CORPUS PUBLISHERS

World Journal of Food and Nutrition (WJFN)

Volume 1, Issue 1, 2021

Article Information

Received date : August 27, 2021

Published date: October 22, 2021

***Corresponding author**

Maryam Shirmohammadi, Principal Scientist, Department of Agriculture and Fisheries, Queensland Government, Australia

Key Words

Volumetric Heating Pasteurization; Post-Harvest; Flavor; Texture; Colour; Sensory Properties; Nutritional Changes

Research Article

Investigation of Different Post-Harvest Treatments on the Quality of Almond Kernels during Ambient Storage

Maryam Shirmohammadi[1*] and Anton Blencowe[2]

[1]*Principal Scientist, Department of Agriculture and Fisheries, Queensland Government, Australia*

[2]*Associate Professor, School of Pharmacy and Medical Sciences, University of South Australia*

Abstract

Maintaining almond kernel quality during and after harvest is crucial in producing premium kernel product for Australian and international markets. In this study, we investigated the effects of different post-harvest treatments on changes in moisture content, texture, colour, nutritional profile and flavour of almond kernels over a storage period of 9 months under ambient conditions. Post-harvest treatments included steam pasteurization, volumetric heating pasteurization, oven roasting and dry roasting, which were compared with raw kernels. Moisture and texture analysis revealed that the average values within each treatment group did not change significantly over 9 months, although the breaking force required to create an initial crack in the kernel structure were markedly lower for Steam Pasteurized (SP) and Oven Roasted (OR) samples after 9 months. Sensory analysis conducted by a trained panel of experts revealed that the chewiness of raw samples increased over time, and both toasted and roasted characteristics were low. For OR and Dry Roasted (DR) samples the chewiness was low and roasted and toasted properties were higher. Average overall enjoyment score given to samples as a part of sensory testing was higher for Volumetric Heating Pasteurization (VHP) and DR at start of the storage (control) and stayed higher than others after 6 and 9 month of storage. Testing of nutritional content of samples showed changes in alpha tocopherol content in roasted samples. However, DR samples had higher content in comparison with OR samples. Volumetric heating treatment didn't diminish tocopherol content of samples in comparison with raw samples while the average alpha tocopherol content of SP over first 3 month of storage was lower. Both SP and OR samples showed lower fat percentage in comparison with raw, VHP and DR. A reduction was observed in Lightness (L*) values for all samples tested. Among the tested treatments OR samples had darker kernels and Raw and VHP samples had lightest colours. The testing results showed the potential of volumetric heating pasteurization and roasting in maintaining quality of kernel over bulk storage period.

Introduction

California, Australia and Spain are the major producers of almonds in the world, producing in-shell and kernel products [1]. Australian export almond products include in-shell (32%) and kernel (68%) products exported to Europe (41%), Asia Pacific (33%), Middle East and Africa (13%) and America (12%) [2]. Almond kernel quality is important for Australian products in this competitive export market, and producing continuous and recognised high quality produce is only possible if effective processes and technologies are used, and in-field processing and storage management best practices are applied to maintain kernel quality throughout the supply chain [3]. Therefore, quality evaluation and monitoring is crucial considering the Australian climate and timing for harvest in comparison with northern hemisphere producers. The Australian almond harvest is between February to April each year, whereas Californian, Spanish, Turkish and Iranian harvests start in late August to October each year [4]. Thus, the climate and harvest differences in Australia requires optimum management of kernel quality during post-harvest processing and storage in order to maintain the highest quality produce. Almonds are harvested in-hull using shakers and leaving the fruit on the orchard ground. The in-hull fruit is left on the orchard ground for drying for one to two weeks [4] before being piled in field prior to shipment to processing factory. The in-hull fruit can be left in-filed stockpiles or on the factory site for several weeks before being processed [4]. In-hull almond are then processed through hulling and shelling stages (10-15 stages) [5-6].

The final kernel products are then sent for further processing and bulk storage before being sold to national or international customers. Size, shape, colour, taste, nutritional and chemical attributes of almond kernel are the most important parameters of kernel products in export market. The current industrial operation uses steam pasteurization and surface heating (hot air or oven) in reducing the kernel moisture content and roasting. The optimum moisture content of raw kernel is 6% and lower moisture level during storage is favourable [7]. The common steam pasteurization and hot air drying and roasting could results in undesirable quality losses of kernels products. The surface heating could affect the appearance and colour of kernel products [8-11].Texture and sensory characteristics of kernel also changes during and after heat treatments. Study of cashew nut, pistachio and sesame seed texture showed a reverse relationship between the kernel hardness and roasting temperature [12]. Surface heating and hot air treatments dry the outer layer of the kernel leading to possible case hardening and damaging the texture of product and reducing consumer acceptability of products. Study of macadamia quality after harvest showed that kernel browning due to drying in high RH environment and oxidation due to high oil content of the kernels can rapidly reduce quality of products [13]. Producing high quality nut kernels requires application of best practice drying such as hybrid drying process and monitoring of initial kernel properties including the oil and moisture content.

Heat treatment such as roasting effects the kernel chemical composition by reducing the Peroxide Value (PV) and increasing the Free Fatty Acid (FFA) content [14]. Existing literature reported the effects of increased temperature, storage time and processing (roasting and blanching) on FFA content [15-17]. The oxidation reactions due to environmental factors such as temperature, light or metal ions after harvest and during storage period could result in changes of taste and rancidity development [18]. Volumetric heating pasteurization reported as an alternative operation for optimising the kernel moisture content and pasteurization with less negative effects on kernel quality [19-24]. However, more work is required to monitor the quality changes of VHP treated products in comparison with raw and commercial steam pasteurised products over storage period. This study aims to determine the quality parameters of almond kernel products including Raw, pasteurised and roasted (oven and VH roasted) during 9 month bulk storage period. The study will investigate the effects of different post-harvest treatments including Steam Pasteurization (SP), Radio Frequency pasteurization (RF), Oven Roasting (OR), VH roasting or Dry Roasting (DR) on quality of Nonpareil variety of almonds.

