Peroxide value: PV was determined using the AOAC Official Method 965.33 (Cunniff 1995), except that titrations were performed using 0.01 M $Na_2S_2O_3$ in a microburette instead of the stated 0.1 M $Na_2S_2O_3$.

Free fatty acid: FFA content was measured using the AOAC Official Method 940.28 (Cunniff 1995), except that the oil was titrated with 0.1 M NaOH in a microburette, instead of the specified 0.25 M NaOH.

Colour: A random selection of 100 kernels from each sample were used to determine the colour by subjectively separating them into three categories (premium, choice and reject) using the Macadamia Industry Standard Colour Chart (AMS 2001) and these were expressed as percentages.

Sensory evaluation: Over 18 sessions, on average ten panellists evaluated the samples. All panellists had extensive training specifically for raw and roasted, salted macadamia kernel assessment and were familiar with a wide range of macadamia kernel qualities as well as the raw and roasted, salted reference kernels.

Raw and roasted, salted macadamia kernels were evaluated in separate sessions. In each session, each panellist was presented with four test samples, plus a reference sample. The reference samples (raw and roasted, salted) were "Style 1, Premium Wholes", which consist of 95% whole kernels with a diameter >17mm (AMS 2001). The reference samples were stored in vacuum sealed (-70 kPa) lacquered cans at 2°C to ensure consistency of the reference across each session. Each sample (both test and reference) was the equivalent of three whole macadamia kernels. The samples were presented in round opaque 45 mL plastic containers that were not covered. Each sample was labeled with a three digit random number. The five samples were presented on a white plastic tray.

To recalibrate the panellists at the start of each session, they standardised their assessment of the reference sample against a reference sheet which outlined the attributes intensities (Table 1). No data were collected for the reference sample.

Assessments were completed in individual booths illuminated with white light (daylight equivalent). Each panellist had purified room temperature water available for palate cleansing between samples. The panellists assessed the samples on line scales (Table 1) using the Standards Association of Australia (1998) rating test. The line scales used verbal anchors with the left hand end of the scale equivalent to 0 and the right hand end equivalent to 100. The intensity values 0 to 100 were not shown to the panelists. On each scale, the reference intensity was marked with a small vertical line and labelled "REF". Data were collected directly into computers using an integrated software package, Compusense five ver. 4.0 (*Compusense*® Inc, Canada).

Experimental design and statistical analysis

For the moisture content, PV, FFA and colour data,

a randomised block analysis of variance was used with the three batches of kernels considered as blocks and sampling time as a factor. Where a significant ($P<0.05$) difference was found among sampling times then pair-wise comparisons were made using Fisher's least significant difference (LSD).

For the sensory evaluation of raw and roasted, salted macadamia kernels, an incomplete block design was used with four samples per session and a total of nine sessions for each macadamia type (raw and roasted, salted). Within a session, four test samples were assessed in randomised order. Mean panel scores were then analysed using the Restricted Maximum Likelihood (REML) procedure in the Genstat 5 statistical package (Payne & others 1988) according to the incomplete block design. Where a significant ($P<0.05$) difference was found among samples then pair-wise comparisons were made using Fisher's LSD.

Results and discussion

Raw kernels

Moisture content: The moisture content of raw macadamia kernels increased with time of storage as shown in Table 2. There was no significant ($P>0.05$) change in the moisture content between the initial sample (storage time 0) and those stored for four days. However, the moisture content of all samples stored for eight days or longer was significantly ($P<0.05$) higher than that of samples stored for four days or less. These results agree with Chu & others (1953) who showed that the moisture content of macadamia kernels increases with storage under ambient conditions.

Moisture content affects the stability of the kernel since hydrolysis of the oil can occur in the presence of moisture. However, at moisture content of approximately 1.4%, enzymatic hydrolysis is unlikely to occur (Cavaletto & others 1996). Moisture absorption also causes the kernel texture to soften and become unacceptable. After storage for four days the kernel moisture content was above the level (1.5%) recommended by AMS (AMS 2001) and remained above this level for the rest of the storage period of 36 days. As a significant ($P<0.05$) increase in moisture occurred after eight days storage, it would appear that this is a critical point in relation to storage stability.

