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Evaluating the Effect of Turmeric Oleoresin on Improving the Oxidative Stability of Fried Instant Noodles and Its Physicochemical and Sensory Characteristics

Paniz Kabiri[1], Samar Mansouripour*[1,2], Afshin Jafarpour [3]

1– Department of Food Science and Technology, TeMS.C., Islamic Azad University, Tehran, Iran.

2 –Nutrition and Food Sciences Research Center, TeMS.C., Islamic Azad University, Tehran, Iran.

3 –Department of Food Science and Technology, Ga.C., Islamic Azad University, Garmsar, Iran.

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*Corresponding Author E-

Sa.mansouripour@iau.ac.ir

ABSTRACT

Given the challenges in supplying palm oil (PO) for frying noodles in Iran and the use of rapeseed oil (RO), this study aimed to improve the oxidative stability of noodles fried in RO by incorporating turmeric oleoresin (TO). Two groups of noodles were fried separately in PO and RO. Then, TO was sprayed onto the noodles, and the quality characteristics were evaluated for 120 days. The samples containing oleoresin showed lower peroxide and anisidine values than their control with the same frying oil. After 120 days, samples fried in RO containing 0.5 and 0.75% oleoresin (T9 and T10) had lower peroxide and anisidine values than the sample fried in PO without oleoresin (T1) ($P<0.05$). A decreasing trend in thiobarbituric acid was observed with increasing oleoresin concentration. The acid value and conjugated diene of samples T8 (0.25% oleoresin and fried in RO), T9, and T10 were also either lower than or not significantly different from those of T1 ($P<0.05$). At the end of the storage, the IP of T1 was shorter than that of T10, with no significant difference compared to T9. A significant increasing trend was observed in phenol content and antioxidant activity with increasing oleoresin concentration ($P<0.05$). There was no significant difference in the overall acceptability between T10 and T1 at the end of storage, and the score of T9 was even higher than that of T1. Therefore, it is recommended to replace PO with RO, along with incorporating TO to noodles, especially at higher concentrations (0.5 and 0.75%).

1-Introduction

Instant noodles are a popular quick-cooking food product made from flour, water, and salt as the main ingredients [1]. The popularity of noodles can be attributed to the characteristics such as taste, convenience, food safety, shelf life, and reasonable price. Color, flavor, texture, cooking quality, rehydration capacity during final preparation, and the absence of off-flavors after prolonged storage are the key quality attributes of instant noodles [2]. Instant noodles are classified into dried instant noodles and fried instant noodles, based on the different dehydrating methods. In instant dried noodles, moisture is removed by hot air, whereas deep-fat frying is used for instant fried noodles for dehydration. Frying is one of the principal methods used in industrial noodle production, and most commercial instant noodles are manufactured by deep-fat frying. This process resulted in a distinctive porous texture and fried flavor in the final product. However, it may also raise potential health concerns due to the oil oxidation [3]. Therefore, utilizing the ingredients that improve oxidative stability and increase the shelf life of fried instant noodles is of considerable importance.

Antioxidants are defined as substances that can prevent or significantly delay oxidative spoilage, even at low concentrations .Some food products lack sufficient natural antioxidants and are highly susceptible to oxidative spoilage during processing and storage, which leads to the use of synthetic antioxidants. Synthetic antioxidants are effective at low concentrations, and adding higher levels may lead to pro-oxidant effects. Previous studies have reported that high doses of synthetic antioxidants may be associated with adverse health effects [4]. Since there are usually challenges in the supply and importation of palm oil used for noodle frying in the Iranian industry, rapeseed oil is used for this purpose. However, due to the higher content of saturated fatty acids in palm oil [5], the oxidative stability of rapeseed oil is lower than that of palm oil, which may result in a reduced shelf life of noodles fried in it and consequently the use of more synthetic antioxidants. Nevertheless, it seems that the oxidative stability of fried noodles can be improved by incorporating natural antioxidants.

Oleoresins are concentrated extracts obtained from plants and have been studied as food additives, including natural antioxidants. These substances are extracted from natural sources by various techniques and are potential alternatives to synthetic additives. They can enhance antioxidant and antimicrobial activities in food products [6]. Oleoresins contain not only volatile essential oils but also non-volatile components such as pigments, oils, and phenolic antioxidants. Due to their lower volatility, oleoresins may provide a more stable antioxidant capacity than essential oils [7]. The bioactive compounds in oleoresins are associated with their antioxidant properties. Previous studies have shown that the application of paprika oleoresin in sausages was successful in controlling chemical and microbial spoilage, and 75% of the initial sodium nitrite level could be replaced with 0.1% paprika oleoresin [8]. Furthermore, the results of another study revealed that the incorporation of lycopene oleoresin into cupcakes increased oxidative stability [9]. Turmeric oleoresin is a rich source of curcumin, which imparts a bright yellow color, and it also contains volatile compounds that contribute to aroma and flavor development [10]. Turmeric curcumin exhibits beneficial effects, including antioxidant, immunomodulatory, anticancer, antimicrobial, and anti-inflammatory properties [11]. According to the study of Jayathilake et al. (2022), the addition of turmeric oleoresin to pasteurized milk increased the antioxidant activity and total phenolic content [12]. Furthermore, Praveen et al. (2024) reported that the incorporation of turmeric industrial by-products, including curcuminoid-removed turmeric oleoresin oil and curcuminoids, in peanut butter enhanced its shelf life by delaying chemical and microbial spoilage while improving its nutritional value [13]. To the best of our knowledge, turmeric oleoresin has not previously been used in instant noodles. Therefore, the present study aimed to evaluate the effect of turmeric oleoresin as a natural antioxidant to improve the oxidative stability and other quality attributes of fried instant noodles.

2-Materials and Methods

2-1-Materials used to prepare noodles

Wheat flour and salt were obtained from Golestan Company (Iran). Palm oil and rapeseed oil were supplied by Alaeddin Food Industries Company (Iran) and Boruj Company (Iran), respectively. Turmeric oleoresin was purchased from Universal Company (India).

