Research Article

Physicochemical Properties and Storage Stability of Lemon Slices (*Citrus limon*) Dried with Oven and Cabinet Dryer

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ABSTRACT

This study aimed to investigate the changes in the quality of lemon dried with oven and cabinet drying methods at different temperatures (40°C, 50°C and 60°C) in three months of storage and packaged in different packaging materials (aluminium laminated polyethylene (ALP) and low-density polyethylene (LDPE)). All lemon slices dried at different temperatures were achieved at <12.95% moisture content and water activity <0.60 to produce microbiologically safe products. As the drying temperature increased in both drying methods, the redness (a*) decreased, while the lightness (L*) and yellowness (b*) values increased. A significant increase in vitamin C and total phenolic content (TPC) was observed with increasing drying temperature at 60°C for both drying methods. After 3-months of storage, lemons dried with cabinet drying at 60°C and packaged in ALP had better retention of vitamin C (42.84 to 13.77 mg/100g – 26% reduction). Dried lemon using a cabinet dryer at 50°C and packed in ALP and LDPE exhibited the lowest loss of total phenolic content (10.72% and 10.71%). In short, drying methods, drying temperature, and packaging materials significantly affected the physicochemical properties of dried lemon slices.

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1. Introduction

Lemon (*Citrus limon*) is one of the most prominent Citrus species in the world due to its distinctive flavour, acidity, and health benefits (Chaturvedi and Suhae, 2016; Miran *et al*., 2016). Lemons contain various phytochemical compounds with high levels of vitamin C, folic acid, soluble fibre, and pectin to reduce the risk of cardiovascular disease, high blood pressure, and cancer (Haida *et al*., 2022; Nasrin *et al*., 2023). In addition, total phenolic content (TPC) in lemons has been widely reported because of their antioxidant, anti-inflammatory and antimicrobial activity (Dong *et al*., 2019).

Fresh lemons contain 84% to 90% moisture (Darvishi *et al*., 2014; Fu *et al*., 2017; Lee *et al*., 2015; Nasr *et al*., 2021). However, high moisture content promotes microbial growth, which accelerates the deterioration rate and reduces the shelf life of lemons. Therefore, removing the moisture content of the lemons using drying methods helps to extend shelf life by reducing the viability of microorganisms and reducing packaging needs and transport weight (Naidu *et al*., 2016). Fruits and vegetables have been dried using various methods, including convective, sun, microwave, freeze and vacuum drying (Lee *et al*., 2015). According to Chin *et al*. (2009), open sun drying causes detrimental losses of active constituents in dry food, weather-dependent and long drying time. Meanwhile, microwave drying aids in preventing vital quality loss and efficient thermal processing. However, this drying method causes uneven heating, which in turn causes colour degradation, nutrient losses, and an increased risk of fungal growth (Darvishi *et al*., 2014; Mongi, 2023). Freeze and vacuum dryers both have high capital and operational costs (Santhoshkumar *et al*., 2023). Thus, due to the above reasons, in this study we chose oven and cabinet drying as inexpensive and effective drying techniques to reduce nutrition loss. Both drying methods are very low-cost and user-friendly methods compared to freeze drying, with high energy consumption and increased maintenance costs (Indiarto *et al*., 2021). Both methods are favoured in this study due to their optimum processing cost and ease of operation (Argyropoulos *et al*., 2011; Vashisth *et al*., 2011).

