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Effect of Addition Loquat (*Eribotrya japonica*) Seed Powder Extract as a Natural Bioactive Compound on The Quality Characteristics of Goat Meat Nuggets During Refrigerated Storage – Part I

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ABSTRACT

The current study aims to evaluate adding powdered loquat seed to goat meat nuggets affects quality characteristics. According to the results, loquat seed extract had a highly significant amount of protein and total dietary fibre, with values of 31.35 and 27.24, respectively. Moreover, a high amount of phosphorus, potassium, magnesium, calcium, and sodium were 442.48, 401.47, 220.14, 207.69, and 124.22 mg/100g, respectively, and a considerable amount of iron, zinc, and copper. In addition, 1.77 and 0.94 mg/100 g of vitamins C and E, respectively. The TPC, TFC, and TTC of loquat seed extract were 9.15 mg GAE g-1, 31.58 mg QE g-1, and 15.11 mg TAEs g/100 g DW, respectively. This study evaluated the use of loquat seed as a natural antioxidant in goat meat nuggets by replacing loquat seed powder with wheat flour at 3 different levels (3.3, 6.6, and 10%). Adding loquat seed powder resulted in less reddish and darker, more yellowish goat nuggets. The T3 obtained the highest cooking yield (91.27%). Loquat seed powder prevented lipid oxidation in goat meat nuggets to the same extent as the synthetic antioxidant, demonstrating potential as a natural antioxidant. These results suggest that extract from loquat seed can significantly retard the oxidation process of food products, which will enhance their quality and prolong their shelf life.

***Keywords*:** Loquat seed extract, antioxidant, goat meat nuggets, quality characteristics, shelf life.

INTRODUCTION

The waste product of *Eribotrya japonica* (loquat fruit) is loquat seed (Zhang, et al. 2021). The Rosaceae family includes the loquat (*E. japonica*) or Japanese plum (Erdal and Taskin 2010, Taskin and Erdal 2011). It originated in south-eastern China and eventually spread to many other countries, including Japan and India (Allam 2022, Kazmi, et al. 2023). Loquat seed have the largest concentration of polyphenols and exhibit the strongest anti-lipid oxidation activity (Perea-Moreno, et al. 2020, Shabaani, et al. 2020, Wang, et al. 2023). Loquat seed contain such active constituents as tannins, flavonoids, and amygdalin (Zhou, et al. 2011, Costa, et al. 2022, De Girolamo, et al. 2022, Dhiman, et al. 2022, Sheikha, et al. 2022). Meat has been an essential component of human nutrition and has played an important role in human evolution since the beginning of time. Meat is an integral component of a healthy and well-balanced diet because of its nutritional superiority over plant-based alternatives (Floros, et al. 2010, Allam, et al. 2021, Mariamenatu and Abdu 2021, Vlaicu, et al. 2022). It also contains significant amounts of vitamins, including niacin, thiamine, riboflavin, and other B-complex group vitamins, as well as essential fatty acids such as linoleic, linolenic, and oleic acids. It also contains a significant nutritional protein rich in minerals (except calcium), particularly the easily absorbable iron and essential amino acids (Lovell 1989, Williams 2007, Marangoni, et al. 2015, Ahmad, et al. 2018). Regular meat consumption improves health, which could be used as a powerful weapon in the battle against malnutrition and a lack of micronutrients (Stoltzfus and Dreyfuss 1998, Tontisirin, et al. 2002, Bouis and Welch 2010, Miller and Welch 2013, Allam and Dolganova 2017, Cashman 2020, Kandil, et al. 2020). Additionally, harmful microbes tend to contaminate the meat. Meat undergoes physical, chemical, and sensory alterations due to the growth and multiplication of these bacteria, which also increases the risk of serious infections from foodborne pathogens (Singh, et al. 2019, Singh and Mondal 2019, Allam, et al. 2021, Marmion, et al. 2021). But even with refrigeration, meat is a specific perishable item that needs to be handled properly to increase its shelf life. Meat deterioration is influenced by various elements, such as composition, ingredients, light, air, and temperature (Gill 1996, Dave and Ghaly 2011, Rawat 2015, Karrar, et al. 2022, Ren, et al. 2022, Tomaszewska, et al. 2022, Tyuftin and Kerry 2023). The main cause of the oxidative degradation of meat is protein and lipid oxidation. Membrane triglycerides include unsaturated fatty acids, while phospholipids and meat proteins are highly oxidizable. The main cause of meat's undesired changes in texture, flavor, color, and appearance, as well as its decreased nutritional value, is largely the oxidation of meat (Amaral, et al. 2018, Domínguez, et al. 2019, Pateiro, et al. 2019, Sultana, et al. 2022, Shivakumar, et al. 2023). Due to several bioactive components, loquat seed have a promising role in foods and pharmacological industries (Fig. 1). Thus, this study's objective was to estimate the nutritional values and quality characterizations of loquat seed extract and evaluate the antioxidant activities via determining the lipid oxidation in goat meat nuggets stored at 4 °C for 15th days.

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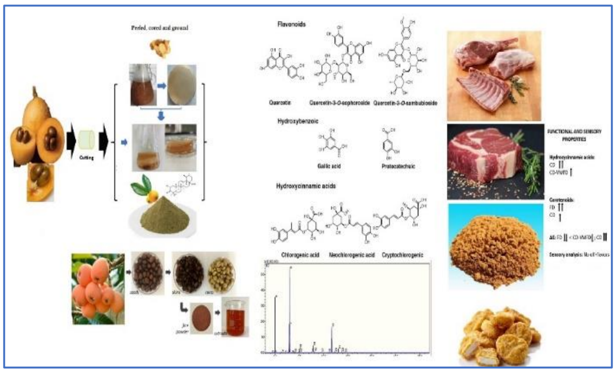

Fig. 1. Graphic abstract

MATERIALS AND METHODS

1. Materials

Loquat (*E. japonica*) fruits were purchased from the El Basatine Research Center in El-Kanatir Al-khairiyah, Qalyubiyah Gove., Egypt, at the stage of commercial maturity. Sunflower oil without antioxidant compounds was obtained from Oil and Soap Co., Cairo-Egypt. Rreagent of Folin-Ciocalteu, gallic acid and DPPH (2,2-diphenyl-1-picrylhydrazyl) were purchased from Sigma Chemical Co., Ltd. (St. Louis, USA). Fresh goat meat and fat were both obtained from a local market under the required criteria and then were transported to the Meat Products Laboratory at the Faculty of Agriculture, Menoufia University, Shibin El Kom, Egypt.