2-2- Evaluation of antioxidant activity of turmeric oleoresin

The antioxidant activity of turmeric oleoresin extract was determined using the DPPH radical scavenging method and measured with a UV–visible spectrophotometer (Philler Scientific, USA) at a wavelength of 517 nm. A mixture of 100 µg of the sample and 100 µL of 0.1 mM DPPH solution was prepared. After 30 min of incubation, the results were expressed as the percentage of DPPH radical scavenging activity, calculated using Equation (1) [14].

$$\mathrm{DPPH} = \frac{\mathrm{AC-AS}}{\mathrm{AC}} \times 100 \qquad (1)$$

AC = absorbance of the DPPH solution without sample addition

AS = absorbance of the DPPH solution after addition of the sample

2-3 Preparation of Noodles

The control noodle formulation consisted of wheat flour (400 g), salt (4 g), and distilled water (108 mL). The ingredients were mixed using a mixer for 7 min until a homogeneous dough was obtained. The dough was then passed through two parallel rotating rollers to obtain a thin sheet, which was immediately cut into strands. The dough strands passed through a steam tunnel at 90 °C for 5 min on a conveyor belt and then fried in a fryer using either palm oil or rapeseed oil at 140 °C for 3 min [15]. After frying, turmeric oleoresin was sprayed at concentrations of 0.1%, 0.25%, 0.5%, and 0.75% onto the hot fried noodle samples prepared with both palm and rapeseed oils (the oleoresin was dissolved in the oil used and sprayed). Noodles fried in palm oil containing 0.1%, 0.25%, 0.5%, and 0.75% turmeric oleoresin were coded as T3, T4, T5, and T6, respectively. In addition, the samples fried in rapeseed oil containing 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin were coded as T7, T8, T9, and T10, respectively. Two noodle samples fried in palm oil (T1) and rapeseed oil (T2) without turmeric oleoresin were considered as controls. Finally, the noodles were cooled to room temperature, packaged in 100 g packs, and stored in a dry, cool place away from direct light at room temperature for 120 days. Analyses were performed on days 1, 30, 60, 90, and 120.

2- 4- Noodle analyses

2-4-1 Physicochemical tests

Moisture and ash contents of noodle samples were determined according to AACC methods Nos 44–15 and 08–03, respectively. Protein content was measured using AACC Method No. 46–10, and fat content was determined according to AACC Method No. 30–25 [16]. Carbohydrate content was also determined according to AOAC Method 986.25 [17]. For pH measurement, 2 g of the noodle sample was mixed with 10 mL of distilled water. The pH was then determined using a digital pH meter (AZ, Taiwan) [18]. The analyses were performed in triplicate during the 120-day storage period (days 1, 30, 60, 90, and 120).

2.4.2 Oxidative Stability Assessment

First, oil was extracted from noodles using hexane as a solvent, and the solvent was then removed using a rotary evaporator [15]. Analyses were performed in triplicate on days 1, 30, 60, 90, and 120 of storage.

2.4.2.1. Peroxide and Anisidine Values

Peroxide value (PV) was determined according to the AOCS Cd 8-53 method, and results were expressed as milliequivalents of oxygen per kilogram of oil. Anisidine value (AV) was measured according to the AOCS Cd 18-90 method[19].

2.4.2.2. Thiobarbituric Acid (TBA) Value

Two grams of the noodles were homogenized with 2 mL of trichloroacetic acid. After centrifugation at 4000 rpm for 30 min, the reaction with thiobarbituric acid was carried out in a thermostatic bath at 97°C for 20 min. After cooling, the absorbance was measured at 532 nm using a spectrophotometer. Results were reported as mg MDA/kg [20].

2.4.2.3. Acid Value

First, 3 g of oil extracted from the noodles was mixed with 80 mL of a 1:1 (w/w) mixture of ethyl ether and ethanol. Phenolphthalein was used as an indicator, and titration was carried out with 0.05 N potassium hydroxide (KOH) in ethanol. The acid value was calculated using Equation (2) [21].

$$Acid\ value = \frac{[A(mL)\times 2/806\times f]}{B(g)} \tag{2}$$

A: volume of potassium hydroxide (KOH) solution (mL)
f: factor of the standard solution
B: weight of extracted oil (g)

2.4.2.4. Conjugated Diene Content

Conjugated diene content was determined according to AOCS Cd 5–91 [22]. Oil samples were diluted at a ratio of 1:60 (w/v) with isooctane. The absorbance of the diluted samples was measured at 233 nm against a blank (isooctane without oil). The conjugated diene content was calculated using Equations (3) and (4) [22].

$$Ccd = \frac{A233}{(\Sigma\times \mathrm{L})} \tag{3}$$

$$CD\ value = \frac{(Ccd\times(2.5\times10^{4}))}{w} \tag{4}$$

CD: conjugated dienes
Ccd: concentration of CD
W: sample weight (g)
A233: difference in absorbance between the sample and the blank at 233 nm
Σ: specific extinction coefficient ($M^{-1}\cdot cm^{-1}$), equal to 2.525×10^{4}
L: length of the cuvette (cm), (1cm)

2.4.2.5. Oxidative Stability under Accelerated Oxidation Conditions

The oxidative stability under accelerated oxidation conditions was evaluated using a Rancimat instrument (Chongqing Gold Mechanical, China). The induction period (IP) was determined by exposing the samples to a saturated air flow rate of 20 L/h at 120 °C [23]. The analysis was performed on days 1 and 120 of storage.

2.4.3 Determination of total phenolic content and antioxidant activity

First, the samples were ground into fine powder. Then, 2 g of noodle powder and 25 ml of 99% methanol were mixed and stirred in a rotary shaker at 25 °C for 24 h. The resulting mixture was centrifuged at 5000 rpm for 10 min and filtered using Whatman filter paper. The obtained extract was stored under refrigeration and used to determine total phenolic content and antioxidant activity [24].

Total phenolic content was determined using the Folin-Ciocalteau method. The sample extract (0.1 mL) was mixed with 1 mL of Folin–Ciocalteu reagent. The mixture was stirred continuously for 10 min, and then 1 mL of sodium carbonate solution (70 g/L) and 3 mL of distilled water were added. The absorbance was measured at 765 nm using a spectrophotometer. Total phenolic content. Total phenolic content was expressed as mg GAE/g [25].

Two milliliters of 0.1 mM DPPH solution in methanol were mixed with 1 mL of noodle extract. The resulting mixture was kept in the dark at room temperature for 30 min. The absorbance of the samples was then measured at 515 nm using a spectrophotometer. Antioxidant activity was calculated using Equation (5)[26].

$$DPPH\% = \frac{(Ab_0 - Ab_s)}{Ab_0} \times 100$$
(5)

Ab_0: absorbance of the control (blank)
Abs: absorbance of the sample

2.4.4 Sensory evaluation

Sensory evaluation of noodle samples was performed using a 9-point hedonic scale from 1 (strong dislike) to 9 (extremely like) scores on the first and 120 days of storage. The samples were coded and evaluated by 10 trained panelists. The sensory characteristics assessed included taste, odor, color, texture, and overall acceptability [27].