Peroxide value: The PV of the oil from raw macadamia kernels (Table 2) were significantly ($P<0.05$) higher at the end of the experiment than initially, increasing from 1.47 meq/kg to 4.67 meq/kg during 36 days storage. However, there was no significant ($P>0.05$) difference in the PV of raw macadamia oil during storage from 0 to 4 days or from 0.5 to 29 days storage indicating that raw macadamia kernels can be stored for four to eight days at 21.7°C and 55.5% RH with only a small increase in oxidative rancidity as measured by PV.

PV is a measure of oxidative rancidity in oils. Even though the PV increased during storage, the levels were generally low (Table 2) and this may have resulted in rancidity not being identified by the sensory panel (Table 3). However, the increases in PV could have resulted in the loss of characteristic raw macadamia flavour as well contributing to the increase in stale flavour (Table 3).

Mason & others (1998) have reported that the oil from raw macadamia NIS stored for four months at 25°C had peroxide value of 1.1 meq/kg. Mason (2000) found that the PV of the oil from unstored macadamia NIS was 2.76 meq/kg. The PV of the oils from stored kernels in this study were below the maximum level proposed by McConachie (1996) of 6.0 meq/kg. However, SAMAC (1998) suggest a PV of less than 3.0 meq/kg as an acceptable standard for kernels in South Africa and in our study after eight days of storage the raw macadamia oil exceeded this level with a PV of 3.46 meq/kg. The AMS (2001) recommend that the PV of macadamia kernel oil should be less than 5.0 meq/kg. No raw kernel

Table 1. Attributes and anchor points used for raw and roasted, salted macadamia kernel assessment

Attribute	Low anchor (0)	High anchor (100)	Reference Value	
			Raw	Roasted salted
Appearance quality	Very poor	Very good	65	70
Colour intensity	Very pale	Very dark	Beige colour chip	Off-white and brown colour chips
Hardness	Very soft	Very hard	60	60
Characteristic raw macadamia flavour	None	Very strong	70	NA
Characteristic roasted macadamia flavour	None	Very strong	NA	70
Roasted flavour	None	Very strong	NA	55
Other flavour	None	Very strong	No reference	No reference
Rancid flavour	None	Very strong	0	0
Stale flavour	None	Very strong	0	0
Saltiness	None	Very strong	NA	50
Overall quality	Very poor	Very good	80	75

NA not applicable

Table 2. Chemical and colour measurements of raw macadamia kernels stored 36 days at 21.7°C and 55.5% RH

Storage time (d)	Moisture content (%)	Peroxide value (meq/kg)	Free fatty acid (%)	Premium colour grade* (%)
0	1.20a	1.47a	0.09a	100
0.25	1.30a	1.73ab	0.09a	100
0.50	1.20a	2.27abc	0.09a	100
1	1.17a	2.40abc	0.10ab	100
2	1.37ab	2.40abc	0.09a	100
3	1.46ab	2.40abc	0.10ab	100
4	1.63ab	2.93abc	0.10ab	100
8	1.83cd	3.46bcd	0.11ab	99
16	2.00de	3.73cd	0.12bc	99
23	2.03de	3.20bcd	0.14c	98
29	2.10de	3.73cd	0.14c	98
36	2.17de	4.67d	0.14c	97
LSD	0.325	1.574	0.026	

a-e Means within a column followed by same letter are not significantly (P>0.05) different
* Not significant (P>0.05)
LSD Least significant difference (P=0.05)

Table 3. Mean scores for sensory quality attributes of raw macadamia kernels stored 36 days at 21.7°C and 55.5% RH