Material and Methods

Almond processing, treatment and storage

Nonpareil Almonds were harvested in the 2016-2017 season from South Australian almond growing regions. Samples of kernels were selected randomly from hulled and shelled kernels. For this study the almond kernels were either Steam Pasteurised (SP), Volumetric Heating Pasteurised (VHP), Oven Roasted (OR), or dry roasted (DR; involving volumetric heating and roasting), and compared with untreated (raw) almonds. Samples of steam pasteurised and oven roasted kernel products were purchased from 206-2017 products. Pasteurization and roasting using volumetric heating was conducted at a radio frequency of 27 MHz for 20 minutes at a temperature range of 94-120 °C. Following treatment, the kernels were packed into plastic bags and kept in cardboard boxes and sealed by tape in industrial style bulk storage. Over a 10-month storage period samples were tested at 0, 1, 3, 6 and 9 months from the storage date. The temperature and relative humidity were monitored continuously during storage. Moisture content of samples were determined during the storage period using oven drying at 103 °C. Sample were kept in oven dryer for minimum of 48 h until all moisture was removed and sample weight stayed constant. The following formula was used in determining moisture content:

$$\%\ of\ Moisture\,Content\left(MC\right)=\frac{W_w-W_d}{W_w}\times 100 \quad (1)$$

Where W_w and W_d are weight of sample in wet and dry conditions.

Mechanical (texture) properties of almond kernels

A Shimadzu EZ Test mechanical tester fitted with a 500 N load cell was used to measure the force-displacement profiles of the kernels. A flat-ended indenter with a diameter of 6 mm was used for mechanical testing. The force-displacement profiles were then used to calculate the breaking force (N), stiffness (N/mm) and toughness (N.mm) of the kernels. The stress (N/mm^2 or MPa) and strain required to break the kernel structure were determined using following equations:

$$stiffness\left(\frac{N}{mm}\right)=\frac{Yield\ Force}{Displacement(mm)} \quad (2)$$

$$Toughness(N.mm)=0.5*\frac{Force\,at\,Yield(N)}{Displacement\ at\ yield(mm)} \quad (3)$$

$$Stress=\frac{Force(N)}{Area\left(mm\right)^2} \quad (4)$$

$$Strain=\frac{Deformation\,applied\left(mm\right)}{Thickness\,of\ \ kernel\ (mm)} \quad (5)$$

Colour measurement of almond kernels

Colour measurements (lightness (L*), redness (a*) and yellowness (b*)) were determined by analysing images of kernels taken using a microscope with top and bottom light sources, and all images were taken in the same lighting conditions. The images were analysed using MATLAB colour reading. From the colour readings the colour differences (ΔE), chroma and browning index (BI) were calculated for each category using the following equations:

$$E=\sqrt{L^{*2}+a^{*2}+b^{*2}} \quad (6)$$

$$Chroma=\sqrt{a^{*2}+b^{*2}} \quad (7)$$

$$Hue\ Angle=\tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (8)$$

$$BI=\frac{\left[100(x-0.31)\right]}{0.17},x=\frac{\left(a^*+1.75L^*\right)}{564L^*a^*3.021b^*} \quad (9)$$

Sensory analysis of almond kernels

A panel of seven assessors experienced in sensory analysis was used to determine the sensory characteristics of the kernels. The survey was designed based on a five choice questionnaire for strongly agree to strongly disagree. The elements questioned included crunchiness, chewiness, roasted, toasted and overall enjoyment. The average results were then used in combination with the texture and nutritional data to evaluate the quality of the kernels treated and stored under different conditions.

Nutritional Content of Almond Kernels

Determination of lipid content

The lipid content in the kernels was determined using a solvent extraction method reported previously [25]. Briefly, freshly ground almond powder (100 mg) was added to 0.9% saline (1.4 mL) and AR methanol (2 mL) and vortexed for 5 min. AR chloroform (4 mL) was added and the mixture was shaken and then left to rest for 5 min before centrifugation (10 min, 3000 rpm). The organic phase was transferred to a clean vial and then concentrated under a nitrogen flow. The resulting lipid extract was weighed and re-dissolved in 9:1 chloroform:methanol (1 mL). An aliquot (100 µL) was heated to 70 °C for 3 hours then cooled. Then 2 mL of n-heptane and 0.75 mL of water were added and mixed. The organic layer was transferred to a GC vial and the fatty acid content was determined using an Agilant HP6890 GC as described previously [25].

Determination of Vitamin E (tocopherols) content

The tocopherol content in the kernels was determined using a solvent extraction method reported previously [25]. To extract the tocopherol from the kernels, freshly ground almond powder (150 mg) was weighed into an amber vial (7 mL) and methanol containing 0.1% BHT (2 mL) and KOH 80% solution (0.5 mL) were added. After sealing the vial, the mixture was vortexed and then placed in an oven at 70 °C for 30 min, with intermittent vortexing every 10 min. The vial was cooled to room temperature, hexane (2.5 mL) was added, and the mixture was vortexed vigorously before the addition of MilliQ water (1.5 mL). The mixture was centrifuged (10 min, 3000 rpm) at 10 °C and the organic phase was transferred to a vial. A second extraction was conducted using hexane (2.5 mL), and the hexane extracts were combined and concentrated under a nitrogen flow. The resulting extract was redissolved in mobile phase (1 mL) and 20 µL of this solution was injected into the HPLC for analysis. To include external standards, varying volume of 1 mg/mL α-tocopherol (0 µL, 5 µL, 10 µL, 20 µL, 30 µL, 40 µL, 50 µL) were spiked into repeated samples of the same amount. The tocopherol content in the kernels was determined using an Agilent 1260 HPLC system fitted with a Agilent ZORBAX Eclipse XDB-C18 column (4.6 x 150 mm), and using a photodiode array detector (PDA) at 292 nm and a fluorescence detector (FLD) at λ_{Ex} = 295 nm and λ_{Em} = 330 nm. The column was held at 30 °C and a mobile phase gradient was employed at a flow rate of 1 mL/min. Mobile Phase A (MPA) consisted of methanol: methyl *tert*-butyl ether (MTBE): H_2O (95:4:1 v/v%) and Mobile Phase B (MPB) consisted of methanol: MTBE (10:90 v/v%). The gradient started with 0 % MPB and ramped up to 40 % MPB at 11.5 min. The mobile phase was then immediately switched back to 100 % MPA for 2 min to equilibrate the HPLC system before the next injection. Agilent Open Lab Data Analysis software was used for quantification of the results.