2.5 Statistical analysis

The statistical analysis of the data was performed using analysis of variance (ANOVA) at a significance level of $p < 0.05$ with SPSS software (Version 26). Mean were also compared using Tukey's test.

3- Results and Discussion

3.1. Physicochemical Properties

The results of the physicochemical characteristics of noodle samples are shown in Table 1. The addition of turmeric oleoresin and the use of palm or rapeseed oil did not result in significant differences in carbohydrate, ash, moisture, fat, protein contents, and pH values of the noodle samples ($p > 0.05$). This may be attributed to the relatively low concentrations of oleoresin used in the present study. Similarly, Kim and Chin reported that the presence or absence of paprika oleoresin had no significant effect on the protein and fat contents of sausages [8]. Although oleoresins naturally contain high amounts of lipid compounds, the low concentration of oleoresin used in the present study may explain the non-significant differences in fat content. In another study, the use of lycopene and chlorophyll oleoresins reduced the moisture content of cakes [9], which could be related to the type of the product and structural differences compared to the present study.

Table1. Physicochemical properties of noodle samples

Sample	(%)Carbohydrates	Moisture (%)	(%) Ash	(%)Protein	Fat	pH
T1	84.59 ± 0.58^a	3.11± 0.032^a	1.29± 0.03^a	9.56± 0.28^a	23.33± 0.58^a	6.12± 0.03^a
T2	84.56 ± 0.58 ^{a}	3.086 ± 0.07 ^{a}	1.30 ± 0.11 ^{a}	9.55 ± 0.19 ^{a}	23.00 ± 0.78 ^{a}	6.09 ± 0.07 ^{a}
T3	83.84 ± 0.46 ^{a}	3.026 ± 0.14 ^{a}	1.29 ± 0.16 ^{a}	9.46 ± 0.02 ^{a}	23.13 ± 0.25 ^{a}	6.22 ± 0.09 ^{a}
T4	83.95± 0.94 ^{a}	3.006 ±0.03 ^{a}	1.26± 0.01 ^{a}	9.67± 0.31 ^{a}	23.60±0.78 ^{a}	6.18 ± 0.005 ^{a}
T5	84.43 ± 0.27^a	2.71 ±0.06 ^{a}	1.29 ± 0.14 ^{a}	9.44 ± 0.33 ^{a}	22.95 ± 0.12 ^{a}	6.26 ± 0.08 ^{a}
T6	83.38±0.44 ^{a}	2.92± 0.11 ^{a}	1.28± 0.14 ^{a}	9.37± 0.44 ^{a}	23.46 ± 1.45 ^{a}	6.17 ± 0.11 ^{a}
T7	83.72 ± 0.09 ^{a}	3.04 ± 0.18 ^{a}	1.04 ± 0.07 ^{a}	9.40 ± 0.22 ^{a}	22.67 ± 0.58 ^{a}	6.19 ± 0.02 ^{a}
T8	83.95 ±0.73 ^{a}	3.03 ± 0.16 ^{a}	1.19 ± 0.12 ^{a}	9.25 ± 0.21 ^{a}	23.30 ± 0.55 ^{a}	6.21 ± 0.11 ^{a}
T9	83.51 ± 0.73 ^{a}	2.95 ± 0.29 ^{a}	1.12 ± 0.17 ^{a}	9.58 ± 0.56 ^{a}	22.82 ± 0.49 ^{a}	6.21 ± 0.25 ^{a}
T10	84.28 ±0.007 ^{a}	3.06 ± 0.17 ^{a}	1.28± 0.12 ^{a}	9.48 ± 0.15 ^{a}	23.38 ± 1.41 ^{a}	6.09 ± 0.02 ^{a}

3.2. Oxidative Stability

3.2.1. Peroxide and Anisidine Values

The results of peroxide and anisidine values are presented in Tables 2 and 3. Peroxide and anisidine values represent the primary and secondary oxidation products, respectively [28]. The results indicated a significant effect of the addition of oleoresin and the type of frying oil on these values ($p < 0.05$). In all storage periods, the highest values were observed in the control sample containing rapeseed oil or T2, and the lowest values were observed in T6, containing palm oil and 0.75% oleoresin. Samples fried in palm oil and containing oleoresin had significantly lower peroxide and anisidine indices than samples fried in rapeseed oil (with similar oleoresin content) ($P<0.05$). This finding was expected because palm oil contains higher levels of saturated fatty acids and lower levels of unsaturated fatty acids than rapeseed oil. Higher levels of unsaturated fatty acids make the oil more sensitive to oxidation, leading to the formation of hydroperoxides and subsequently secondary oxidation products [29]. In this regard, the results of the study by Allam et al. (2023) showed significant differences in peroxide values among palm oil, canola oil, and their blend, and palm oil exhibited lower peroxide values during thermal treatment [30]. Aniołowska and Kita (2015) also observed significant differences in the anisidine values of rapeseed and palm oils during potato frying. Although anisidine values increased significantly in both oils, the increase was considerably greater in rapeseed oil [31]. In the present study, samples containing turmeric oleoresin exhibited lower peroxide and anisidine values than their controls fried in the same oil (T1 or T2) on most days of storage. In addition, a decreasing trend in these oxidation indices was observed with increasing concentrations of turmeric oleoresin.

The antioxidant activity of turmeric oleoresin in the present study was 97.46%, indicating high antioxidant activity and consistent with previous studies [32, 33]. The polyphenolic compound curcumin is the main bioactive ingredient of turmeric, which is primarily responsible for its antioxidant properties. Two antioxidant mechanisms have been proposed for curcumin, including the donation of hydrogen atoms from phenolic groups and from the methylene group CH2 [34]. Therefore, the incorporation of antioxidants such as curcumin enhanced oxidative stability. After 120 days of storage, the peroxide and anisidine values of samples fried in rapeseed oil containing 0.5% and 0.75% turmeric oleoresin (T9 and T10, respectively) were significantly lower than those