Udomkun *et al*. (2016) reported that although dried fruits are relatively stable in low pH, water activity, and moisture content, they are sensitive to high temperature, humidity, light, and oxygen, which trigger physicochemical changes during storage and distribution. In this study, the main issue related to dried lemon slices is oxidation due to the presence of oxygen during storage, causing the colour to darken (Fu *et al*., 2017). Therefore, the proper packaging material is vital to prevent colour deterioration and prolong their shelf life. According to Hossain & Gottschalk (2009), preserved fruits are often stored in glass, metal containers, and plastic. Although glass jars and metallic containers provide inertness and resistance against water vapour, they are weighty and take up a lot of space, raising transportation costs (Miranda *et al*., 2019). Meanwhile, plastic packaging makes it difficult to provide an effective barrier against oxygen, but they are light, rigid and elastic (Korese *et al*., 2022; Miranda *et al*., 2019). Sagar and Kumar (2014) suggested that high-density polyethylene (HDPE) was better at preserving bale powder quality as compared with low-density polyethylene (LDPE). According to Dak *et al*. (2014) and Pua *et al*. (2008), aluminium laminated polyethylene (ALP) pouches are more effective at preserving the quality of jackfruit powder and dried pomegranate arils. Pa *et al*. (2019) agreed that aluminium displayed the least reduction in the physicochemical properties of the mixed fruit bar when compared to the LDPE and HDPE. Therefore, two different packaging materials are chosen (Low-Density Polyethylene (LDPE) and Aluminium Laminated Polyethylene (ALP) pouch to determine the stability of dried lemon slices in 3 months of storage. Low-density polyethylene (LDPE) is a thermoplastic resin made from the ethylene monomer.

Although numerous studies have used various drying methods, there is insufficient information on the effects of oven and cabinet dryers on lemon slices in different packaging materials. Therefore, this study investigated the effect of drying methods, drying temperatures (40, 50, and 60°C), and packaging materials (LDPE, ALP) during 3-month storage on the physicochemical changes of dried lemon slices.

2. Materials and Methods

2.1 Sample preparation and drying process

Lemons were obtained from LLS Fresh Fruits Marketing Sdn. Bhd. in Penampang, Sabah. Lemons with no damaged or bruised parts were selected and washed with tap water. Samples were then kept in refrigerated storage at 4 ± 1°C for further analyses.

2.2 Drying process

Lemon fruits were sliced into 5 mm ± 0.5 mm thickness and placed evenly on parchment paper (Figure 1). The samples were then dried at 40, 50, and 60°C in an electric deck oven (Sinmag, Malaysia) and cabinet dryer (CD-9R, Shin-1, Taipei) (Muhamad and Mohd Redzuan, 2019). Weight loss of the samples was monitored at every two-hour interval (Bishnoi *et al*., 2020). The drying process was terminated when the slices achieved no measurable weight loss (Darvishi *et al*., 2014; Mongi, 2023) or achieved less than 15% moisture content (dry basis).

Figure 1. Lemon slices before drying

2.3 Sample packaging and storage conditions

Dried lemon slices were equally divided and packed into two different packaging materials: a) Low-Density Polyethylene (LDPE) and b) Aluminium Laminated Polyethylene (ALP) pouch, as characterised in Table 1. These pouches were added with a silica gel sachet as a moisture absorber. The pouches were then sealed and stored at room temperature (25 ± 3°C) for 12 weeks (Obadina *et al.*, 2018). Water activity, colour values, vitamin C and total phenolic content were evaluated at biweekly intervals (0, 4^{th}, 8^{th}, and 12^{th} week). The experiment was replicated three times.

Table 1. Comparisons of ALP and LDPE packaging

Materials	Composition	Thickness, µm	Material properties
ALP	15 µm PET + 95 µm LDPE + 7 µm Al (Udomkun *et al.*, 2016)	117	LT: 0% WVTR: 6.44 x 10^{-5} g/m^2/day OP: 21.3 cm^3/m^2/day
LDPE	Single layer LDPE (Niazmand *et al.*, 2021)	40	WVTR: 0.207 g/m^2/day OP: 2200 cm^3/m^2/day
	Single layer LDPE (Ordon *et al.*, 2021)	140	LT: 85% WVTR: 0.260 g/m^2/day

*PET: Polyethylene Terephthalate; Al: Aluminium; Light Transmissivity; WVTR: Water Vapour Transmission Rate; OP: Oxygen Permeability

2.4 Physicochemical analysis of dried lemon slices

2.4.1 Moisture content

Moisture content was analysed using the oven-dryer method (AOAC, 2000).

2.4.2 Water activity (a_w)

Water activity was analysed using a HygroLab C1 Water Activity Meter (Rotronic HygroLab, USA). Approximately one gram of lemon slice samples was placed in the measurement chamber at room temperature (25 ± 1°C) until equilibrium was reached. All measurements were carried out in triplicate and the average value was obtained.