Preparation of Loquat seed powder

To prepare loquat (*Eriobotrya japonica*) seed powder, the seed were selected, sanitized with a 2.5% sodium hypochlorite solution, and then rinsed in water. Afterward, the seed were ground with the peel in a food processor and dried in an air-circulating oven (Shel-lab, USA) at 40 °C for 7 hours until constant weight. They were ground with an analytical mill (Model 3510, Jenway Technology, Italy), sieved up to 40 mesh, stored in plastic packaging in a dark place at room temperature, and kept in a dry and ventilated place until analysis. For 4 hours at room temperature (25 2 °C), 250 gm of sieve-size powder was homogenized with 1000 ml of distilled water (w/v) in a 2-liter Erlenmeyer flask using a magnetic stirrer. After filtering the crude aqueous extract through the Whatman paper (No. 1), we collected and lyophilized the filtrate. The lyophilized extract was kept at -18 ± 2 °C until utilization.

Determination of the chemical composition of loquat (*E. japonica*) seed

Moisture, protein, fat, and total ash contents of loquat seed powder were determined according to the described methods in the AOAC, 2005 (Horwitz 2000). Carbohydrates were calculated by difference. The determination of minerals content such as potassium, sodium, calcium, magnesium, phosphorus, zinc, iron, and copper in Loquat seed, according to AOAC, 2005.

Quantification of Vitamin

Using HPLC Agilent system (Chrastany u Prahy, 2000 ECOM, CZ 252 19, USA) at 254 nm with detection of UV, vitamin C and E concentrations in loquat seed extracts were measured. Analytical column C18 (YMC-Triart 4.6 × 150 mm) with a mobile phase of 33/67 (A/B), A: potassium acetate (0.1M), distilled water (50:50), pH (4.9), and 1 mL/min flow rate at room temperature was used for the measurement of vitamin C. A Luna phenomenex chromatography column (Si100- 4 x 250 mm, 5 L) and a Phenomenex (Si100- 3 x 4 mm) protection column were used to identify vitamin E, and the mobile phase consisted of hexane, isopropanol, and glacial acetic acid (98.9:0.6:0.5, v/v/v). Flow rate 1.0 mL/min and 22 min run time (Diack and Saska 1994).

Determination of pH value

Using a pH meter (Jenway Digital - Model 3500), the pH value was calculated using a 10% dispersion of samples in distilled water following the technique reported by (Fernández-López, et al. 2008).

Determination of radical scavenging activity ($ABTS^{+}$, DPPH, and FRAP)

By decreasing iron (Fe2+) and iron (Fe3+) in loquat seed extracts, the FRAP reagent maintained antioxidant activities (Deng, et al. 2012, Shabaani, et al. 2020). The *$ABTS^{+}$* assay was determine according to the stabilization of the ABTS+ radical cation (Jia, et al. 2012). The DPPH analysis depends on antioxidants' ability to reduce the effects of a stable free radical (DPPH-) and, consequently, decrease color intensity. Because it has an odd electron, this radical gives off a deep purple hue that fades out in the absence of an antioxidant (Choi, et al. 2002). Evaluated the capacity of the samples to effectively scavenge 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals following (Nanjo, et al. 1996). The DPPH test assessed the antioxidant ability of the 0.1 Mm DPPH radical in ethanol solution. The absorbance at 519 nm was determined after 20-minute incubation at room temperature. According to the following equation, the inhibitory DPPH (%) was calculated:

DPPH inhibitory (%) = (Abs. C – Abs. S) / (Abs. s) × 100

Determination of total phenolic contents (TPC)

Using a stirrer benchtop lab (Heidolph, Germany), 100 ml of ethanol solution (0%–75%) and 5 gm of powdered dry loquat seed were blended to extract the polyphenolic compounds. The stirring was performed at maximum speed for 30–60 minutes. At room temperature, three times of each extraction experiment were performed. For further investigation, the extract was filtered and stored at 4 °C. According to the approach of Ozsoy et al., the total phenolic contents (TPC) of loquat extracts were assessed (Maher, et al. 2015) with some modifications. Each dried extract (100 g/mL) dissolved in 10 mL of its own solvent (1 mg/mL) at a rate of 10 mg/mL. A 5 mL volumetric flask containing 0.2 mL of extract was filled with 3 mL of deionized water and stirred. Folin-reagent Ciocalteu's was added and stirred after 0.25 mL was added. After 3 minutes, 0.75 mL of a 20% (w/v) na2co3 solution were added and stirred. To make the volume exactly 5 mL, deionized water was added. After fully mixing the solution, it was let to remain at room temperature for 2 hours until the solution's distinctive blue hue appeared. A spectrophotometer was used to test the reaction mixture's absorbance at 760 nm (SCHOTT Instruments, UviLine 9400, EU). The TPC was calculated in mg GAE /g DW (mg of gallic acid) equivalents (GAEs).

Determination of total flavonoid contents (TFC)

According to the method (Sakanaka, et al. 2005) described Briefly, 5 mL of distilled water, 0.3 mL NaNO2, and 0.5 mL of extract (5 mg/mL) were added to a 10 mL volumetric flask (1:20). Alum chloride (1:10) in a volume of 3 mL was added after five minutes. Following the addition of

2 mL of sodium hydroxide (4%) after 6 minutes, distilled water was used to bring the total volume to 10 mL. Using a spectrophotometer, the solutions' absorbance was measured against a blank at 510 nm after all components had been well mixed (SCHOTT Instruments, UviLine 9400, EU). In terms of mg quercetin equivalents (QEs) per g of extract, the TFC (total flavonoid content) was assessed.

Determination of tannic acid contents (TTC)

Potassium iodide (2.5%; 5 mL) and loquat extracts (1 mL) were mixed, and then the container was closed and placed in a water bath at 30 °C (10 min). At 590 nm absorbance, tannic acid equivalents (TAEs) were calculated as mg TAEs g/100 g DW (Maher, et al. 2015).

HPLC analysis

Using HPLC technology Agilent 1260 series, the optimal loquat extract was assessed (Agilent Technologies Inc. CA, USA). A C18 column (4.6 mm × 100 mm i.e., 5 µm) was used for the separation. At a flow rate of 0.6 ml/min, the mobile phase was constituted of (A) water containing 0.2% H_3PO_4, (B) methanol, and (C) acetonitrile. Gradient elution followed this formula: 96% A, 2% B (0–11 min), 50% A, 25% B (11–13 min), 40% A, 30% B (13–17 min), 50% B, 50% C (17–20.5 min), and 96% A, 2% B (20.5–30 min). The detecting wavelength was calibrated to 284 nm. The column temperature was maintained at 30 °C, and the injection volume was 20 µl. By correlating their retention times with those from authentic standards, compounds were identified. To calculate the ingredient amounts, calibration curves were utilized.