Results and Discussion

Initially, the physical characteristics (mass, dimensions and moisture content) of the kernels were determined following treatment and prior to bulk storage (Table 1). Compared to raw kernels (control), all of the treatments resulted in a reduction in the kernel dimensions and mass, although this was least pronounced for VHP treated samples. The moisture content of the raw kernels (5.96%) was also found to decrease for all treatments with the exception of SP, which showed a slight increase. Increased moisture content has previously been reported following SP of kernels, leading to the requirement for further drying processes and a loss of skin quality [26]. Interestingly,

Table 1: Summary of initial physical properties of kernels recorded prior to packing and storage.

	Raw	SP	VHP	OR	DR
Moisture content (% w.b.)	5.96%	6.38%	4.13%	2.84%	2.12%
Thickness (mm)	8.79 ± 0.46	8.18 ± 0.53	8.79 ± 0.42	8.50 ± 0.29	8.62 ± 0.48
Width (mm)	13.00 ± 0.31	12.06 ± 0.55	12.31 ± 0.42	11.38 ± 0.15	11.63 ± 0.22
Length (mm)	22.27 ± 0.87	21.10 ± 0.81	21.14 ± 0.80	19.82 ± 0.87	19.26 ± 0.70
Mass (g)	1.29 ± 0.09	1.11 ± 0.09	1.16 ± 0.05	0.93 ± 0.04	1.0 ± 0.06
Sphericity (%)	38.08 ± 2.48	32.89 ± 2.57	36.03 ± 2.48	32.25 ± 1.29	33.41 ± 1.81

the increase in moisture content for the SP kernels with lower average mass, could suggest that this treatment results in higher water content of kernel that need to be addressed to avoid microbial growth later during long storage of kernels. Additionally, the steam pasteurization has been reported to be effective in eliminating microbial growth (Salmonella Enteritidis) only with high temperature which could cause quality loss and rancidity development [27].

Following these initial measurements the kernels from each treatment group were packaged and stored under ambient conditions for 9 months (from August to April), during which time the temperature and Relative Humidity (RH) were constantly recorded (Figure 1). Almonds in Australia are harvested during hot summer and processed and stored in winter. . As it is illustrated in Figure 1, the changes in the RH at the beginning of bulk storage affected the changes in moisture content of kernels. Higher temperature during summer months (September to April) could cause loss of average moisture content. Laboratory environmental conditioning showed that changes in storage RH, temperature and its effects on almond and walnut kernel quality during storage leads to lower moisture content of kernels when stored in higher temperature [28,29].

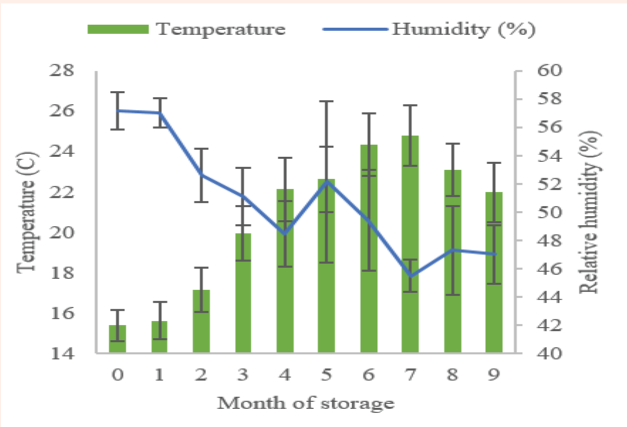

Figure 1: temperature and relative humidity changes during the storage period (0 is July and 9 is April).

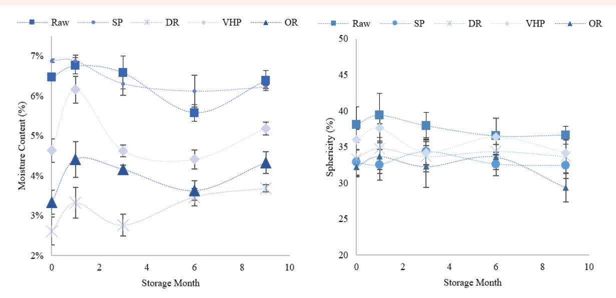

Figure 2: Moisture content and sphericity changes over 10 month storage period.

Changes in sphericity and size of kernel recorded during 9-month storage is shown in (Figure 2 & 3) respectively, shows the variation in kernel size in different sample batches. Sphericity changes of kernel with moisture content is reported in literature is similar to the decreasing trend as moisture content decreased [30]. The effects of heat treatment and oven roasting on sphericity of cashew nut and melon kernel has been studied before indicating the direct relation between moisture content and changes in shape of the kernel that could affect the effectiveness of post-harvest operations on the kernels [31,32].