Storage period (d)	Appearance quality	Colour intensity*	Hardness	Characteristic raw macadamia flavour	Other flavour*	Rancid flavour*	Stale flavour	Overall quality
0	58abc	41	54d	56b	10	1	3ab	61b
0.25	58abc	41	55d	55b	6	2	3ab	60b
0.50	59bc	40	51cd	54b	6	1	4ab	57ab
1	58abc	41	52d	55b	5	1	2a	62b
2	59bc	41	53d	55b	7	0	4ab	62b
3	59bc	41	54d	54b	6	1	3ab	62b
4	57ab	41	55d	55b	4	3	3ab	60b
8	58abc	40	53d	56b	7	0	5ab	61b
16	57ab	40	46b	51ab	6	3	7bc	54ab
23	60c	41	47bc	51ab	8	2	7bc	54ab
29	56a	40	47bc	51ab	7	1	6abc	56ab
36	56a	40	39a	46a	7	1	10c	49a
LSD	2.8		4.6	7.2			4.9	8.1

a-d Scores within a column followed by same letter are not significantly (P>0.05) different
* Not significant (P>0.05)
LSD Least significant difference (P=0.05)
All sensory scales 0-100 as described in Table 1

oil in this study exceeded this level. Macadamia kernels contain around 80% of monounsaturated fatty acids (Kaijser & others 2000) which may contribute to the oxidative stability of the kernels.

Free fatty acids: The FFA increased from an initial value of 0.09% to 0.14% after 36 days storage (Table 2). There was no significant ($P>0.05$) difference in FFA level from day 0 to day 8. However, the FFA from day 23 to day 36 were significantly ($P<0.05$) higher than those of the oil from kernels stored up to day eight. These results support Chu & others (1953) who reported an increase in FFA (0.19% to 0.43%) during storage, albeit from a higher base level. Mason (2000) has also reported an increase in FFA from 0.04% to 0.11% after four months storage of kernels.

FFA are the result of oil hydrolysis and for this to occur sufficient moisture must be present. Cavaletto & others (1966) have proposed a moisture content of about 1.4% is necessary to cause hydrolytic rancidity of macadamia kernels. Table 2 indicates that kernels stored for four or more days had a moisture content higher than this value and that the level was also higher than that recommended by the AMS of 1.5% (AMS 2001). The increase in moisture content between four and eight days may have contributed to the increase in FFA as well as causing a decrease in the hardness scores for the kernels.

The results presented here show that the FFA level of oils from raw macadamias stored under retail conditions are likely to increase after eight days. However, overall the FFA levels were low and were within the acceptable range of 0.1%-0.3% reported by McConachie (1996), and less than the level of 0.5% recommended by AMS (2001) and SAMAC (1998). The increase in FFA is commensurate with the increase in moisture content. Hydrolytic separation of the fatty acids from the triglycerides may be caused by the presence of moisture (Potter & Hotchkiss 1995).

Colour: There was no significant ($P>0.05$) change in the percentage of premium grade raw kernels from 0 to 36 days storage (Table 2) and the values ranged from 97% to 100% premium grade at all storage times. This indicates that subjective colour assessment is unlikely to be useful in evaluating the quality of kernels during retail storage.

Sensory evaluation: Sensory evaluation of raw macadamia kernels (Table 3) revealed no significant ($P>0.05$) changes in colour intensity, rancid flavour and other flavour of raw macadamia kernels stored for up to 36 days, indicating that these sensory parameters were not affected by the simulated retail storage conditions (21.7°C and 55.5% RH). The lack of change in rancidity level supports the chemical assessment, which showed that the maximum PV and FFA levels remained below the levels (5.0 meq/kg and 0.5% respectively) proposed by AMS (2001).

However, appearance quality, hardness, characteristic raw macadamia flavour, stale flavour and overall quality changed significantly ($P<0.05$) with storage time. For appearance quality, the results did not show a consistent trend during storage and the scores for the raw kernels ranged only from 56 to 60 across the 36 days storage. However, all samples were scored below the reference sample (70).

The hardness of the raw kernels did not change significantly ($P>0.05$) for the first eight days of storage, after which it decreased significantly ($P<0.05$) for the remainder of the storage period (16 to 36 days). This decrease in hardness is consistent with an increase in moisture content during storage (Table 2). As hardness is a key quality factor in macadamia kernels, loss in hardness after eight days storage indicates that this is the possible limit for storage under retail conditions.