2. Application of loquat seed powder extract

Preparation of goat meat nuggets

The formulas Nuggets of goat meat are shown in table (1). Mixed the minced goat meat with skim milk powder, wheat flour, garlic, salt, dried onion, and pepper powder (Bintoro, 2008). The mixture was served as (a control sample). Then, replay the same method with loquat seed powder for wheat flour at various levels 0.00% (Control), 3.3% (T1), 6.6% (T2), and 10% (T3), and then mix to create a homogeneous meat mixture (Sakanaka, et al. 2005, El-Gammal, et al. 2018). A formulation with 0.25% synthetic antioxidant sodium erythorbate (SET) was also prepared (Sakanaka, Tachibana et al. 2005). The resulting mixture was frozen for five minutes. The shape size of goat nuggets was round and molded into dimensions of 5 cm in diameter and approximately 1 cm in height, and they were coated with medium grain industrial breadcrumbs. Goat nuggets were shaped and cooled for 15 min at 5 ºC. Samples were kept until analysis in plastic bags. The goat nuggets are then deep-fried to preserve their shape after being pre-fried in sunflower oil for 1 minute at 180°C (standard procedure). The replicates of each treatment were placed in zip-top bags and frozen at -18 °C after cooling to room temperature. Then, all treatments were analyzed in triplicate on days 0, 4, 8, and 12th days of the storage at 4 °C. The quality indices, lipid oxidation, and texture profile analysis of nuggets formula were examined.

Evaluation of lipid oxidation

Using the distillation method for thiobarbituric acid-reactive compounds (TBARS), the products of secondary lipid oxidation were measured. The TBARS values were determined in triplicate samples by the extraction method of Kandil, et al. (2020). The results were calculated as mg MDA/kg meat from the standard curve of the TEP (1,1,3,3 – tetraethyloxypropane) parameters.

Table 1. Formula for goat meat nugget ingredients (g/100g).

Ingredients (g)	Treatments (T)				
	Control	SET	T1	T2	T3
Goat meat	80	80	80	80	80
Wheat flour	8	8	5.30	2.60	0
Loquat powder	0	0	2.70	5.40	8
Sodium erythorbate	0	0.25	0	0	0
Skim milk powder	8	8	8	8	8
Dried garlic	1.4	1.4	1.4	1.4	1.4
Sodium chloride	1.0	1.0	1.0	1.0	1.0
Pepper powder	0.8	0.8	0.8	0.8	0.8
Dried onion	0.8	0.8	0.8	0.8	0.8

3. Statistical analysis

The statistical programme SAS version 9.4 and Microsoft Excel program (2019) were used to examine the data analysis. Three triplicates of the experiment were performed. Results were presented as mean standard deviation. The impacts of the parameters under study were shown to be significant by using ANOVA two-way and Tukey's test. The degree of relationship between variables was estimated as the Pearson correlation coefficient (Addinsoft, XLSTAT 2020.5.03, program, USA). A two-way analysis of variance was used to evaluate the data for multiple variable comparisons (ANOVA). Duncan's test was run on the findings of physicochemical and microbiological studies to identify the statistically significant variations between storage regimens. The 95% confidence level ($P \leq 0.05$) was used to determine the statistical significance.

RESULTS AND DISCUSSION

1. Fundamental extraction tests

Proximate composition, mineral, vitamin contents, total phenolic and flavonoids compounds, and antioxidant activity of loquat (*E. japonica*) seed powder *(Table 2)* included (68.12 ± 0.15) carbohydrates, which is the primary component of its structure and matrix.

Other publications have reported similar results, with carbohydrates ratios ranging from 60 to 79.39% (Costa, et al. 2023). The protein, lipids, and ash content values were 6.20 ± 0.03, 1.22 ± 0.78, and 5.48 ± 0.19, respectively. Given that the resultant powder has a moisture content of 8.98 ± 0.21, it can be classified as flour and conforms with the applicable legal requirements, providing a maximum value of 15% (Delfanian, et al. 2015, Georgiadou, et al. 2018, Cares-Pacheco and Falk 2023, Costa, et al. 2023, Simona, et al. 2023). Numerous studies on natural products have shown that phenolic compounds are particularly responsible for their antioxidant activities. Various investigations on antioxidants are presently being performed because, in addition to their importance in protecting edible foods, they may prove helpful in treating food spoilage where oxidative stress is implicated. The total phenolic compounds content in loquat extract (9.15 ± 1.12 mg GAE g^{-1}) and total tannin (15.11 ± 0.25 mg TAEs g/100 g DW) (Table 1) were similar to the values found by (Okatan, et al. 2022, Mwamatope, et al. 2023), of 7.89 mg GAE g^{-1} and (Sagar, et al. 2018), with 6.75 mg GAE g^{-1}. Loquat seed extract showed a total flavonoid compound of 31.58 ± 0.83 mg QE g^{-1} (Table 1). These studies also used ethanol as the extracting solvent. The solvent employed is important because the phenolic compounds in loquat extract are polar and poorly soluble in water (Herrero, et al. 2010, Rykowska, et al. 2018). This value was higher than that obtained by (Koba, et al. 2007, Silva, et al. 2020) of 4.30 mg QE g^{-1}, who evaluated loquat seed extract using a 70% ethanol and 0.1% formic acid solution. Our extract contains a high concentration of monoterpenes, including 1,8-cinéole, α -pinene, Coumaric acid, limonene, and linalool, which impacts its antioxidant activity. Previous studies have tested each of these compounds individually and found low antioxidant activity (Martínez-Valverde, et al. 2002, Djeridane, et al. 2006, Al Jumayi, et al. 2022). In contrast, this extract contains a high concentration of phenolic compounds, including carvacrol and thymol, which have significant ($p < 0.05$) antioxidant potential. Loquat seed extract had high ABTS, DPPH, and FRAP activities by 4.125 ± 0.11, 46.81 ± 3.57, and 4.125 ± 0.11 mmol TEAC/g DW, respectively. According to (Raghavi, et al. 2018, Al Jumayi, et al. 2022), reconstituted freeze-dried loquat extract had greater values (85.0 mg QE g-1); however, (Teixeira, et al. 2022) observed comparable values (10.09 mg QE g^{-1}) for loquat extract powder. This result was expected because the dried extract was used rather than the crude filtrate. The antioxidant capacity was *46.81 ± 3.57,* inhibited by the DPPH methodology (Table 2). This value is two times higher than those found in the traditionally dried loquat extract powder reported by (Mlyuka, et al. 2016, Cardoso, et al. 2022). It's possible to preserve the antioxidant components involved in oven-drying loquat extract at a low temperature (50 °C). The loquat flour had a dark ($L^* = 60.54 \pm 1.86$) and yellowish ($b^* = 52.32 \pm 2.13$) color, which is likely because the peel was used in its manufacture (Table 1). Phosphorus, potassium, magnesium, calcium, and sodium 442.48 ± 4.21, 401.47 ± 3.14, 220.14 ± 1.48, 207.69 ± 1.48, and 124.22 ± 1.22 mg/100g, respectively, represent the abundant mineral content of loquat seed. Meanwhile, iron, zinc, and copper were the lowest (8.16 ± 0.17, 4.52 ± 0.47, and 3.13 ± 0.14 mg/100g, respectively). Loquat seed contained 1.77 ± 0.51 and 0.94 ± 0.11 mg/100 g of vitamins C and E, respectively.