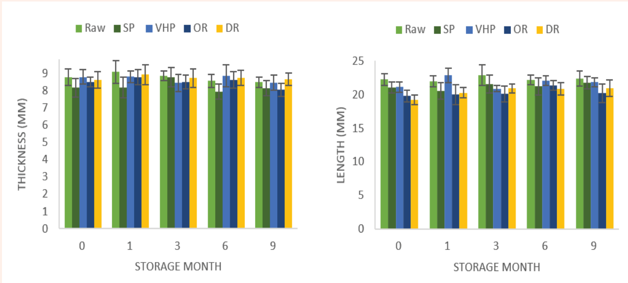

Figure 3: The changes in physical properties of kernel during 9-month storage.

Texture and sensory analysis

Force required to break the kernel was determined conducting a uniaxial loading test. (Figure 4) shows the force values for different treated samples. The force required to break Raw and VHP kernels were in same range while the breaking force required for SP was lower than what expected considering the treatment applied. The average breaking force required were 117, 115, 92, 86 and 90 N for Raw, VHP, DR, SP and OR respectively. The average deformation at the breaking point were 1.05, 0.81, 0.55, 1.20 and 0.62 mm for Raw, VHP, DR, SP and OR respectively. With increase in kernel moisture level the observed force required to break, the kernel was lower.

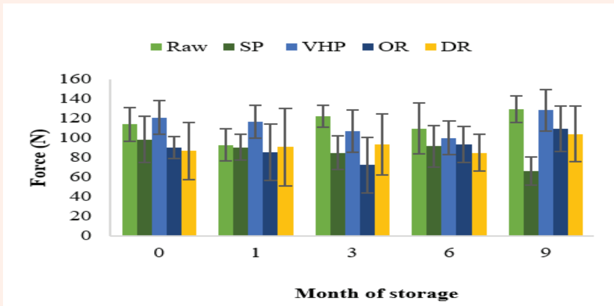

Figure 4: Force required to break kernel recorded during storage period.

Values of stiffness (N/mm) and toughness (N.mm) are presented in (Figure 4). A gradual increase was observed in stiffness values from beginning of storage to three months of storage then the values dropped. The stiffness decrease after 9 month of storage and the changes in SP was more obvious with large changes of 124 N/mm in the beginning

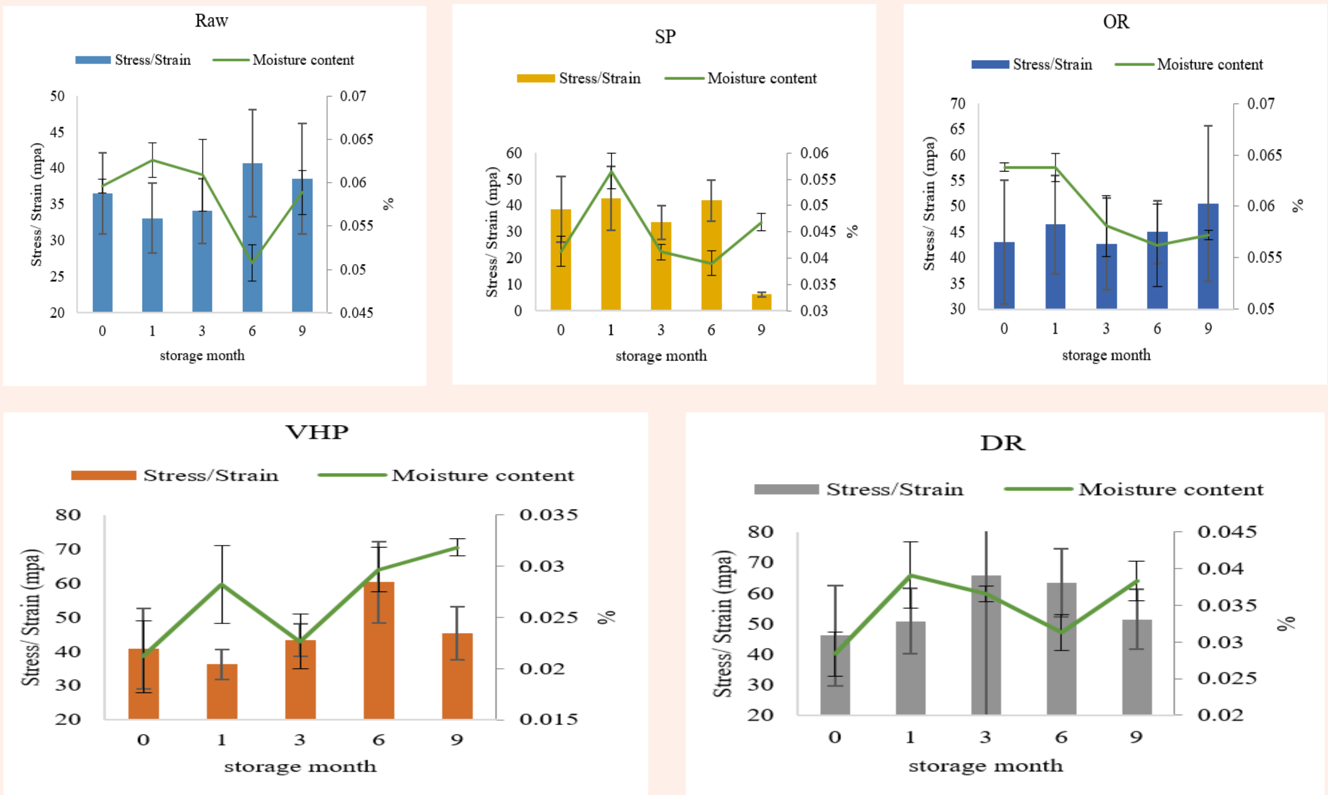

Figure 5: Mechanical characteristics of samples presented in stress vs strain curves.