The characteristic raw macadamia flavour of the raw kernels did not change significantly ($P>0.05$) for kernels stored from 0 to 29 days, but after 36 days was significantly ($P<0.05$) lower than that of kernels stored from 0 to 8 days. These results indicate raw kernels stored under simulated retail storage conditions suffered a decrease in characteristic raw macadamia flavour. Mason & others (1998) also found a decrease in raw flavour during the storage of macadamia NIS.

There was no significant ($P>0.05$) difference in the stale flavour of macadamia kernels stored for 29 days and those that were not stored (storage time 0), but after 36 days it was significantly ($P<0.05$) higher than that of kernels stored up to eight days. Raw kernels stored under simulated retail storage conditions are therefore not likely to develop staleness up to 29 days.

There was no significant ($P>0.05$) difference in the overall quality scores of the macadamia kernels stored up to 29 days. However, the overall quality scores of the macadamia kernels stored for 36 days was significantly ($P<0.05$) lower than that of kernels stored for less than eight days except those stored for 0.5 days.

Roasted, salted kernels

Moisture Content: The moisture content of the roasted, salted kernels increased during storage from 0.90% (storage time 0) to 1.93% (storage time day 36) as shown in Table 4. The result supports the findings of Mason (2000) that macadamia kernels absorb moisture during storage. After eight days storage, the moisture content of the roasted, salted kernels was significantly ($P<0.05$) higher than that of all the samples stored for three days or less (Table 4). However, there was no significant ($P>0.05$) difference in moisture content of the kernels between 16 and 36 days of storage. After 16 days of storage the moisture content (1.8%) was above the level (1.5%) recommended by AMS (2001). Cavaletto & others (1966) proposed that at a moisture content of about 1.4%, enzymatic reactions are unlikely to occur.

The level of moisture content (Table 4) did not cause any detectable rancidity in the kernels but there was a slight effect on the texture of the roasted, salted kernels (Table 5).

Peroxide value: Table 4 shows that the PV of the roasted, salted kernels generally increased with storage time and between eight and 36 days were significantly ($P<0.05$) higher than those of other storage times except those stored for one and three days. There was no significant ($P>0.05$) difference in the PV of oil from kernels stored between eight and 23 days. However, in all cases the PV were lower than those obtained for the raw kernels and none were higher (maximum 1.6 meq/kg) than the value of 5.0 meq/kg proposed by the AMS (2001).

Free fatty acids: There was no significant ($P>0.05$) difference in FFA levels of the oils from roasted, salted kernels stored up to 16 days (Table 4), nor of the oils

Table 4. Chemical and colour measurements of roasted, salted macadamia kernels stored 36 days at 21.7°C and 55.5% RH

Storage time (d)	Moisture content (%)	Peroxide value (meq/kg)	Free fatty acid (%)	Premium colour grade * (%)
0	0.90a	0.53a	0.08a	100
0.25	0.83a	0.80a	0.08a	100
0.50	0.93ab	0.80a	0.08a	100
1	0.93ab	0.93bc	0.09ab	98
2	1.10bc	0.80a	0.08a	99
3	1.20cd	0.93bc	0.09ab	96
4	1.33de	0.80a	0.09ab	97
8	1.43e	1.20cde	0.09ab	98
16	1.80f	1.067bcd	0.09ab	97
23	1.87f	1.33def	0.11b	96
29	1.83f	1.47ef	0.11b	96
36	1.93f	1.60f	0.11b	97
LSD	0.185	0.287	0.019	

a-f Means within a column followed by same letter are not significantly (P>0.05) different
* not significant (P>0.05)
LSD Least significant difference (P=0.05)

Table 5. Mean scores for sensory quality of roasted, salted macadamia kernels stored 36 days at 21.7°C and 55.5% RH