Table 2. Proximate composition, total phenolic and flavonoid compound content, DPPH and FRAP assays, and flour color (*L, *a**, and *b**) of loquat (*E. japonica*) seed powder.**

Parameter		**Loquat (*E. japonica*) seed powder**
Proximate composition	Moisture (g 100 g-1)	8.98 ± 0.21
	Proteins (g 100 g-1)	31.35± 0.03
	Total lipid (g 100 g-1)	17.64± 0.78
	Ash (g 100 g-1)	5.48 ± 0.19
	Carbohydrates (g 100 g-1)	68.12 ± 0.15
	Crude fibers (%)	27.24 ± 2.41
	Soluble dietary fibers (%)	17.98 24 ± 2.82
	Insoluble dietary fibers (%)	10.26 ± 1.45
Total phenolic and flavonoid compound content	Total phenolic compounds, (mg GAE g-1)	0.98± 1.12
	Total flavonoid compounds, (mg QE g-1)	31.58 ± 0.83
Total tannin (mg TAEs g/100 g DW)		15.11 ± 0.25
Radical scavenging activity ($ABTS^+$)		4.125 ± 0.11
% Inhibition (DPPH)		46.81 ± 3.57
FRAP (mg QE g -1)		9.11 ± 0.70
Flour color	*L**	60.54 ± 1.86
	*a**	10.42 ± 1.31
	*b**	52.32 ± 2.13
Mineral content (mg/100g)	Phosphorus	442.48 ± 4.21
	Potassium	401.47 ± 3.14
	Magnesium	220.14 ± 1.48
	Calcium	207.69 ± 1.48
	Sodium	124.22 ± 1.22
	Iron	8.16 ± 0.17
	Zinc	4.52 ± 0.47
	Copper	3.13 ± 0.14
	Vitamin C	1.77 ± 0.51
	Vitamin E	0.94 ± 0.11

Note:

- Values are presented as mean ±SD (n=3). Color parameters: *lightness (L^*), redness (a^*) and yellowness (b^*).* ABTS+; [2,2 V-azinobis (3-ethylbenzothiazoline-6-sulfonic acid)

2. HPLC

Using HPLC, the phenolic components of the loquat (*E. japonica*) extract prepared at optimal conditions were identified and quantified (Table 3 and Figure 2).

According to their elution sequence, the compounds are presented in Table (3) alongside the common chemical profile of the evaluated extract, retention indices, percentage content (%) of each component, and chemical class distribution of the phenolic compounds. The total numbers of detected components were twenty-three compounds, representing 99.99% of the total detectable constituents. The major investigated phytochemicals compounds were 1.8 cinéole (41.24 %), a-pinene (15.22 %), D-limonene (15.371 %), mystery acetate (14.35 %), Propionic acid, 2-methyl-, 2-methyl propyl ester (13.284%), Rosmarinic acid (11.484 %), o-Coumaric acid (11.025 %), Resveratrol (5.031 %), and Quercetin (4.015%) (Delfanian, et al. 2015, Kim, et al. 2022), which showed significant DPPH radical scavenging properties ($p < 0.05$). Other components were detected in less than 4%. Therefore, the significant *($p < 0.05$)* antioxidant activity of the produced extracts could be attributable to their phenolic component content and their synergistic interaction with other components of the same extract (Pellegrini, et al. 2003, Costa, et al. 2021).

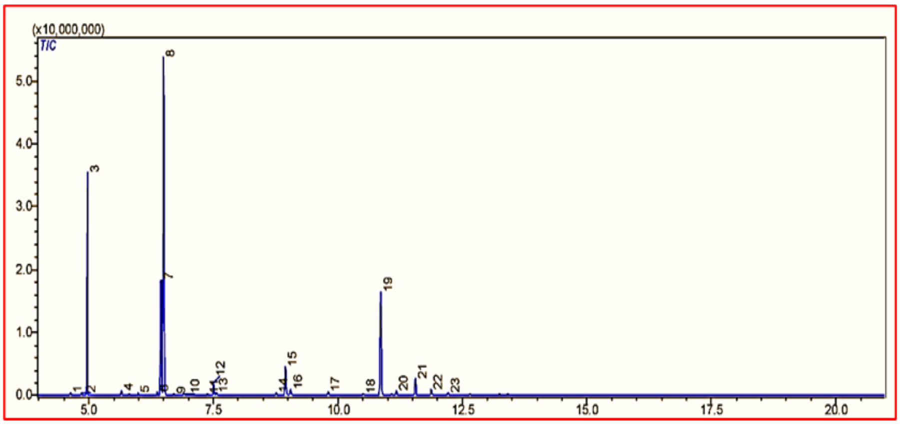

Figure 2. HPLC profile of phenolic compounds in loquat (*Eriobotrya japonica*) extract

Table 3. Phenolic compounds of loquat (*Eriobotrya japonica*) extract.

Compounds	RT %	Area
1. Gallic acid	4.533	0.265
2. Propionic acid, 2-methyl-, 2-methyl propyl ester	4.633	13.284
3. Catechin	4.857	0.185
4. Chlorogenic acid	4.975	0.454
5. α-Pinene	4.975	15.224
6. Vanillic acid	5.565	2.245
7. Caffeic acid	5.899	0.158
8. Syringic acid	6.274	0.175
9. p-Coumaric acid	6.345	13.48
10. D-Limonene	6.450	15.371
11. 1,8-cinéole	6.500	41.241
12. Benzoic acid	6.501	0.168
13. Ferulic acid	6.604	0.148
14. Rutin	7.375	3.024
15. Ellagic acid	7.908	0.178
16. o-Coumaric acid	7.553	11.025
17. Resveratrol	9.254	5.031
18. Quercetin	9.058	4.015
19. Rosamultic acid	9.807	11.484
20. Naringenin	10.507	10.175
21. Myricetin	10.859	3.258
22. Kaempferol	11.178	2.158
23. α -Terpineol	8.950	3.810

3. Evaluation of the goat meat nuggets

The approximate chemical composition of the raw goat meat nuggets was adequate (Table 4). Each formulation had fat content below 23%, protein content above 15%, and total carbohydrate content below 3%, all of which were required by Egyptian legislation (Tamime, et al. 2014, Hall, et al. 2017, El Zokm, et al. 2021). The amounts of moisture, protein, and ash were not comparable among formulations (p > 0.05). Additionally, the performances in the treatments, including the T2 and T3 samples, had the highest lipids, followed by the T1 sample, which wasn't different from the others. Since loquat flour is rich in lipids, the higher lipid content was likely attributable to intrinsic differences in the raw materials. The formulations had no variations ($p \geq 0.05$) in pH values. The values have been between 6.00 and 6.11 (Table 4). In terms of cooking yield (Table 5), SET and T2 achieved the highest values on day 1st, while Control formulation demonstrated the lowest yield ($p < 0.05$). While control samples showed lower yields, T3 yield values were significantly higher ($p \leq 0.05$) or equal to those of the other formulations in the durations of 5, 10, and 15 days ($p < 0.05$). Due to the high carbohydrate content of loquat flour, the addition likely enhanced the yield. The ability of the soluble flour fibers to gel-forming may have positively influenced the final patty's stability and water-holding capacity (Borderías, et al. 2005, Kim and Paik 2012). All formulations, except for T3 samples, demonstrated a reduction in yield throughout the 5th and 10th days of storage compared to the beginning periods (1 and 15th days). But there was no reduction seen after the 15th day. With the exception of the control formulation, which had more shrinkage on the 10th day of storage, there was no difference ($p \geq 0.05$) in the percent shrinkage of the meat nuggets among the formulations. Regarding color, T3 sample on the first day were darker than SET but were the same as control sample and the other samples using loquat flour (Table 6).