2.4.3 pH value

One gram of each sample was homogenised with 10 mL of distilled water at a ratio of 1:10. After 10 min of stirring, the pH of the homogenate was determined using a pH metre (Eutech pH 2700, Fisher Scientific, USA).

2.4.4 Colour measurement

Colour (L*, a*, and b* values) was measured using a ColourFlex colorimeter (Hunterlab, USA). Fresh lemon slices were milled to obtain the lemon juices, while dried lemon slices were ground into powder and filtered with distilled water. The L* value represents the level of lightness or darkness, a* value represents redness and greenness, while b* value represents yellowness and blueness.

2.4.5 Vitamin C analysis

The vitamin C content was determined by redox titration using iodine (Satpathy *et al.*, 2021). To prepare lemon extracts, 10 g of fresh lemon slices were milled and filtered with portions of distilled water to yield a 200 mL liquid extract. Alternatively, dried lemon slices were ground into powder and washed with distilled water until an equivalent liquid extract was obtained. Each trial involved the pipetting of a 10 mL aliquot, the addition of 50 mL of distilled water, and 1ml of starch indicator into a conical flask. Titration was carried out with 0.005 M iodine solution until the solution turned pale blue. The volume of iodine solution used for complete titration was recorded. A blank titration was performed using L (+)-ascorbic acid standard solution by dissolving 30 mg in 100 mL of water.

2.4.6 Total phenolic content

The total phenolic content (TPC) of lemon slices was measured in accordance with Fu *et al.* (2017). One gram of lemon slices was milled in 10 mL of 80% acetone aqueous solution. This mixture was then centrifuged at 5,000 x *g* for 10 min. After thoroughly mixing, 1 mL of Folin-Ciocalteu reagent that has been diluted to 1/10 (v/v) with distilled water was added to 2.5 mL of the supernatant. After resting for one minute, another 1 mL of saturated sodium carbonate (10 g/100 mL) was added and mixed. After incubating the mixture for one hour at room temperature, the absorbance of the mixture was determined at 765 nm using a UV-Vis Spectrophotometer (Lambda 25, Perkin Elmer, USA). The TPC was expressed as gallic acid equivalent (mg GAE) per gram of sample.

2.5 Storage evaluation

The dried lemon slices were packed into two packaging materials (LDPE pouch and ALP pouch) with a moisture absorber silica gel sachet and stored at room temperature (25 ± 1°C) for three months (twelve weeks) as shown in Table 2. The vitamin C analysis and total phenolic content was done biweekly (0^{th}, 4^{th}, 8^{th}, and 12^{th} week) as described in section 2.4.5 and 2.4.6, respectively.

2.6 Statistical data analysis

All analyses were carried out in triplicates, and the results were expressed as mean values ± standard deviation (mean ± SD). SPSS Statistical Analysis Software (Version 29) was used to analyse the data. A three-way factorial design was applied for the assessment of the physicochemical properties of dried lemon slices (Two drying methods × Three drying temperatures × Two packaging materials). Each combination was replicated three times, giving 12 treatment samples (Table 2). Analysis of variance (ANOVA) and significant differences between mean values are established using Tukey HSD test ($p<0.05$).

Table 2. Lemon slices dried using different drying methods, temperatures, and packaging materials

Drying method	Samples	Drying temperature	Packaging materials + silica gel sachet
Oven drying	OA40	40°C	ALP
	OL40		LDPE
	OA50	50°C	ALP
	OL50		LDPE
	OA60	60°C	ALP
	OL60		LDPE
Cabinet drying	CA40	40°C	ALP
	CL40		LDPE
	CA50	50°C	ALP
	CL50		LDPE
	CA60	60°C	ALP
	CL60		LDPE

3. Results and Discussion

3.1 Effect of different drying methods and temperature

Table 3 demonstrates the effect of different drying methods and temperatures on drying time to reduce the moisture content of fresh lemon slices, ranging from 17 to 46 ho All samples have moisture levels below 15%, which is suitable for consuming dried fruits. The drying process was completed when there was no further reduction in moisture content, indicating that the minimal amount of leftover water had been reached (Kusuma *et al.*, 2023).