of trial to 22 N/mm after 9-month storage. Interestingly the changes in stiffness values in Raw, VHP and DR followed a similar pattern while the stiffness value for OR samples increased at the last month of storage. The toughness (rupture energy) recorded for Raw and VHP samples were similar at the first month of the storage and after three month the stiffness value for VHP treated samples dropped. The Toughness values recorded for DR and OR samples showed lowest changes over the storage period. The texture analysis reported in literature shows that volumetric heating pasteurization could maintain the quality of kernel even if the treatment last for 10, 20 and 30 min while the quality reduces significantly after steam pasteurization [33]. (Figure 4) presents the values of stress and strain for tested samples. The ratio of stress over strain or Elastic modulus (E) was lower for raw and SP and VHP compare to roasted samples at the beginning of the storage period. The Elastic modulus values were higher when moisture content of sample reduced during the storage period. Reverse relation between Elastic modulus and moisture content of cashew nut and carob pods reported previously [34,35]. The combined effects of changes in force and deformation due to less brittle and more ductile characteristics of kernels at different moisture level has been reported as one of the important factors in developing more effective technologies and reducing unwanted damage on kernel in post-harvest and processing of nut products [6].

The changes in environmental factors including RH, temperature, light and packaging type has shown effects on changes in kernel moisture content which can result in texture changes and chewy characteristics [18].

Figure 7 shows the changes in sensory properties of samples tested in the beginning of trial after 6 and 9 month of storage. The results showed overall lower toasted texture for SP confirming the reduction in stiffness and increase in toughness values. Very similar pattern was observed for samples when roasted characteristic was recorded by the trained panel while for VHP treated samples the toasted characteristic increased and the roasted characteristic reduced slightly. In comparison the chewiness characteristic of VHP, DR and OR samples were lower than Raw and SP. Study of storage effects on shelf life and sensory quality of almond samples during storage shown better quality parameters for fresher products [36]. Texture, appearance and flavour degradation was significantly lower for raw almond kernels packed with oxygen absorber after 4 and 6 months of storage at 20°C and 4°C respectively [37]. Study on shelf life of IR roasted almonds concluded due to flavour loss after 3 month of storage in paper bags at 37±0.5°C and 7-8% RH, IR roasted products are not suitable for sale [36]. In this study, over 9 months of storage roasted and toasted characteristics of samples received lowest average score by the trained panel for Raw, VHP, and SP. While for DR the stale and oiliness and for OR toasted and chewiness had lowest average score.

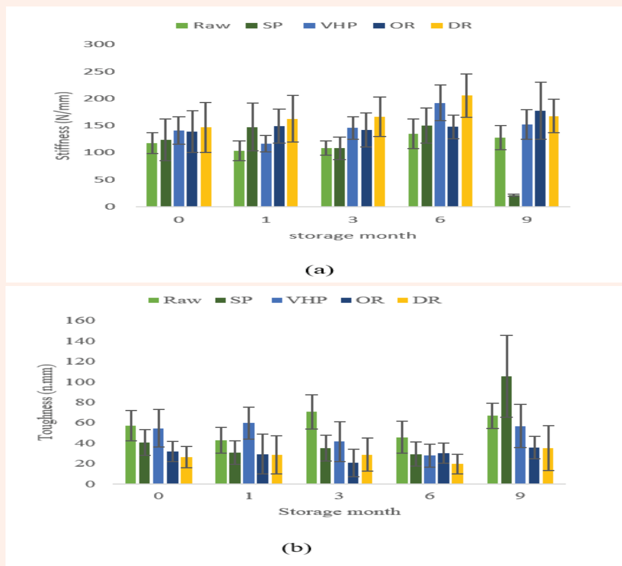

Figure 6: Mechanical properties of kernel determined (a) stiffness (N/mm) and (b) toughness (N.mm) values versus storage month.

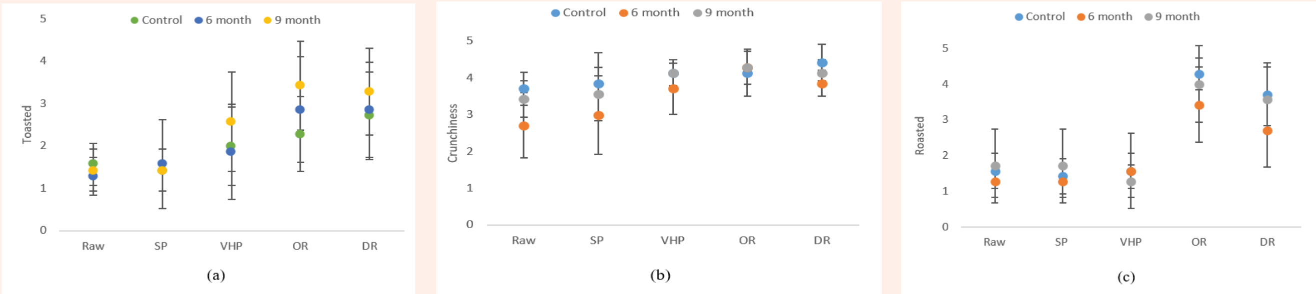

Figure 7: Sensory results for the samples tested including (a) the toasted (b) crunchiness and (c) roasted characteristics.

Changes in tocopherol and fat content

Changes in nutritional content of samples were recorded by testing the vitamin E (tocopherols) and fat content. Both VHP and DR samples maintained the tocopherol content in comparison with the raw kernel while SP and OR samples had lower tocopherol content. Similar study was found when in-shell and roasted kernels stored for 9 month the tocopherol content reduced significantly for the roasted samples while in-shell raw products maintained the quality [38]. Heat treatment through roasting has shown reducing effects on tocopherol content of pine nut, mustard seed extracted oil and soybeans [39-41], the VH process however showed loess negative effects on tocopherol content. Changes in saturated and mono-saturated fatty acid in almonds is function of storage/aging length [37]. The existing literature reports a decrease in mono-saturated and increase in saturated fatty acid when almonds are stored for longer period [18-37, 42-44]. However the authors found no previous publication that reported and compared the effects of storage on raw and volumetric heating pasteurized almonds after bulk storage period.