Table 4. Approximate chemical composition (At 0 time) of goat meat nuggets prepared with *loquat (E. japonica)* extracts during cold storage at 4 ºC for 15 days.

Parameter	Goat meat nuggets				
	Control	SET (Negative control)	T1	T2	T3
Moisture (g 100 g-1)	71.13 ± 0.30 ^{a}	71.16 ± 0.50 ^{a}	69.81 ± 0.59 ^{a}	69.60 ± 0.79 ^{a}	70.66 ± 0.61 ^{a}
Proteins (g 100 g-1)	15.64 ± 0.42 ^{a}	15.92 ± 0.37 ^{a}	16.00 ± 0.72 ^{a}	16.02 ± 1.45 ^{a}	16.02 ± 0.46 ^{a}
Lipids (g 100 g-1)	9.59 ± 0.29 ^{a}	9.34 ± 0.57 ^{a}	9.53 ± 0.72 ^{a}	10.10 ± 0.85 ^{ab}	10.98 ± 0.70 ^{b}
Ash (g 100 g-1)	2.69 ± 0.01 ^{a}	2.71 ± 0.06 ^{a}	2.74 ± 0.14 ^{a}	2.80 ± 0.05 ^{a}	2.78 ± 0.04 ^{a}
Carbohydrates (g 100 g-1)	0.94 ± 0.15 ^{a}	0.87 ± 0.59 ^{a}	1.35 ± 0.42 ^{a}	1.34 ± 1.97 ^{a}	1.01 ± 0.20 ^{a}
pH	6.10 ± 0.05 ^{a}	6.07 ± 0.04 ^{a}	6.00 ± 0.09 ^{a}	6.04 ± 0.05 ^{a}	6.11 ± 0.03 a

Note:
- Values are presented as mean ±SD (n=3). a-b by various small letters in the same row, the Tukey test shows a significant difference ($p \leq 0.05$) between the means followed. A-C by various small letters in the same row, the Tukey test shows a significant difference ($p \leq 0.05$) between the means followed.

As did (Karpińska and Draszanowska 2019, Negrão, et al. 2023), who reported L^* of 59.21 for chekien meat nuggets treated with sodium erythorbate (Martinez, 2003) observe comparable L^* values (54.15) while analyzing rabbit patties with 3.5% loquat flour. In comparison to the Control and SET samples, T2 samples were lighter after 15th days of storage. However, The formulations prepared with loquat flour were the darkest on the 10th day. At 15th days, L^* was approximately 54 in all samples other than the Control samples, and there was no difference ($p \geq 0.05$). Due to the color of the flour, the addition of loquat flour generally caused the patties to be brown (Table 1 & 6). At all investigated times, T1, T2, and T3 had less reddish values for the a^* parameter when compared to the control samples and SET formulations ($p \leq 0.05$). According to (Allam, et al. 2021, Gao, et al. 2021), who examined raw meatballs using 0.5% loquat extract, they observed similar results. This is a result of the flour's low a^* value. Compared to the control samples and SET formulations, T1, T2, and T3 were more yellowish regarding the b^* parameter ($p \leq 0.05$). When examining raw meatballs with 1% loquat extract, (Gao, et al. 2021) observed higher average b^* values (26.75) than those found in the present study, most likely because of the higher concentration of loquat extract utilized. Small color changes were noticed throughout storage time, however, T3 stayed unchanged.

Table 5. Percent cooking yield and shrinkage of goat meat nuggets prepared with loquat *(E. japonica)* extracts during cold storage at 4 ºC for 15 days.

Parameter	Period (days)	Goat meat nuggets				
		Control	SET (Negative control)	T1	T2	T3
Cooking yield (%)	0th day	83.61 ± 0.45 dA	88.92 ± 0.67 abA	86.81 ± 0.41 cA	89.45aA ± 0.52	87.47 ± 0.48 bcA
	5th day	83.66 ± 0.98 bA	84.39 ± 0.50 bB	86.63 ± 0.66 abA	88.26 ± 0.81 aAB	86.02 ± 1.43 abA
	10th day	73.80 ± 0.58 bB	74.92 ± 0.80 abC	78.11 ± 1.41 abC	79.81 ± 1.07 abC	84.34 ± 7.01 aA
	15th day	83.89 ± 0.72 bcA	82.87 ± 1.16 cB	82.13 ± 0.32 cB	87.11 ± 0.23 bB	91.27 ± 0.72 aA
Shrinkage (%)	0th day	12.92 ± 0.84 aA	13.35 ± 0.97 aA	13.53 ± 1.86 aA	13.06 ± 1.07 aA	11.35 ± 0.82 aA
	5th day	13.93 ± 0.30 aA	13.06 ± 1.15 aA	13.46 ± 1.93 aA	12.84 ± 1.18 aA	13.20± 0.86 aA
	10th day	15.97 ± 0.42 aB	15.74 ± 0.94 aA	15.99 ± 1.39 aA	15.16± 0.50 aA	13.10 ± 2.79 aA
	15th day	13.31 ± 0.99 aA	13.30 ± 1.41 aA	14.87 ± 1.08 aA	14.64± 1.03 aA	11.35± 0.57 aA

***Note*:**

- Values are presented as mean ±SD (n=3). a-b by various small letters in the same row, the Tukey test shows a significant difference (p ≤0.05) between the means followed. A-C by various small letters in the same row, the Tukey test shows a significant difference (p ≤0.05) between the means followed.

Table 6. Color parameters L^*, a^*, and b^* of goat meat nuggets prepared with *loquat (E. japonica)* extracts during cold storage at 4 ºC for 15 days.