Storage time (d)	Appearance quality	Colour intensity*	Hardness	Characteristic roasted macadamia flavour	Other flavour*	Rancid flavour*	Stale flavour*	Roasted flavour	Saltiness*	Overall quality
0	58abc	35	54abc	59b	7	0	3	45c	35	61de
0.25	57ab	36	54abc	55ab	8	2	4	43c	31	57bcde
0.50	55a	37	54abc	53ab	7	1	4	43c	32	56abcd
1.00	57ab	36	54abc	56ab	8	1	2	41bc	36	57bcde
2.00	61abc	36	54abc	53ab	11	2	5	38abc	28	54abc
3.00	65c	37	58c	55ab	8	1	1	43c	34	62e
4.00	62abc	38	56bc	56ab	9	1	2	43c	34	59cde
8.00	65c	36	57c	54ab	8	1	3	38abc	33	55abc
16.00	63bc	39	52ab	51a	10	0	7	39abc	32	55abc
23.00	62abc	36	54abc	55ab	5	3	7	43c	34	56abcd
29.00	63bc	36	56bc	50a	11	1	5	32a	29	52ab
36.00	64bc	37	50a	51a	9	1	5	34a	30	51a
LSD	7.0		4.3	6.3				7.0		5.9

a-e Scores within a column followed by same letter are not significantly (P>0.05) different
* not significant (P>0.05)
LSD Least significant difference (P=0.05)
All sensory scales 0-100 as described in Table 1

from kernels stored between three and 36 days. Overall the level of FFA was low (0.11%) even after 36 days when compared to the level of 0.5% as proposed by AMS (2001). There is therefore little likelihood of fatty acid hydrolysis during storage of roasted, salted macadamia kernel in retail dispensers up to 36 days.

PV and FFA are indicators of rancidity and off-flavour development in oils. From the simulated storage trial these values were too low (Table 4) to cause detectable off-flavour development. This result was supported by sensory evaluation (Table 5) that showed the mean sensory scores for stale and rancid flavour did not change over the storage period.

Colour: There was no significant ($P>0.05$) change in the percentage of premium grade roasted, salted kernels (96% to 100%) during the storage period as shown in Table 4. This finding confirms that colour grading would not be a practical method of evaluating quality during retail storage.

Sensory evaluation: The results from the sensory evaluation of the roasted, salted macadamia kernels are shown in Table 5. There was no significant ($P>0.05$) change in colour intensity, saltiness, rancid flavour, stale flavour and other flavour. These results are similar to those obtained for the raw kernels.

There was little or no change in appearance quality with storage time even though it was observed that the mottled appearance of the kernels at the start of the trial became less obvious as storage time advanced. This may have been due to oil coming to the surface of the kernels during storage. Changes in hardness, while significant ($P<0.05$), were only minor.

After 16, 29 and 36 days storage, the characteristic roasted macadamia flavour was significantly ($P<0.05$) lower than that at time zero, but there were no other significant ($P>0.05$) changes in this attribute over the storage period.

The roasted flavour of the kernels after 29 and 36 days storage was significantly ($P<0.05$) lower than that of the unstored kernels or those stored up to 1 day. The roasted flavour of kernels stored for 29 and 36 days was significantly ($P<0.05$) lower than that of kernels stored for 23 days. However, there was no significant ($P>0.05$) difference in roasted flavour of kernels stored under simulated retail conditions between 0 and 23 days.

The overall quality of macadamia kernels stored for 29 and 36 days was significantly ($P<0.05$) lower than that of macadamia kernels that had not been stored. However, there was no significant ($P>0.05$) difference in overall quality between kernels stored for 0.5, 2, 8, 16, 23, 29 and 36 days.

Conclusion and recommendations

Results from this trial indicate that raw macadamia kernels should not be held for more than eight days under simulated retail storage conditions (21.7°C and 55.5% RH). Roasted, salted kernels showed very little change in sensory characteristics for most of the storage period (36 days) in spite of increases in moisture content and PV.

While this research did not investigate the storage of macadamia kernels at retail level prior to placement in the dispensers, it is likely that similar changes would occur once packages were opened resulting in an even shorter period of retail display before quality deteriorated. For consistency and to ensure maximum quality retention, it is recommended that both raw and roasted, salted macadamia kernels should not be stored for more than eight days at the retail level after opening.

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