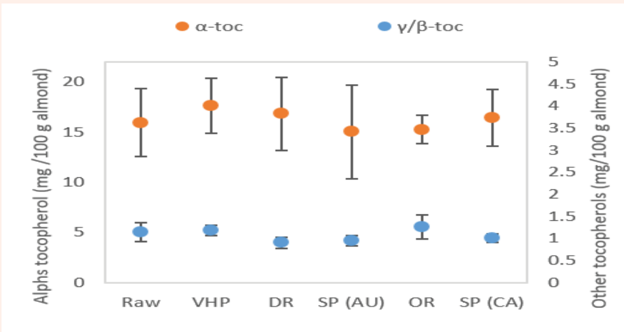

Figure 8: Average changes in tocopherol content of samples over three month of storage.

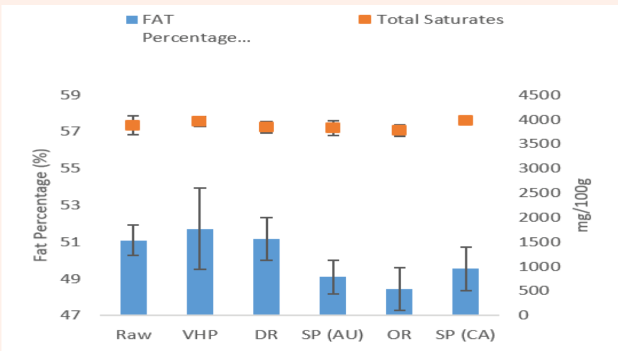

Figure 9: Fat percentage and total saturates recorded for almond kernel during storage period.

Figure 7 presents the values recorded for fat and total saturates of samples during storage period. The VHP and DR samples maintained similar fat content range to the raw samples while OR and SP samples had lower level. Lower satisfaction due to rancid flavor has been previously reported for almonds stored with oxygen absorber showing the effects of oxidation on quality changes [37]. Study of shelled and roasted almonds during storage showed degradation of flavor as storage continues [38], this study indicated the need for further investigation of effects of processing, storage type and temperature and environmental factors on quality of nut in range of conditions. The results of our experiment showed that there is a difference between products storage quality and shelf life depending on treatment applied. The OR product showed lower nutritional and sensory quality while storing raw and VHP pasteurized product showed better texture and sensory quality. This could indicate the need for optimizing storage of less processed products and processing to roasting as the market demand requires [36].

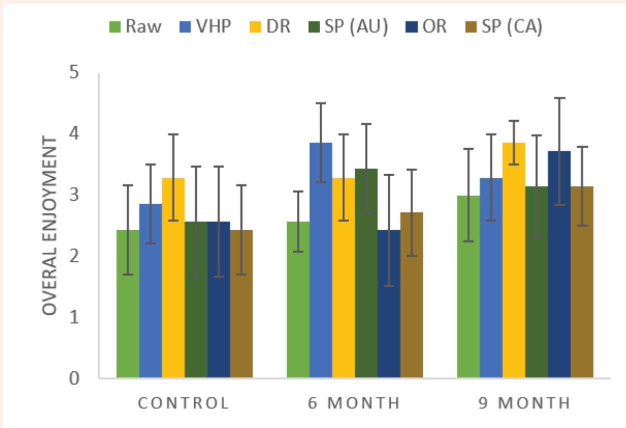

Figure 10: Overall enjoyment parameter recorked for samples during 9 month storage.

Colour changes

The recorded values of lightness (L*) and Browning Index (BI) are shown in (Figure 11). The changes in lightness of kernels indicates a darkening trend for all of the samples and OR samples had darkest colour. Although the BI determined for samples didn't show a significant difference between treatments, the results corresponded with darker colour determined for roasted and steam pasteurised kernels. Study of colour changes of raw and roasted walnut, peanut , almonds and hazelnuts showed better sensory panel acceptance for raw products with lighter colour [45]. The no enzymatic browning occur during steam pasteurization can be the cause of darker skin colour in SP and OR samples [33] while VHP pasteurization and roasting can maintain lighter and natural colour of the kernels.

The values of hue angle and Chroma recorded showed the similarity of VHP treated and raw samples in maintaining the natural color intensity in comparison with the SP and OR samples. The changes in hue angle values for each sample batches over the storage period reported to be indicating the degradation process [46].

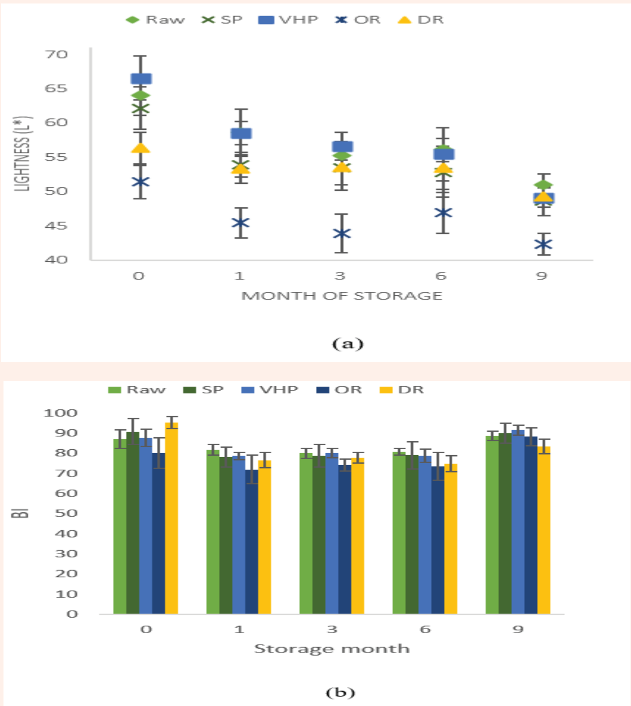

Figure 11: Lightness (L*) values determined for samples during 10 month storage.