Table 3. Drying time and moisture content at different drying methods and temperature

Drying methods/samples	Temperature (°C)	Drying time (h)	Moisture content (%)
Fresh lemon	-	-	87.15 ± 0.11
Oven drying	40	37.54 ± 0.01^{a}	12.83 ± 0.03^{a}
	50	26.01 ± 0.01^{b}	12.70 ± 0.07^{a}
	60	17.59 ± 0.00^{c}	12.95 ± 0.07^{a}
Cabinet drying	40	46.02 ± 0.01^{a}	12.61 ± 0.01^{a}
	50	32.00 ± 0.02^{b}	12.90 ± 0.13^{a}
	60	24.01 ± 0.01^{c}	12.86 ± 0.04^{a}

Mean values ± standard deviation of three replicates. $^{a-b}$ Means in the same column with different letters are significantly different ($p<0.05$) measured by Tukey's test

The results indicated that fresh lemon fruits had significantly high water content (87.15 ± 0.11%), which leads to high metabolic activity and is prone to spoiling (Darvishi *et al.*, 2014). As depicted in Table

3, the oven drying at 60°C resulted in the shortest drying time (17.59 h). On the other hand, the longest drying time of 46 h was observed using a cabinet drier at 40°C. The variation in drying periods and techniques might be due to the different effectiveness of the equipment in reducing the moisture content (Muhamad and Redzuan, 2019). In this study, the oven dryer emits heat that spreads in all directions inside its enclosed space without needing any medium. This leads to a faster drying process than a cabinet dryer, which requires a medium for heat transfer (Aboud *et al.*, 2019; Pan and Atungulu, 2010). Moreover, as shown in Table 3, there were significant differences (p<0.05) in the drying time due to variations in the drying temperature. Increasing the drying temperature reduces the duration needed to eliminate moisture from the sample. These findings are consistent with Alam *et al.* (2023), who reported that an increase in the rate of drying is associated with an increase in the temperature. As the temperature increases, the molecules in a liquid or wet substance acquire more energy, resulting in enhanced motion and a higher probability of transitioning from liquid to the vapour state.

Table 4 depicted noticeable variations (p<0.05) in L* and a* values between oven and cabinet drying. However, there were no significant variances (p>0.05) in b* values in all dried samples. Increasing the temperature for the lemon dried with a cabinet dryer resulted in higher L* values than other samples, possibly due to enzymatic browning or Maillard reactions, leading to less lightness.