Parameter	Period (days)	Goat meat nuggets				
		Control	SET (Negative control)	T1	T2	T3
L^*	0th day	57.30 ± 3.37 abA	58.25 ± 1.18 aA	57.07 ± 1.83 abA	56.11 ± 1.88 abA	54.51 ± 2.33 bA
	5th day	56.12 ± 1.14 aA	56.75 ± 1.85 aA	55.23 ± 1.83 abAB	53.60 ± 1.59 bB	54.48 ± 2.60 abA
	10th day	55.56 ± 1.66 abA	56.31 ±1.85 aA	54.49 ± 1.94 bcB	53.09 ± 0.42 cB	54.58 ± 0.83 bcA
	15th day	57.44 ± 0.87 aA	54.38 ± 1.65 bB	54.21 ± 1.16 bB	54.31 ± 0.64 bB	54.64 ± 1.06 bA
a^*	0th day	6.14 ± 1.17 bA	7.72± 1.09 aA	5.33± 0.84 bcA	4.18 ± 0.65 cdAB	3.75 ± 0.97 dA
	5th day	6.12 ± 0.42 bA	7.41 ± 1.17 aA	4.37 ± 0.72 cAB	3.12 ± 0.38 cB	4.06 ± 0.99 cA
	10th day	5.48 ± 0.26 bA	7.40 ± 0.48 aA	4.83 ± 0.53 bcAB	4.76 ± 0.76 bcA	4.29 ± 0.99 cA
	15th day	6.62± 1.07 aA	6.71 ± 0.82 aA	3.94 ± 1.27 bB	3.96 ± 0.90 bAB	3.92 ± 0.89 bA
b^*	0th day	11.84 ± 2.12 bA	13.65± 1.44 bA	20.24 ± 0.80 aA	22.18 ± 2.96 aA	22.94 ± 2.05 aA
	5th day	11.30 ± 1.61 cA	12.73 ± 0.94 cA	17.16 ± 1.33 bB	20.25 ± 2.05 aAB	22.42 ± 2.24 aA
	10th day	10.24 ± 1.64 cA	12.84 ± 1.98 cA	17.02 ± 1.99 bB	19.46 ± 2.94 abAB	21.95 ± 3.45 aA
	15th day	11.65 ± 1.17 cA	10.16 ± 2.19 cB	15.47 ± 2.57 bB	18.80 ± 2.09 aB	21.00 ± 2.93 aA

Note:

- Color parameters: *lightness (L^*), redness (a^*) and yellowness (b^*).*

- Values are presented as mean ±SD (n=3). a-b by various small letters in the same row, the Tukey test shows a significant difference (p ≤0.05) between the means followed. A-C by various small letters in the same row, the Tukey test shows a significant difference (p ≤0.05) between the means followed.

Table (7) and Fig (3) illustrate the meat nuggets textural profiles after cooking. Regarding hardness, T1 samples were the softest between day 1st and day 10th of storage. Samples SET were the second softest on the 1st and 15th days. But on day 15th, there was no difference between the formulations ($p \geq 0.05$). Springiness did not change between the formulations after the 10th day of storage. On the 15th day, T2 was less springy than the others. In comparison to the other textural characteristics, the cohesiveness of the SET and T2 formulations is significantly higher ($p \leq 0.05$) than that of the T3 and Control formulations. The results showed no change (p > 0.05) between formulations for the chewiness characteristic, indicating that loquat flour had no effect on this important texture characteristic. Regarding the meat samples treated with pomegranate peel and bagasse powder (Adorjan and Buchbauer 2010) found that chewiness values increased ($p \leq 0.05$). Throughout storage, SE showed the highest level of resiliency. T2 and T3 provided comparable results to the Control formulation. At 15th days, all formulations showed comparable resiliency.

Concerning lipid oxidation, the Control samples showed increased oxidation compared to the other samples on days 0, 5, 10, and 15 (Table 8), demonstrating the significance of using antioxidants while preparing meat naggets. On the day 1st of storage, the SET samples showed about 1.9 times lower $TBARS^+$ values than the control, showing no difference from T1 samples and T2 samples. The T3 samples demonstrated the lowest amount of lipid oxidation, twice as low as the control. On day 10th of storage, no changes (p > 0.05) between all samples were detected, probably due to the significant standard ($p \leq 0.05$) deviation obtained for the control samples. On day 15th of storage, the control samples was six times more oxidized than the SET and loquat flour formulations, indicating that loquat flour, like sodium erythorbate, performed as an antioxidant. On the 15th day of storage, SET and T3 exhibited the lowest $TBARS^+$ values compared to the other samples (Table 8). According to (Mancini, et al. 2016), who reported that decreased $TBARS^+$ levels in meat patties cooked with 3.5% loquat flour (0.13 mg kg^{-1}) and 0.1% ascorbic acid (0.18 mg kg^{-1}) when compared to the control (0.30 mg kg^{-1}). Using loquat extract prevented an increase in *TBARS*$^{+}$ levels in meatballs (0.17 versus 0.39 mg MDA kg^{-1}) compared to the control (0.39 mg MDA kg^{-1}) (Akarpat, et al. 2008, Agregán, et al. 2019). When the storage time was evaluated, *TBARS*$^{+}$ values increased up to 15th days in all samples. This demonstrated that this period had the highest peak of Malondialdehyde formation and that the oxidation values were significantly lowered ($p < 0.05$) with the biodegradation of this compound; this strategy can be implemented in some lipid oxidation products (Akarpat, et al. 2008), caused by secondary malonaldehyde reactions, as confirmed by (Al-Bulushi, et al. 2005) in meat sausage. The control samples had higher *TBARS*$^{+}$ levels after 10th days of storage than the human detection limit of 2 mg MDA kg^{-1} (Bilal, et al. 2006), creating a rancid odor and taste detectable to consumers. According to the lipid oxidation data, loquat flour has antioxidant activity comparable to sodium erythorbate. This suggests that it has significant potential ($p < 0.05$) to replace this synthetic antioxidant without affecting chemical properties, shrinkage, or textural profile.