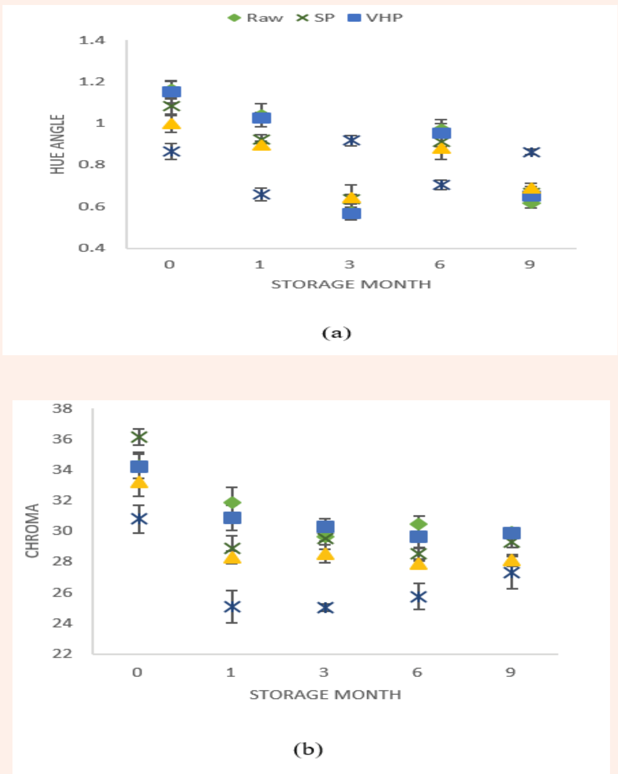

Figure 12: Values of (a) Hue angle and (b) Chroma determined for samples calculated for 10 month of storage.

Conclusion and Future Work

Results shown in this study indicates the importance of storage and quality loss monitoring for almond kernel products. The changes in quality parameters indicates the need for better process management, minimal post-harvest heat treatment and quality determination during and after harvest. Existing literature on shelf life of roasted products [36] showed faster quality degradation of heat treated products in 3 month storage could illustrate that higher quality can be achieved by storing fresh raw products and further process them to roasted as market demand requires [36,38]. VH pasteurization and roasting showed great potential as an industrial process in maintaining the kernel products quality in comparison with common steam pasteurization. The results showed that better management of quality by storing raw and VHP pasteurized product can be achieved while storing roasted products increases the possibility of product quality loss.

References

1. Willis B (2017) Australia's Almond Industry is Booming and South Australia is Central to Driving its Export Growth, in the Advertiser. UK.
2. Almond Insights (2014-15) Horticulture Innovation Australia: Almond Board of Australia. UK, p. 1-19.
3. All about Australian Almonds (2009) Almond Board of Australia in a Nutshell.
4. Micke W (1996) Almond Production Manual. UCANR Publications, 33(64): 1-294.
5. Shirmohammadi M, Fielke J (2017) Conditioning reduces kernel damage when impact shelling almonds. International Journal of Food Engineering 13(8).
6. Shirmohammadi M, Charrault E, Blencowe A (2018) Micromechanical properties of almond kernels with various moisture content levels. International Journal of Food Properties 21(1): 1820-1832.
7. Yang J, Gokhan B, Zhongli P, Maria TB, Tara H, et al. (2010) Infrared heating for dry-roasting and pasteurization of almonds. Journal of Food Engineering 101(3): 273-280.
8. Walton D (2005) Anatomy and handling: Implications for macadamia nut quality.
9. Nizamlioglu NM, Nas S (2016) Kinetic of color changes in almond (Akbadem Variety) during roasting and storage. International journal of food properties 19(10): 2363-2376.
10. Chang SS, Han AR, Reyes-De-Corcuera JI, Powers JR, Kang D-H (2010) Evaluation of steam pasteurization in controlling salmonella serotype enteritidis on raw almond surfaces. Letters in Applied Microbiology 50(4): 393-398.
11. Cheng T, Wang S (2019) Modified atmosphere packaging pre-storage treatment for thermal control of *E. coli* ATCC 25922 in almond kernels assisted by radio frequency energy. Journal of Food Engineering 246: 253-260.
12. Olatidoye O, Awonorin SO, Shittu TA, Ajisegiri ESA, Sobowale SS, et al. (2017) Optimizing the effect of temperature-time combinations on the quality attributes of roasted cashew (*Anacardium Occidentale*) Kernel. J Bioprocess Biotech 7(6): 1-11.
13. Borompichaichartkul C, Kanonrat L, Ninnart C, Sakamon D (2009) Improving quality of macadamia nut (*Macadamia integrifolia*) through the use of hybrid drying process. Journal of Food Engineering 93(3): 348-353.
14. Shahla HB, Ian D, Tio N, Godfrey H, Dalsie H, et al. (2017) Effects of roasting on kernel peroxide value, free fatty acid, fatty acid composition and crude protein content. PLoS One 12(9).
15. Lin X, Jia W, Rongbi Z, Paul C, Guangwei H, et al. (2012) California almond shelf life: Lipid deterioration during storage. Journal of Food Science 77(6): C583-C593.
16. Pleasance EA, William LK, Ronald BP, Ruthann BS, Anna NC et al. (2018) Effects of storage conditions on consumer and chemical assessments of raw 'Nonpareil' almonds over a two-year period. Journal of Food Science 83(3): 822-830.
17. Labavitvh JM (2016) The commercial storage of fruits, vegetables, and florist and nursery stocks. In: Hardenburg RE, Watada AE, Wang CY (eds), Food and Agriculture Organization of the United States, USA, pp. 102-130.
18. Cheely AN (2014) Consumer acceptability of dry medium-roasted almonds stored under varying storage conditions. Georgia.
19. Hou L, Johnson JA, Wang S (2016) Radio frequency heating for postharvest control of pests in agricultural products: A review. Postharvest Biology and Technology 113: 106-118.
20. Gao M, Juming T, Rossana V-R, Yue W (2011) Pasteurization process

development for controlling Salmonella in in-shell almonds using radio frequency energy. Journal of Food Engineering 104(2): 299-306.