Table 4. Physicochemical properties of fresh and dried lemon

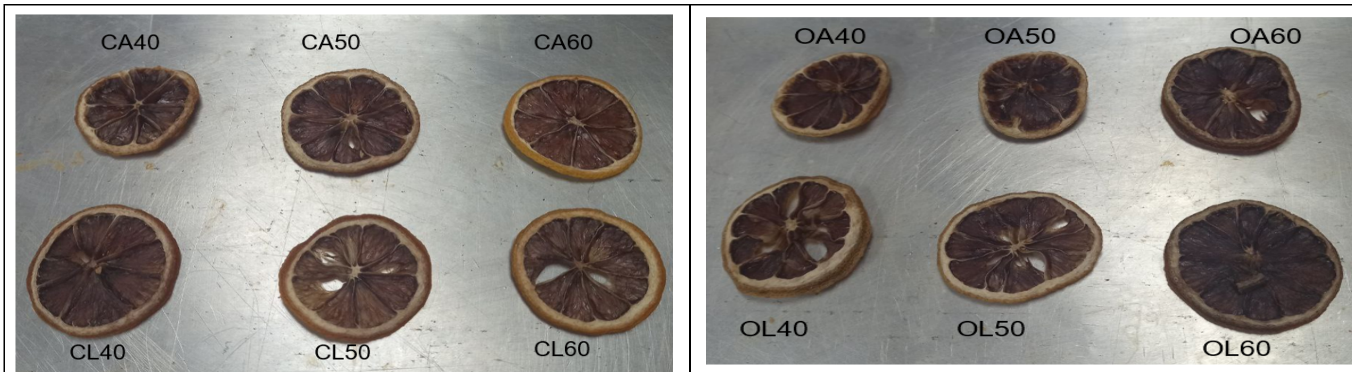
	Temperature (°C)	Physicochemical Properties				
		Colour value			TPC, mg (GAE/100 g)	Vitamin C, (mg/100 g)
		L*	a*	b*		
Fresh lemon	-	44.05 ± 0.40^{f}	-6.11 ± 0.02^{e}	10.02 ± 0.62^{b}	30.24 ± 0.01^{a}	79.79 ± 0.10^{a}
Oven drying	40	60.95 ± 0.33^{e}	9.65 ± 0.18^{a}	31.89 ± 0.11^{a}	11.76 ± 0.23^{f}	22.99 ± 0.00^{g}
	50	64.40 ± 0.41^{d}	7.44 ± 0.16^{b}	31.86 ± 0.03^{a}	14.83 ± 0.05^{d}	35.58 ± 0.16^{ef}
	60	60.31 ± 0.28^{e}	10.15 ± 0.04^{a}	35.25 ± 0.33^{a}	16.46 ± 0.00^{ab}	43.60 ± 1.78^{d}
Cabinet drying	40	70.79 ± 0.96^{c}	5.39 ± 0.63^{c}	34.57 ± 1.69^{a}	12.45 ± 0.00^{e}	36.96 ± 0.16^{e}
	50	73.51 ± 1.29^{b}	5.28 ± 1.10^{c}	38.65 ± 0.38^{a}	15.02 ± 0.02^{c}	52.41 ± 0.58^{c}
	60	76.81 ± 0.85^{a}	3.42 ± 0.06^{d}	35.62 ± 2.17^{a}	16.74 ± 0.00^{a}	68.35 ± 1.11^{b}

Mean values ± standard deviation of three replicates. $^{a-g}$ Means in the same column with different letters are significantly different (p<0.05) measured by Tukey's test

Senadeera *et al*. (2020) and Obadina *et al*. (2018) also observed similar findings in the drying of persimmon slices, cherry, and plum tomatoes using a convective dryer and oven, respectively. Nevertheless, lemon dried using the oven method at 40°C had the lowest L* value (60.95). This might be attributed to the extended exposure to heat, which caused the breakdown of pigments and consequent loss of colour (Fu *et al*., 2017). Meanwhile, the a* values of dried lemons showed significant differences (p < 0.05) using oven and cabinet dryer. Lemons dried with oven dryers had the highest a* values compared to lemons dried with cabinet dryers. These might be due to the degradation of limonoids and carotenoids caused by the passage of radiant heat in oven drying. In general, cabinet drying exhibited better outcomes regarding both L* and a* values (Figure 2).

As shown in Table 4, different drying methods and temperatures resulted in a substantial decrease (p<0.05) in the TPC as compared to the fresh sample. Lemon dried using in cabinet or oven dryer at 60°C obtaining the highest TPC (16.46 and 16.74 26.64 mg GAE/100 g, respectively). These results were in line with those reported by Vega-Gálvez *et al*. (2009) who studied the effect of air-drying temperature on the TPC of red pepper. These authors reported that the highest TPC was reached at 60°C, and decreased in high temperatures (70 and 80°C).

Similarly, Hihat *et al*. (2017) also reported that coriander leaves dried in the oven dryer had the highest TPC at 60°C. In terms of vitamin C content, all dried lemon slices were lower than that of fresh lemons. Lemons dried with cabinet dryer had higher vitamin C content than those dried with oven drying in all drying temperatures. This may be due to the different heat transfer mechanisms used by the two drying methods. Cabinet drying uses convection heat that leads to a more uniform distribution of thermal energy throughout the sample during drying and, therefore, reduces the hot spots forming and retains more vitamin C (Natalia *et al.*, 2018).