Table 2. Peroxide values of noodle samples during storage

Sample / Time	Peroxide value (meq/kg)				
	Day1	Day30	Day60	Day90	Day120
T1	1.15 ±0.15^{Dd}	1.09 ±0.04^{Dc}	2.28 ±0.22^{Cc}	2.77 ±0.12^{Be}	4.10 ±0.02^{Ac}
T2	4.01 ±0.43^{Da}	4.68 ±0.14^{Da}	6.40 ±0.25^{Ca}	8.65 ±0.17^{Ba}	11.37 ±0.27^{Aa}
T3	0.95 ±0.02^{Bde}	1.05 ±0.04^{Bc}	1.23 ±0.10^{Bd}	1.32 ±0.07^{Bf}	2.68 ±0.28^{Ae}
T4	0.87 ±0.03^{Dde}	0.92 ±0.03^{CDc}	1.00 ±0.01^{BCde}	1.04 ±0.04^{ABg}	1.08 ±0.02^{Af}
T5	0.77 ±0.07^{Cde}	0.83 ±0.02^{BCc}	0.89 ±0.05^{ABe}	0.95 ±0.03^{Agh}	0.99 ±0.01^{Af}
T6	0.66 ±0.01^{Be}	0.67 ±0.01^{Bd}	0.72 ±0.02^{ABf}	0.74 ±0.03^{ABh}	0.77 ±0.06^{Af}
T7	3.34 ±0.08^{Db}	3.87 ±0.09^{Cb}	4.00 ±0.09^{Cb}	4.61 ±0.04^{Bb}	4.95 ±0.05^{Ab}
T8	3.17 ±0.06^{Dbc}	3.36 ±0.03^{CDb}	3.43 ±0.04^{BCb}	3.60 ±0.11^{Bc}	4.03 ±0.07^{Ac}
T9	2.99 ±0.05^{Cbc}	3.08 ±0.06^{BCb}	3.22 ±0.92^{Bbc}	3.51 ±0.07^{Ac}	3.59 ±0.07^{Ad}
T10	2.83 ±0.08^{Cc}	2.87 ±0.08^{Cb}	3.07 ±0.03^{Bbc}	3.15 ±0.05^{ABd}	3.26 ±0.02^{Ad}

T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. Results are presented as a mean value

± SD. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) in each identical column and row, respectively.

Table 3. Anisidine values of noodle samples during storage

Sample/ Time	Anisidine value				
	Day1	Day30	Day60	Day90	Day120
T1	1.25 ±0.02^{Dcd}	1.43 ±0.04^{Cc}	1.57 ±0.11^{BCc}	1.71 ±0.02^{Bd}	2.09 ±0.07^{Ac}
T2	2.22 ±0.16^{Ca}	2.23 ±0.02^{Ca}	2.63 ±0.06^{BCa}	3.44 ±0.16^{ABa}	3.60 ±0.13^{Aa}
T3	1.01 ±0.01^{Dcde}	1.11 ±0.02^{CDd}	1.21 ±0.01^{Cd}	1.50 ±0.06^{Bd}	1.76 ±0.06^{Ad}
T4	0.87 ±0.03^{Ede}	0.98 ±0.01^{De}	1.09 ±0.07^{Cde}	1.21 ±0.01^{Be}	1.47 ±0.02^{Ae}
T5	0.82 ±0.04^{Ce}	0.89 ±0.01^{Cf}	0.93 ±0.03^{Ce}	1.11 ±0.01^{Be}	1.26 ±0.10^{Af}
T6	0.53 ±0.01^{Cf}	0.62 ±0.03^{Cg}	0.76 ±0.07^{Bf}	0.85 ±0.03^{ABf}	0.89 ±0.02^{Ag}
T7	2.06 ±0.05^{Dab}	2.41 ±0.02^{Ca}	2.37 ±0.11^{Cab}	2.96 ±0.06^{Bb}	3.26 ±0.05^{Aab}
T8	1.89 ±0.04^{Db}	1.94 ±0.04^{CDb}	2.13 ±0.11^{BCb}	2.49 ±0.04^{ABc}	2.85 ±0.04^{Ab}
T9	1.32 ±0.03^{Dc}	1.47 ±0.07^{Cc}	1.55 ±0.04^{BCc}	1.64 ±0.04^{ABd}	1.71 ±0.05^{Ad}
T10	0.91 ±0.03^{Cde}	1.03 ±0.05^{BCde}	1.19 ±0.08^{ABd}	1.25 ±0.09^{Ae}	1.30 ±0.09^{Aef}

T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. Results are presented as a mean value ± SD. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) in each identical column and row, respectively.

of the control sample fried in palm oil without oleoresin (T1) ($p < 0.05$). These findings indicate the effective role of turmeric oleoresin in reducing oxidation. Praveen et al. (2024) investigated the effects of curcuminoid-removed turmeric oleoresin, curcuminoids, and curcuminoid-removed turmeric oleoresin oil on peanut butter. The results showed that the highest peroxide value was observed in the control, while the oleoresin oil exhibited the greatest effectiveness in reducing peroxide value [13]. Similarly, Wong et al. (2019) reported that the addition of rosemary oleoresin resulted in a significant reduction in the anisidine value of palm olein during potato chip frying [35]. A significant increase in both peroxide and anisidine values was observed during the storage period of the noodle samples ($p < 0.05$). This increase can be attributed to the continued progression of oxidation over time and the formation of oxidation products.

3-2-2 Thiobarbituric acid value

The results of the thiobarbituric acid value, which indicates the progress of oxidative deterioration, were significantly higher in samples fried with rapeseed oil than in the corresponding samples fried in palm oil at the same oleoresin concentration ($p < 0.05$) (Table 4). The reason is probably related to the higher content of saturated fatty acids in palm oil compared to rapeseed oil.

The measurement of thiobarbituric acid determines the amount of malondialdehyde as a secondary product of lipid oxidation in food systems. In general, oils with a higher degree of unsaturation are more susceptible to oxidative degradation. When the peroxide value reaches a certain value, volatile aldehydes and ketones increase the TBA value [36]. However, this value can also be reduced by the incorporation of antioxidants and by reducing the peroxide value and oxidation products. A decreasing trend in TBA values was observed with increasing concentrations of turmeric oleoresin in the noodle samples. Up to day 90 of storage, there was no significant difference between the control with palm oil and without oleoresin (T1) and the samples fried in rapeseed oil with 0.5 and 0.75% oleoresin. This finding indicates the positive role of turmeric oleoresin in improving oxidative stability. Similarly, Mancini et al. (2016) reported that the addition of 3.5% turmeric powder to beef burgers resulted in lower thiobarbituric acid values compared with burgers without additives [37]. In another study, Irfiana et al. (2017) found that the incorporation of cinnamon oleoresin into packaged beef significantly reduced the thiobarbituric acid value compared with the control sample [38].