21. Li R, et al. (2018) Application of radio frequency pasteurization process to almond kernels: Heating uniformity improvement. ASABE Annual International Meeting, American Society of Agricultural and Biological Engineers.
22. Li R, Zhang S, Kou X, Ling B, Wang S (2017) Dielectric properties of almond kernels associated with radio frequency and microwave pasteurization. Scientific Reports 7: 42452.
23. Zhang S, Zhou L, Ling B, Wang S (2016) Dielectric properties of peanut kernels associated with microwave and radio frequency drying. Biosystems Engineering 145: 108-117.
24. Tang J, Ikedialaa JN, Wanga S, Hansenb JD, Cavalieri RP (2000) High-temperature-short-time thermal quarantine methods. Postharvest Biology and Technology 21:129-145.
25. Zhu Y, Taylor C, Sommer K, Wilkinson K, Wirthensohn M (2015) Influence of deficit irrigation strategies on fatty acid and tocopherol concentration of almond (Prunus dulcis). Food chemistry 173: 821-826.
26. Lee SY, Oh S, Chung HJ, Reyes-De-Corcuera JI, Powers JR, et al. (2006) Reduction of *Salmonella enterica* serovar enteritidis on the surface of raw shelled almonds by exposure to steam. Journal of Food Protection 69: 591-595.
27. Li R, Kou X, Cheng T, Zheng A, Wang S (2017) Verification of radio frequency pasteurization process for in-shell almonds. Journal of Food Engineering 192: 103-110.
28. Kazantzis I, Nanos GD, Stavroulakis GG (2003) Effect of harvest time and storage conditions on almond kernel oil and sugar composition. Journal of the Science of Food and Agriculture 83: 354-359.
29. Christopoulos M, Tsantili E (2011) Effects of temperature and packaging atmosphere on total antioxidants and colour of walnut (*Juglans regia L.*) kernels during storage. Scientia Horticulturae 131: 49-57.
30. Altuntaş E, Yıldız M (2007) Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba L.*) grains. Journal of Food Engineering 78: 174-183.
31. Obi OF, Offorha LC (2015) Moisture-dependent physical properties of melon (*Citrullus colocynthis lanatus*) seed and kernel relevant in bulk handling. Cogent Food & Agriculture 1: 1020743.
32. Kilanko O, Joshua OS, Omieraokholen IA, Adeyinka IT, Oluwafemi LR, et al. (2018) Effect of pre-shelling treatment on physical and mechanical properties of cashew nut. IOP Conference Series: Materials Science and Engineering.
33. Riggio M, Schmidt E, Mustapha G (2019) Moisture monitoring data of mass timber elements during prolonged construction exposure: The case of the Forest Science Complex (Peavy Hall) at Oregon State University. Frontiers in Built Environment 5: 98.
34. Ekinci K, Yılmaz D, Ertekin C (2010) Effects of moisture content and compression positions on mechanical properties of carob pod (Ceratonia siliqua L.). African Journal of Agricultural Research 5: 1015-1021.
35. Swain S, Gupta J (2013) Moisture related mechanical properties of drum-roasted cashew nut under compression loading. Journal of Crop and Weed 9: 164-167.
36. Yang J, Pan Z, Takeoka G, Mackey B, Bingol G, et al. (2013) Shelf-life of infrared dry-roasted almonds. Food Chemistry 138: 671-678.
37. Mexis SF, Kontominas MG (2010) Effect of oxygen absorber, nitrogen flushing, packaging material oxygen transmission rate and storage conditions on quality retention of raw whole unpeeled almond kernels (*Prunus dulcis*). LWT-Food Science and Technology 43: 1-11.
38. Garcıa Pascual P (2003) Influence of storage conditions on the quality of shelled and roasted almonds. Biosystems Engineering 84: 201-209.
39. Cai L, Cao A, Aisikaer G, Ying T (2013) Influence of kernel roasting on bioactive components and oxidative stability of pine nut oil. European Journal of Lipid Science and Technology 115: 556-563.
40. Vaidya B, Choe E (2011) Effects of seed roasting on tocopherols, carotenoids, and oxidation in mustard seed oil during heating. Journal of the American Oil Chemists' Society 88(1): 83-90.
41. Yoshida H, Takagi S, Mitsuhashi S (1999) Tocopherol distribution and oxidative stability of oils prepared from the hypocotyl of soybeans roasted in a microwave oven. Journal of the American Oil Chemists' Society 76(8): 915-920.
42. Kodad O, Socias RI (2008) Variability of oil content and of major fatty acid composition in almond (Prunus amygdalus Batsch) and its relationship with kernel quality. Journal of agricultural and food chemistry, 2008. 56(11): 4096-4101.
43. Miraliakbari H, Shahidi F (2008) Lipid class compositions, tocopherols and sterols of tree nut oils extracted with different solvents. Journal of Food Lipids 15(1): 81-96.
44. Mexis SF, Badeka AV, Chouliara E, Riganakos KA, Kontominas MG (2009) Effect of γ-irradiation on the physicochemical & sensory properties of raw unpeeled almond kernels (Prunus dulcis). Innovative Food Science and Emerging Technologies, 2009. 10(1): 87-92.
45. Savage GP, Connor S, Vanhanen LP (2005) Sensory evaluation of different levels of roasting of New Zealand grown hazelnuts.
46. Craig AL, Debra EP (2006) Degradation of almond pellicle color coordinates at different storage temperatures. Postharvest Biology and Technology 40(2006): 295-300.