(a) (b)

Figure 2. Lemon dried at 40°C, 50°C, and 60°C with (a) cabinet and (b) oven dryer and packed with ALP and LDPE. (CA40= cabinet dryer at 40°C, ALP, CA50 = cabinet dryer at 50°C, ALP, CA60= cabinet dryer at 60°C, ALP, CL40= cabinet dryer at 40°C, LDPE, CL50= cabinet dryer at 50°C, LDPE, CL60= cabinet dryer at 60°C, LDPE) (OA40= oven dried at 40°C, ALP, OA50 = oven dried at 50°C, ALP, OA60= oven dried at 60°C, ALP, OL40=oven dried at 40°C, LDPE, OL50= oven dried at 50°C, LDPE, OL60= oven dried at 60°C, LDPE)

3.2 Effect of packaging materials on vitamin c content during storage

Table 5 demonstrates that dried lemon slices using a cabinet dryer at 60°C and packed in ALP packaging (CA60) had better retention of vitamin C after 12 weeks of storage (42.84 to 13.77 mg/100 g – 26% reduction) as compared to other samples. Meanwhile, the highest reduction of vitamin C after 12 weeks of storage was observed in OL50 (lemons dried with an oven dryer at 50°C packed in LDPE (35.47 to 6.21 mg/100 g – 82.49% reduction). The findings are aligned with the study by Dak *et al*. (2014) which found ALP to be better than HDPP in maintaining the acidity levels in pomegranate arils. A similar study by Niazmand *et al*. (2021) reported that LDPE exhibited a reduced level of ascorbic acid compared to oriented polypropylene (OPP). The decrease in vitamin C content in all dried lemons is due to the formation of dehydroascorbic acid and the capacity of packaging materials to allow oxygen to get through and oxidise the vitamin C. Moreover, packaging transparency may enable the light source to penetrate the material, thus triggering vitamin C degradation (Yue *et al.*, 2021).

3.3 Effect of packaging materials on total phenolic content during storage

As shown in Table 6, the TPC decreased considerably ($p<0.05$) in all samples after 12 weeks of storage. Sample CA50 and CL50 (dried lemon using a cabinet dryer at 50°C and packed with ALP and LDPE, respectively) exhibited the lowest loss of TPC (10.72% and 10.71%) as compared to other samples. Although ALP provides an excellent barrier towards light and oxygen penetration, enzymes that are naturally present in lemon slices would be one of the factors that degrade the phenolic compounds during storage. Besides, variations in heat transmission before storage may affect the food's molecules and may cause localized warming and the disintegration of phenolic compounds (Miranda *et al.*, 2019).

Table 5. Effect of the packaging materials on the vitamin C of dried lemon slices during storage

Samples	Drying methods	Temperature (°C)	Packaging materials	Vitamin C (mg/100g) Storage period (weeks) 0	4	8	12	Vitamin C reduction (%)
OA40	Oven drying	40	ALP	22.99 ± 0.20[a]	11.34 ± 0.10[b]	8.04 ± 0.15[cd]	6.89 ± 0.10[d]	70.03
OL40			LDPE	22.99 ± 0.10[a]	10.96 ± 0.26[b]	7.82 ± 0.10[bc]	5.30 ± 0.06[d]	76.95
OA50		50	ALP	35.47 ± 0.06[a]	22.27 ± 0.15[bc]	15.51 ± 0.10[d]	11.34 ± 0.10[e]	68.03
OL50			LDPE	35.47 ± 0.06[a]	15.36 ± 0.06[c]	9.50 ± 0.10[d]	6.21 ± 0.06[e]	82.49
OA60		60	ALP	35.47 ± 0.10[a]	22.27 ± 0.15[bc]	15.51 ± 0.31[c]	11.34 ± 0.10[e]	68.03
OL60			LDPE	22.99 ± 0.66[a]	15.36 ± 0.10[b]	9.50 ± 0.10[cd]	6.21 ± 0.10[e]	72.99
CA40	Cabinet drying	40	ALP	42.84 ± 0.06[a]	28.59 ± 0.12[bc]	17.20 ± 0.15[cd]	13.77 ± 0.20[e]	67.86
CL40			LDPE	41.36 ± 0.06[a]	27.38 ± 0.15[bc]	16.27 ± 0.12[c]	9.86 ± 0.10[d]	76.16
CA50		50	ALP	56.20 ± 0.16[a]	46.66 ± 0.06[ab]	35.02 ± 0.11[c]	28.99 ± 0.06[c]	48.42
CL50			LDPE	52.00 ± 0.15[a]	38.00 ± 0.10[b]	26.78 ± 0.06[bc]	21.03 ± 0.15[c]	59.56
CA60		60	ALP	64.47 ± 0.15[a]	52.00 ± 0.21[bc]	42.59 ± 0.12[cd]	39.19 ± 0.06[de]	39.21
CL60			LDPE	63.56 ± 0.06[a]	45.37 ± 0.10[b]	32.37 ± 0.06[c]	27.38 ± 0.15[d]	56.92