Table 4. Thiobarbituric values of noodle samples during storage

Sample/ time	TBA (mg MDA/kg)				
	Day1	**Day30**	**Day 60**	**Day90**	**Day120**
T1	0.41 ±0.02^{Dcde}	0.46 ±0.01^{CDcd}	0.56 ±0.03^{BCcdef}	0.76 ±0.02^{ABcd}	0.84 ±0.02^{Ad}
T2	0.80 ±0.05^{Ca}	1.00 ±0.10^{Ca}	1.30 ±0.14^{Ba}	1.61 ±0.14^{Aa}	1.90 ±0.02^{Aa}
T3	0.35 ±0.05^{Cde}	0.43 ±0.01^{BCcd}	0.47 ±0.03^{Bdef}	0.63 ±0.05^{Ade}	0.72 ±0.04^{Ad}
T4	0.31 ±0.01^{Ce}	0.33 ±0.02^{BCde}	0.36 ±0.01^{BCefg}	0.42 ±0.01^{ABe}	0.51 ±0.07^{Ae}
T5	0.28 ±0.01^{Ce}	0.33 ±0.04^{BCde}	0.35 ±0.00^{ABfg}	0.40 ±0.005^{Aef}	0.40 ±0.01^{Af}
T6	0.21 ±0.005^{Df}	0.25 ±0.03^{CDe}	0.27 ±0.02^{BCg}	0.33 ±0.03^{ABf}	0.37 ±0.01^{Ag}
T7	0.80 ±0.005^{Da}	0.91 ±0.02^{CDab}	1.17 ±0.19^{BCab}	1.54 ±0.04^{ABab}	1.60 ±0.08^{Ab}
T8	0.77 ±0.005^{Eab}	0.83 ±0.01^{Dab}	0.95 ±0.02^{Cbc}	1.14 ±0.03^{Bbc}	1.37 ±0.02^{Abc}
T9	0.60 ±0.04^{Dbc}	0.72 ±0.04^{CDbc}	0.85 ±0.04^{BCbcd}	0.96 ±0.11^{Bcd}	1.24 ±0.03^{Ac}
T10	0.55 ±0.01^{Ccd}	0.61 ±0.01^{Bbc}	0.64 ±0.02^{Bcde}	0.72 ±0.01^{Acd}	0.74 ±0.02^{Ad}

T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. Results are presented as a mean value ± SD. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) in each identical column and row, respectively.

3-2-3- Acid value

As shown in Table 5, the highest acid value was observed in the control fried in rapeseed oil (T2). In addition, the noodles fried in rapeseed oil exhibited higher acid values than those containing palm oil at the same oleoresin concentrations. Similarly, in the study of Wroniak (2021), the acid value of palm olein oil was lower compared to rapeseed oil used for frying potato and tofu samples[39]. However, the acid values of noodle samples containing 0.5% and 0.75% turmeric oleoresin (T9 and T10) fried in rapeseed oil were either lower ($P<0.05$) or not significantly different than those of the control fried in palm oil without oleoresin (T1). The acid value reflects the content of free fatty acids generated by oil hydrolysis. The presence of unsaturated fatty acids can accelerate the formation of free fatty acids and an increase in the acid value [40]. However, antioxidant compounds such as oleoresins can help reduce acid values by inhibiting lipid hydrolysis and the formation of free fatty acids. In previous studies, the findings of Kehili et al. (2018) showed that the addition of tomato peel oleoresin reduced the acidity of sunflower and olive oils [41]. Similarly, Upadhyay and Mishra (2015) found that rosemary oleoresin improved

Table 5. Acid values of noodle samples during storage

Sample/ Time	Acid value (mg KOH/g)				
	Day1	**Day30**	**Day 60**	**Day90**	**Day120**

T1	1.24 ± 0.04^{Bc}	1.28 ± 0.07^{Bbc}	1.39 ± 0.01^{Ab}	1.47 ± 0.02^{Ab}	1.49 ± 0.02^{Acd}
T2	1.67 ± 0.06^{Ba}	1.75 ± 0.05^{Ba}	1.84 ± 0.03^{Ba}	2.26 ± 0.16^{Aa}	2.43 ± 0.08^{Aa}
T3	1.12 ± 0.02^{Cd}	1.13 ± 0.02^{Cc}	1.23 ± 0.02^{Bc}	1.31 ± 0.01^{Abc}	1.34 ± 0.03^{Ade}
T4	1.01 ± 0.01^{Ad}	1.15 ± 0.21^{Abc}	1.08 ± 0.03^{Ad}	1.13 ± 0.02^{Acd}	1.18 ± 0.02^{Aef}
T5	0.84 ± 0.04^{Be}	0.82 ± 0.005^{Bd}	0.90 ± 0.01^{Be}	1.01 ± 0.02^{Ad}	1.04 ± 0.06^{Afg}
T6	0.77 ± 0.02^{Be}	0.82 ± 0.005^{ABd}	0.90 ± 0.01^{ABe}	0.99 ± 0.10^{Ad}	0.99 ± 0.12^{Ag}
T7	1.48 ± 0.06^{Db}	1.61 ± 0.02^{Ca}	1.78 ± 0.06^{Ba}	1.94 ± 0.02^{Aa}	2.04 ± 0.03^{Aab}
T8	1.29 ± 0.03^{Cc}	1.35 ± 0.02^{Cb}	1.42 ± 0.03^{BCb}	1.50 ± 0.07^{Bb}	1.72 ± 0.06^{Abc}
T9	1.08 ± 0.01^{Cd}	1.14 ± 0.02^{Cbc}	1.32 ± 0.06^{Bbc}	1.41 ± 0.06^{ABb}	1.52 ± 0.02^{Acd}
T10	1.05 ± 0.05^{Dd}	1.21 ± 0.03^{CDbc}	1.24 ± 0.06^{BCc}	1.40 ± 0.10^{ABb}	1.42 ± 0.02^{Ad}

T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. Results are presented as a mean value ± SD. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) in each identical column and row, respectively

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the oxidative stability of sunflower oil [42]. The acid value of fried noodle samples increased throughout the storage period, which could be due to the hydrolysis of lipids and the release of free fatty acids during storage [15].