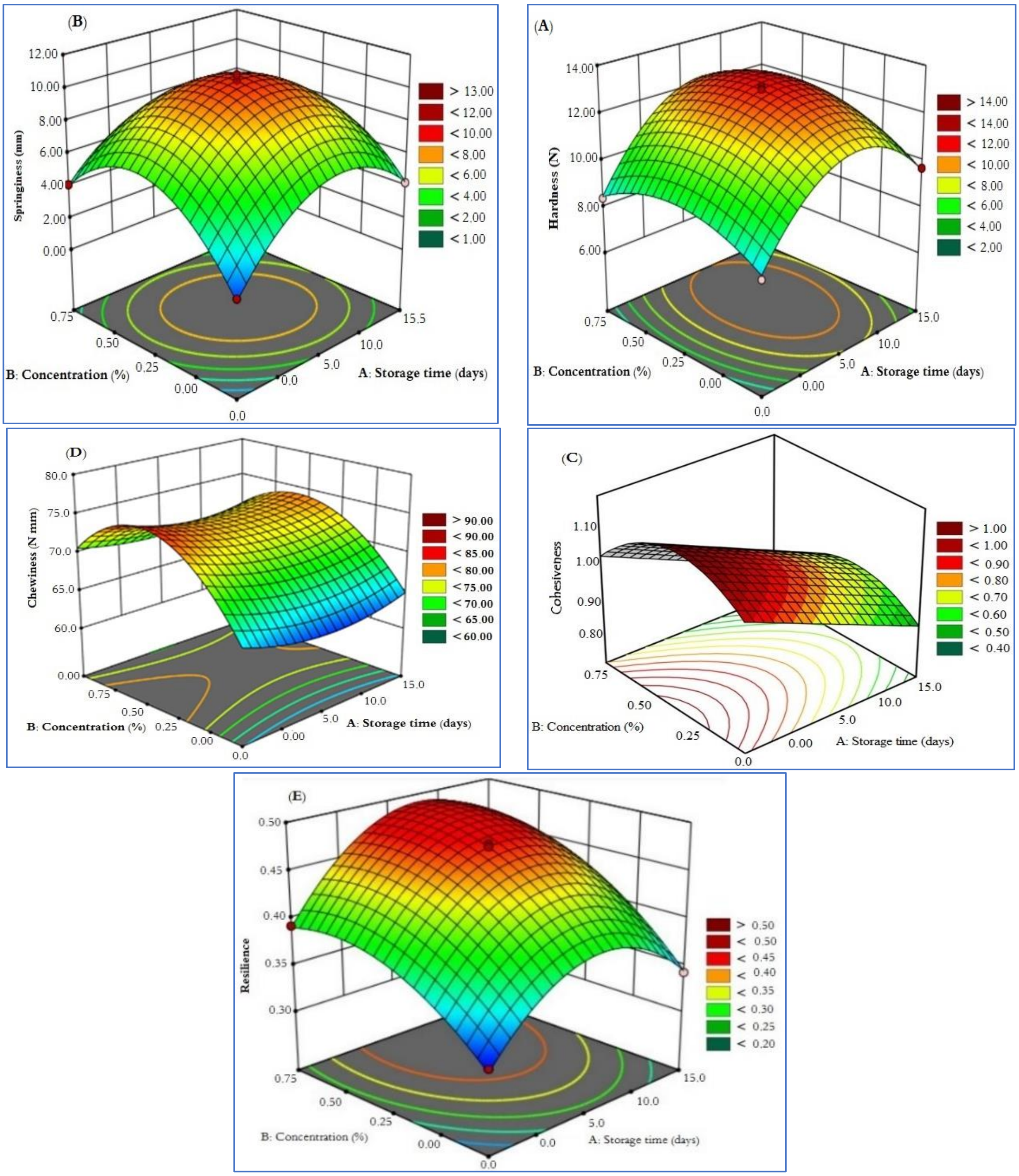

Fig 3. Three-dimensional (3D) response surface plots of texture profile analysis (A: Hardness); (B; Springiness); (C; Cohesiveness); (D; Chewiness); and (E; Resilience) of goat meat nuggets prepared with loquat (*E. japonica*) extracts during cold storage at 4 ºC for 15 days.

Table 7. Texture profile analysis *(TPA)* of goat meat nuggets prepared with loquat *(E. japonica)* extracts during cold storage at 4 ºC for 15 days.

Parameter	Period (days)	Goat meat nuggets				
		Control	**SET (Negative control)**	**T1**	**T2**	**T3**
Hardness (N)	0^{th} day	12.40 ± 1.77 ^{aB}	10.39 ± 1.34 ^{bcB}	9.35 ± 1.11 ^{cB}	11.56 ± 0.48 ^{abB}	12.47 ± 0.71 ^{aA}
	5^{th} day	15.62 ± 2.33 ^{aA}	11.14± 0.51 ^{bcB}	9.26 ± 0.81 ^{cB}	14.93 ± 2.63 ^{aA}	11.97 ± 0.65 ^{bAB}
	10^{th} day	11.73± 1.19 ^{bB}	14.9 ± 2.20 ^{aaA}	9.63 ± 1.07 ^{cB}	12.47 ± 1.42 ^{bAB}	11.12 ± 1.02 ^{bcB}
	15^{th} day	11.59 ± 0.84 ^{aB}	12.04 ± 1.66 ^{aB}	11.69 ± 1.31 ^{aA}	12.47 ± 2.31 ^{aB}	10.06± 0.62 ^{aC}
Springiness (mm)	0^{th} day	6.41 ± 0.10 ^{aA}	6.45 ± 0.04 ^{aA}	6.45 ± 0.06 ^{aA}	6.41± 0.08 ^{aA}	6.37± 0.08 ^{aA}
	5^{th} day	6.39 ± 0.06 ^{aA}	6.46 ± 0.03 ^{aA}	6.41 ± 0.09 ^{aA}	6.38 ± 0.09 ^{aA}	6.41 ± 0.06 ^{aA}
	10^{th} day	6.33 ± 0.06 ^{aA}	6.42± 0.06 ^{aA}	6.43 ± 0.07 ^{aA}	6.10 ± 0.18 ^{bB}	6.38± 0.10 ^{aA}
	15^{th} day	6.38 ± 0.08 ^{abA}	6.45 ± 0.04 ^{aA}	6.41 ± 0.08 ^{aA}	6.27± 0.10 ^{bAB}	6.42 ± 0.06 ^{aA}
Cohesiveness	0^{th} day	0.87 ± 0.02 ^{dB}	1.00 ± 0.03 ^{aA}	1.01 ± 0.02 ^{aA}	0.96± 0.02 ^{bA}	0.91 ± 0.01 ^{cB}
	5^{th} day	0.89 ± 0.01 ^{cB}	0.97 ± 0.02 ^{aA}	0.95 ± 0.05 ^{abB}	0.88 ± 0.03 ^{cB}	0.92 ± 0.01 ^{bcAB}
	10^{th} day	0.89 ± 0.01 ^{abB}	0.86 ± 0.02 ^{bB}	0.91 ±0.03 ^{aB}	0.85 ± 0.03 ^{bB}	0.87 ± 0.04 ^{abC}
	15^{th} day	0.95 ± 0.02 ^{abA}	0.99 ± 0.03 ^{aA}	0.92 ± 0.02 ^{bB}	0.97 ± 0.05 ^{abA}	0.95 ± 0.02 ^{abA}
Chewiness (N mm)	0^{th} day	69.99 ± 3.41 ^{aA}	62.96± 3.58 ^{aA}	61.32 ± 8.40 ^{aA}	70.93 ± 1.70 ^{aA}	70.93 ± 5.59 ^{aA}
	5^{th} day	74.28 ± 10.09 ^{aA}	69.84 ± 3.81 ^{aA}	63.13± 4.38 ^{aA}	73.75 ± 8.08 ^{aA}	69.23 ± 3.93 ^{aA}
	10^{th} day	65.86 ± 3.04 ^{aA}	75.78 ± 12.73 ^{aA}	62.04 ± 2.92 ^{aA}	69.71 ± 7.55 ^{aA}	62.33 ± 1.82 ^{aA}
	15^{th} day	68.62 ± 5.29 ^{aA}	67.27± 5.11 ^{aA}	67.62 ± 6.50 ^{aA}	70.56 ±13.97 ^{aA}	61.98 ± 2.86 ^{aA}
Resilience	0^{th} day	0.44 ± 0.01 ^{bcA}	0.48± 0.02 ^{aA}	0.45 ± 0.03 ^{abcA}	0.46 ± 0.01 ^{abA}	0.42 ± 0.02 ^{cA}
	5^{th} day	0.43 ± 0.01 ^{bA}	0.46 ± 0.01 ^{aA}	0.43 ± 0.02 ^{bAB}	0.42 ± 0.01 ^{bB}	0.43± 0.02 ^{bA}
	10^{th} day	0.40 ± 0.01 ^{bcB}	0.43 ± 0.02 ^{aB}	0.41 ± 0.01 ^{abB}	0.39 ±0.00 ^{cdC}	0.38 ± 0.01 ^{dB}
	15^{th} day	0.44 ± 0.01 ^{abA}	0.45 ± 0.02 ^{aAB}	0.42 ± 0.01 ^{bAB}	0.45 ± 0.02 ^{aA}	0.44 ± 0.01 ^{abA}