Mean values ± standard deviation of three replicates. [a-e] Means in the same row with different letters are significantly different ($p<0.05$) measured by Tukey's test

Table 6 Effect of the packaging materials on the total phenolic content (TPC) of dried lemon slices during storage

Samples	Drying methods	Temperature (°C)	Packaging materials	Total phenolic content (mg GAE/100g) Storage period (weeks)				TPC reduction (%)
				0	4	8	12	
OA40	Oven drying	40	ALP	11.78 ± 0.01^{abc}	10.79 ± 0.04^{abc}	10.28 ± 0.03^{abc}	10.14 ± 0.02^{bc}	13.92
OL40			LDPE	11.74 ± 0.13^{abc}	10.32 ± 0.01^{abc}	10.08 ± 0.03^{abc}	9.94 ± 0.02^{bc}	15.33
OA50		50	ALP	14.79 ± 0.17^{abc}	13.40 ± 0.04^{abc}	12.68 ± 0.04^{abc}	12.04 ± 0.03^{abc}	18.59
OL50			LDPE	14.86 ± 0.02^{abc}	13.11 ± 0.04^{abc}	12.13 ± 0.03^{abc}	11.68 ± 0.02^{abc}	21.40
OA60		60	ALP	16.46 ± 0.03^{ab}	15.07 ± 0.03^{abc}	14.40 ± 0.06^{bc}	13.94 ± 0.07^{bc}	15.31
OL60			LDPE	16.45 ± 0.02^{abc}	14.61 ± 0.05^{abc}	14.00 ± 0.03^{abc}	13.16 ± 0.01^{abc}	20.00
CA40	Cabinet drying	40	ALP	13.45 ± 0.02^{abcd}	12.44 ± 0.05^{abcd}	12.18 ± 0.02^{bcd}	11.04 ± 0.04^{cd}	17.92
CL40			LDPE	13.44 ± 0.02^{abc}	11.91 ± 0.05^{abc}	11.37 ± 0.03^{abc}	10.66 ± 0.02^{bc}	20.68
CA50		50	ALP	15.03 ± 0.03^{abc}	13.84 ± 0.01^{abc}	13.53 ± 0.03^{abc}	13.42 ± 0.02^{abc}	10.72
CL50			LDPE	15.03 ± 0.02^{abc}	13.84 ± 0.04^{abc}	13.53 ± 0.03^{abc}	13.42 ± 0.03^{abc}	10.71
CA60		60	ALP	16.74 ± 0.04^{ab}	15.38 ± 0.04^{abc}	14.76 ± 0.02^{abc}	14.50 ± 0.03^{abc}	13.38
CL60			LDPE	16.73 ± 0.02^{abc}	14.43 ± 0.06^{abc}	13.81 ± 0.03^{bc}	13.46 ± 0.02^{bc}	19.55

Conclusion

This study explored the effect of two different drying conditions and packaging materials on the quality and stability of vitamin C and total phenolic content during 12 weeks of storage. The results revealed that different drying methods and temperatures significantly affected the total phenolic and vitamin C content, lightness, and redness values of the dried lemons. Findings from storage stability of the dried lemons discovered that drying using a cabinet dryer at 50 to 60°C and packing using ALP or LDPE had the lowest TPC and vitamin C reduction.

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