3.2.4. Conjugated Dienes

The results of conjugated diene measurements are presented in Table 6. Samples containing turmeric oleoresin exhibited lower conjugated diene values than their controls fried in the same oil, and this difference was more pronounced as the oleoresin concentration increased ($p < 0.05$). At the end of the storage period, higher amounts were observed in the samples fried in rapeseed oil containing 0.1 to 0.5 turmeric oleoresin than in the samples with similar amounts of oleoresin and fried in palm oil ($P>0.05$). This finding may be attributed to the higher degree of unsaturation of rapeseed oil compared to palm oil. Conjugated dienes are generally formed during the formation of hydroperoxides from unsaturated fatty acids and represent the formation of primary oxidation products in fats and oils [43]. Similarly, Ahmed et al. (2024) reported lower conjugated diene values for palm oil than for canola oil under different storage periods and temperature conditions, which was attributed to the lower content of unsaturated fatty acids in palm oil [44]. It should be noted that, in the present study, samples fried in rapeseed oil containing turmeric oleoresin exhibited lower conjugated diene values than the palm oil containing control sample (T1) up to day 90 of storage. At the end of the storage period, the conjugated diene value of T10 (3.51) was lower than that of the palm oil control sample (4.92), and other samples fried in rapeseed oil containing turmeric oleoresin did not differ significantly from T1. Antioxidant compounds reduce the formation of conjugated dienes by reducing oxidation [45]. Therefore, it can be concluded that by adding turmeric oleoresin with antioxidant properties to rapeseed oil, reduced the formation of conjugated dienes in noodles fried in rapeseed oil despite the high content of unsaturated fatty acids in this oil. This effect became more pronounced as the concentration of turmeric oleoresin increased. According to the results of Huang et al. (2017), the addition of different concentrations of curcumin (0.1, 0.2, and 0.3 mg/g) to fish oil significantly reduced conjugated diene values in samples containing curcumin compared to the control [46]. Lodh et al. (2018) also studied the effect of adding turmeric curcumin to ghee from buffalo butter. Although conjugated diene values increased with increasing temperature and storage time, this value was significantly lower in samples containing curcumin than in other samples. Furthermore, conjugated diene values decreased as the concentration of curcumin increased [43].

Table 6. Conjugated dienes of noodle samples during storage

Sample/ Time	Conjugated dienes (mmol/kg)				
	Day1	Day30	Day 60	Day90	Day120
T1	4.01 ±0.10^{Da}	4.13 ±0.11^{CDb}	4.40 ±0.22^{BCa}	4.64 ±0.10^{ABb}	4.92 ±0.05^{Ab}
T2	4.02 ±0.08^{Da}	4.57 ±0.09 ^{Ca}	4.71 ±0.07 ^{Ca}	5.20 ±0.09 ^{Ba}	5.90 ±0.24 ^{Aa}
T3	3.54 ±0.005 ^{Db}	3.77 ±0.03 ^{Cc}	4.05 ±0.05 ^{Bb}	4.11 ±0.01 ^{Bde}	4.34 ±0.01 ^{Acd}
T4	3.28 ±0.07^{Dc}	3.57 ±0.02^{Cd}	3.89 ±0.01^{Bbc}	3.91 ±0.02^{Bef}	4.11 ±0.01^{Ade}
T5	2.77 ±0.01^{Dd}	3.50 ±0.005^{Ce}	3.64 ±0.04^{Bcd}	3.70 ±0.10^{Bfg}	3.87 ±0.02^{Aef}
T6	2.35 ±0.01^{De}	3.41 ±0.01^{Cf}	3.41 ±0.02^{Cd}	3.54 ±0.04^{Bg}	3.76 ±0.02^{Afg}
T7	3.55 ±0.10^{Db}	3.63 ±0.03^{Dd}	4.08 ±0.12^{Cb}	4.43 ±0.10^{Bc}	4.96 ±0.05^{Ab}
T8	3.11 ±0.01^{Dc}	3.33 ±0.01^{Df}	4.05 ±0.05^{Cb}	4.34 ±0.04^{Bcd}	4.68 ±0.19^{Ab}
T9	2.51 ±0.02^{De}	2.82 ±0.10^{Cg}	3.91 ±0.02^{Bbc}	4.18 ±0.05^{Bd}	4.65 ±0.06^{Abc}
T10	2.01 ±0.01^{Cf}	2.22 ±0.12^{BCh}	2.57 ±1.21^{Be}	3.25 ±0.11^{Ah}	3.51 ±0.11^{Ag}

T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. Results are presented as a mean value ± SD. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) in each identical column and row, respectively.

3.2.5. Accelerated Oxidation Stability

The results of the accelerated oxidation test are presented in Fig 1. On both days 1 and 120 of storage, the highest induction period (IP) was observed in T6, whereas the lowest value was recorded for the rapeseed oil control sample (T2) ($p < 0.05$). However, no significant differences were found between the T6 and T5, or between T2 and T7 on day 120 of storage ($p > 0.05$). Similarly, Maszewska et al. (2018) observed significant differences in induction periods between rapeseed and palm oils, with palm oil exhibiting a longer induction period [47].

At the beginning of storage, samples containing 0.5 and 0.75% oleoresin and rapeseed oil had higher induction periods (21.36 and 23.45 h), respectively, than T3 (0.1 % oleoresin and palm oil) by 19 h and T1 by 18.43 h. At the end of the storage period, the induction period of the control sample containing palm oil (17.51 h) was lower than that of T10 (22.70 h) ($p < 0.05$), and there was no significant difference with T9 (20.74 h) ($P>0.05$). A significant decrease in induction period over the storage period was observed only in samples containing 0.1% oleoresin and palm oil, as well as in samples containing 0.1–0.5% oleoresin with rapeseed oil ($p < 0.05$). In contrast, the reduction in induction period was not significant in samples containing higher concentrations of oleoresin, indicating the effective role of turmeric oleoresin in oxidative stability. Antioxidants significantly inhibit or delay lipid oxidation reactions in food systems [43], and the presence of antioxidant compounds prolongs the time required for a substance to be oxidized, and IP increases. Tinello et al. (2020) investigated the effect of turmeric rhizome and turmeric peel powders on soybean oil and stated that the induction period increased compared to the control [48]. In another study, Ramírez-Carrasco et al. (2020) found that pate samples formulated with flaxseed oil organogels containing curcumin exhibited longer induction periods than the control, which was attributed to the antioxidant properties of curcumin [34].