Note:

- Values are presented as mean ±SD (n=6). a-b by various small letters in the same row, the Tukey test shows a significant difference (p ≤0.05) between the means followed. A-C by various small letters in the same row, the Tukey test shows a significant difference (p ≤0.05) between the means followed.

Table 8. Lipid oxidation values (mg malonaldehyde kg^{-1} sample) of goat meat nuggets prepared with loquat (*E. japonica*) extracts during cold storage at 4 ºC for 15 days.

Period (days)	goat meat nuggets				
	Control	**SET (Negative control)**	**T1**	**T2**	**T3**
0^{th} day	0.47^{aB} ± 0.02	0.27± 0.01 ^{bB}	0.27 ± 0.03 ^{bA}	0.23 ± 0.02 ^{bcB}	0.21 ± 0.03 ^{cC}
5^{th} day	0.51^{aB} ± 0.20	0.28 ±0.05 ^{aB}	0.40 ± 0.09 ^{aA}	0.42 ± 0.05 ^{aAB}	0.35 ± 0.01 ^{aAB}
10^{th} day	2.52^{aA} ± 0.17	0.38 ± 0.07 ^{bA}	0.48 ± 0.04 ^{bA}	0.45 ± 0.06 ^{bAB}	0.36 ± 0.05 ^{bA}
15^{th} day	1.27 ± 0.64 ^{aB}	0.33b ± 0.01^{bAB}	0.62 ± 0.34 ^{abA}	0.59 ± 0.28 ^{abA}	0.28 ± 0.01 ^{bB}

Note:

- Values are presented as mean ±SD (n=4). a-b by various small letters in the same row, the Tukey test shows a significant difference (*p ≤0.05*) between the means followed. A-C by various small letters in the same row, the Tukey test shows a significant difference (*p ≤0.05*) between the means followed.

CONCLUSION

As a conclusion of this study, it was observed that loquat seed powder had significant protein levels and total dietary fibre. Moreover, a high amount of phosphorus, potassium, magnesium, calcium, sodium, and a considerable amount of iron, zinc, and copper. Total phenolic, flavonoids, and total tannins contents in loquat (E. japonica) flour were substantial and exhibited antioxidant activity. Adding loquat seed powder resulted in less reddish and darker, more yellowish goat meat naggets. When loquat flour was utilized for synthetic polymer antioxidants in goat meat nuggets, the resulting meat product had oxidative stability comparable to the synthetic antioxidant, enhanced cooking yield, and no changes to its chemical composition or textural profile. Our research established that adding loquat seed extract positively impacts meat products' physicochemical properties and quality characteristics. The results showed that the loquat seed extract's natural antioxidant content significantly slowed fat oxidation during cold storage. Therefore, extracts from loquat seed could be used as potent natural additives with multi-dimensional benefits in the meat industry and its products.

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Ethics statements:

- This manuscript does not contain any animal studies.
- This manuscript does not contain any human studies.
- No potentially identifying human photographs or data are presented in this study.

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تأثير إضافة مستخلص بذور البشملة على صفات جودة ناجتس لحم الماعز أثناء التخزين المبرد

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الملخص

تهدف الدراسة إلي تقييم تأثير إضافة مسحوق بذور البشملة (*Eriobotrya japonica*) على خواص جودة قطع اللحم (ناجتس الماعز). حيث أوضحت النتائج أن مطحون بذور البشملة يحتوي على نسبة عالية من البروتين الخام والرماد والدهن. علاوة على ذلك ، إحتوائة على نسبة عالية من العناتصر المعدنية مثل من الفوسفور والبوتاسيوم والمغنيسيوم والكالسيوم والصوديوم 442.48 و 401.47 و 220.14 و 207.69 و 124.22 مجم / 100 جرام على التوالي وكمية كبيرة من الحديد والزنك والنحاس. بالإضافة إلى ذلك ، 1.77 و 0.94 مجم / 100 جرام من الفيتامينات *C* و *E* على التوالي. وبناء على النتائج السابقة وما ترتب علية من التدعيم بمطحون بذور البشملة فقد قيمت هذه الدراسة استخدام مسحوق بذور البشملة كمضاد طبيعي للأكسدة في قطع لحم الماعز من خلال استبدال بدقيق القمح على 3 مستويات مختلفة (3.3 ٪، 6.6 ٪، و 10٪). وأوضحت النتائج المتحصل عليها زيادة محتوى عينات الناجتس من البروتين الخام والرماد والدهن مقارنة بالعينة القياسية. حيث أدت إضافة مطحون بذور البشملة إلى تقليل احمرار وإسمرار قطع اللحم وزيادة اصفرارها أثناء وبعد عملية القلي والتحمير. وأظهرت النتائج التأثير المضاد للأكسدة لمطحون بذور البشملة (كمادة طبيعيه) في قطع لحم المخزن. حيث تعتبر مصدرا جيدا للمركبات الفينولية ذات الأهمية الكبرى كمصدر للنشاط المضاد للأكسدة على المستوى الصناعي حيث أثبتت دراستنا أن إضافة مستخلص بذور البشملة له تأثير إيجابي على مؤشرات الجودة الفيزيائية والكيميائية. ولوحظ أنة يقلل بشكل فعال من أكسدة الدهون أثناء التخزين. لذا ، يمكن استخدام مستخلصات بذور البشملة كواحدة من المضافات الطبيعية القوية ذات الفوائد متعددة الأبعاد في صناعة اللحوم ومنتجاتها مما سيعزز جودتها ويطيل عمرها الافتراضي.

الكلمات الدالة: بذور البشملة ، مضادات الأكسدة ، ناجتس لحم الماعز ، مؤشرات الجودة ، فترة التخزين.