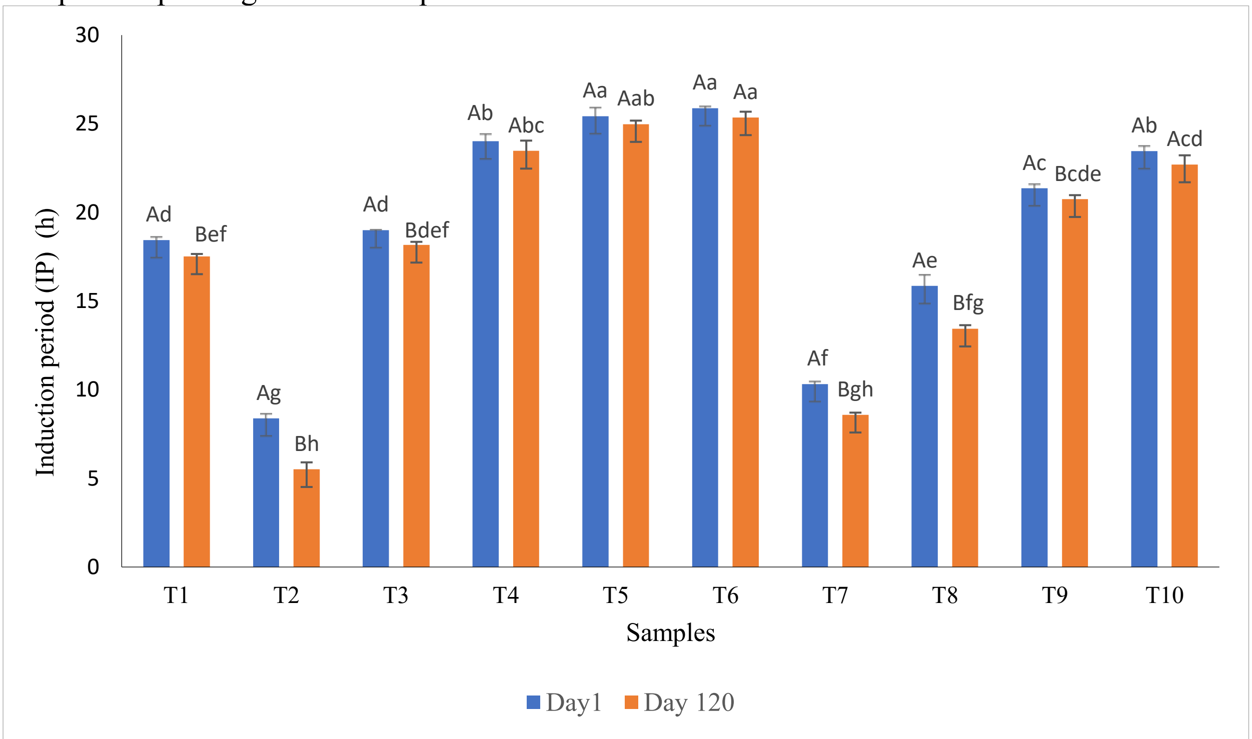

Fig1. Induction period of noodle samples on the 1st and 120th days of storage. T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) on the same day and during the storage period, respectively.

3.3. Total Phenolic Content and Antioxidant Activity

As shown in Tables 7 and 8, a significant increasing trend in total phenolic content and antioxidant activity was observed with increasing concentrations of turmeric oleoresin in the noodle samples ($p < 0.05$). This effect is because of the presence of phenolic compounds with antioxidant properties in turmeric, such as curcumin and its derivatives, including demethoxycurcumin and bisdemethoxycurcumin [49]. Therefore, the incorporation of turmeric oleoresin not only reduced oxidative deterioration in the noodle samples but also enhanced the nutritional value of the product by increasing phenolic content and antioxidant activity. This finding is particularly important given that modern consumers are increasingly aware of the impact of food products on health and tend to choose healthier food choices [50]. In previous studies, the results of Jayathilake et al. (2022) showed that the addition of turmeric oleoresin to pasteurized milk increased antioxidant properties and phenolic content [12]. In addition, the findings of Praveen et al. (2024) indicated that higher antioxidant activity was observed in peanut butter samples containing oleoresin and turmeric oleoresin oil without curcuminoids (0.25%) and curcuminoids (0.045%) compared to the control [13]. Furthermore, the results of Sıçramaz (2025) showed that yogurt samples containing turmeric powder (0.5% and 1.0%) exhibited higher total phenolic content and antioxidant activity than the control treatment. Both parameters increased as turmeric concentration elevated [49], which is consistent with the present study.

A significant decreasing trend in total phenolic content and antioxidant activity was observed during storage of noodle samples ($p<0.05$), which is probably due to the degradation of phenolic compounds over time, as well as their consumption during the inhibition of lipid oxidation [51].

Table 7. Total phenolic contents (TPC) of noodle samples during storage

	Total phenol content (mg GAE/g)				
	Day 1	**Day 30**	**Day 60**	**Day 90**	**Day 120**
T1	0.003 ±0.002^{Ac}	0.003 ±0.002^{Acd}	0.002 ±0.002^{Ab}	0.00 ±0.00^{Ab}	0.00 ±0.00^{Ab}
T2	0.00 ±0.000^{Ac}	0.000 ±0.000^{Ad}	0.000 ±0.000^{Ab}	0.000 ±0.000^{Ab}	0.000 ±0.000^{Ab}
T3	0.006 ±0.002^{Ac}	0.002 ±0.002^{Bd}	0.001 ±0.001^{Bb}	0.000 ±0.000^{Bb}	0.000 ±0.000^{Bb}
T4	0.01 ±0.001^{Ac}	0.003 ±0.002^{Bcd}	0.001 ±0.001^{Bb}	0.000 ±0.000^{Bb}	0.000 ±0.00^{Bb}
T5	0.06 ±0.02^{Ab}	0.03 ±0.008^{Ab}	0.01 ±0.00^{Bb}	0.005 ±0.002^{Bb}	0.000 ±0.00^{Bb}
T6	0.12 ±0.01^{Aa}	0.097 ±0.009^{Aa}	0.04 ±0.01^{ABa}	0.013 ±0.005^{BCa}	0.0076 ±0.0005^{Ca}
T7	0.000 ±0.000^{Ac}	0.000 ±0.000^{Ad}	0.000 ±0.000^{Ab}	0.000 ±0.000^{Ab}	0.000 ±0.000^{Ab}
T8	0.001 ±0.000^{Ac}	0.000 ±0.000^{Ad}	0.000 ±0.000^{Ab}	0.000 ±0.000^{Ab}	0.000 ±0.000^{Ab}
T9	0.002 ±0.001^{Ac}	0.001 ±0.001^{Ad}	0.00 ±0.000^{Bb}	0.000 ±0.000^{Bb}	0.000 ±0.000^{Bb}
T10	0.010 ±0.002^{Ac}	0.008 ±0.002^{Bc}	0.004 ±0.001^{Cb}	0.000 ±0.000^{Db}	0.000 ±0.000^{Db}

T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. Results are presented as a mean value ± SD. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) in each identical column and row, respectively.

Table 8. Antioxidant activity of noodle samples during storage

Sample/ Time	DPPH scavenging capacity (%)				
	Day1	**Day30**	**Day 60**	**Day90**	**Day120**
T1	2.08 ± 0.05^{Ad}	1.30 ± 0.20^{Bcde}	0.64 ± 0.08^{Cf}	0.041±0.02^{CDef}	0.33 ± 0.03^{De}
T2	1.02±0.03^{Ah}	0.93 ±0.04^{Ae}	0.69 ± 0.04^{Bf}	0.26 ± 0.15^{Cf}	0.03 ± 0.005^{Df}
T3	2.16± 0.03^{Ad}	1.39 ± 0. 19^{Bbcd}	0.74 ± 0. 08^{Cef}	0.51 ± 0.01^{CDdef}	0.43 ± 0.02^{Dd}
T4	2.31 ± 0.03^{Ac}	1.56 ± 0.17^{Bbc}	0.90 ± 0.09^{Cde}	0.66 ± 0.01^{CDcde}	0.57±0.03^{Dc}

T5	2.56 ± 0.06 ^{Ab}	1.75 ± 0.17 ^{Bab}	1.14 ± 0.04 ^{Cc}	0.90 ± 0.01 ^{Dabc}	0.81 ± 0.02 ^{Db}
T6	2.83 ± 0.06 ^{Aa}	2.04 ± 0.16 ^{Ba}	1.36 ± 0.10 ^{Cab}	1.11 ± 0.10 ^{Da}	0.98 ± 0.03 ^{Da}
T7	1.11 ± 0.04 ^{Ah}	1.006 ± 0.02 ^{Ae}	0.78 ± 0.03 ^{Bdef}	0.38 ± 0.12 ^{Cef}	0.11 ± 0.01 ^{Df}
T8	1.26 ± 0.04 ^{Ag}	1.18 ± 0.04 ^{Ade}	0.93 ± 0.03 ^{Bd}	0 .51 ± 0.15 ^{Cdef}	0.28 ± 0.27 ^{De}
T9	1.50 ± 0.02 ^{Af}	1.40 ± 0.03 ^{Abcd}	1.17 ± 0.04 ^{Bbc}	0.74 ± 0.14 ^{Cbcd}	0.51 ± 0.29 ^{Dcd}
T10	1.73 ± 0.03 ^{Ae}	1.64 ± 0.05 ^{Abc}	1.41 ± 0.03 ^{Ba}	1.01 ± 0.27 ^{Cab}	0.74 ± 0.30 ^{Db}

T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. Results are presented as a mean value ± SD. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) in each identical column and row, respectively.

3.4. Sensory Evaluation

The results of the sensory evaluation are presented in Table 9. At the beginning of the storage, increasing the oleoresin concentration up to 0.75% in palm oil-fried samples caused a decrease in taste and odor scores. A similar decreasing trend was also observed in the rapeseed oil-fried samples. The reduction in taste and odor scores with increasing turmeric oleoresin concentration may be related to the enhanced bitterness associated with phenolic compounds such as curcumin.

Because plant extracts that are rich in phenolic compounds probably play a role in the bitterness and astringency of foods [52]. Lučan Čolić et al. (2023) reported that the addition of turmeric powder at concentrations of 1% and higher to ice cream significantly reduced taste and odor scores compared to the control and resulted in a more bitter taste. However, no significant difference was observed between the sample containing 0.5% turmeric powder and the control [53]. Wang et al.

(2020) also investigated the effect of incorporating 0.05% curcumin into fresh millet noodles. The sensory evaluation results indicated that the addition of curcumin did not adversely affect the taste or odor of the noodles [54].

After 120 days of storage, all samples containing oleoresin and rapeseed oil had higher taste and odor scores than the control containing rapeseed oil (T2). The flavor of rapeseed oil is mainly influenced by three pathways: glucosinolate degradation, thermal oxidation, and Maillard reactions. These processes generate more than 300 volatile compounds, including sulfur- and nitrile-containing compounds, pyrazines, aldehydes, furans, and nitriles [55]. Since rapeseed oil is more sensitive to oxidation and thermal degradation than palm oil, it is possible to reduce the development of undesirable tastes and odors by reducing oxidation in this Therefore, the addition of turmeric oleoresin to samples fried in rapeseed oil improved flavor and odor scores compared with the corresponding control without oleoresin by reducing oxidation and the formation of oxidation-derived compounds. This effect became more evident at the end of the storage period. Regarding color index, samples containing turmeric oleoresin had significantly higher color scores than the control sample with the same frying oil on both days 1 and 120 of storage ($p < 0.05$). The yellow color of turmeric is mainly attributed to the presence of three main pigments, including curcumin (50-60%), demethoxycurcumin (20-30%), and bisdemethoxycurcumin (7-20%) [56]. Therefore, adding turmeric oleoresin to yellow noodles may be desirable. In the study of Wang et al. (2020), using turmeric curcumin in noodles improved color characteristics [54], which is consistent with the present study. The texture scores of the samples on day 1 of storage were not significantly different ($p > 0.05$). After 120 days of storage, there was no significant difference between samples containing oleoresin or between these samples and T1. The addition of 0.5% oleoresin to noodles caused a higher overall acceptability score in the sample fried in rapeseed oil compared to the control containing palm oil. Although overall acceptability scores decreased by increasing oleoresin concentration, the samples remained within an acceptable sensory range. Similarly, Guo et al. (2022) reported that the addition of curcumin (0.05–0.25%) to potato noodles improved sensory quality; however, a declining trend was observed at higher concentrations [57]. An interesting finding of the present study was that the addition of 0.25% and 0.75% turmeric oleoresin to noodles fried in rapeseed oil resulted in overall acceptability scores that were not significantly different from those of the palm oil control (T1) at the end of the storage period. Moreover, the sample containing 0.5% turmeric oleoresin (T9) exhibited a higher overall acceptability score than T1.

Table 9. The sensory evaluation of noodle samples on the 1st and 120th days of storage

Sample/ Time	Sensory parameters									
	Taste		Odor		Color		Texture		Overall acceptance	
	Day 1	Day120	Day 1	Day120	Day 1	Day120	Day 1	Day120	Day 1	Day120
T1	8.20 ± 0.63^{Bb}	9.00 ± 0.00^{Aa}	8.80 ± 0.42^{Aa}	8.10 ± 0.31^{Bab}	7.90 ± 0.31^{Ab}	6.90 ± 0.31^{Bc}	8.10 ± 0.31^{Ba}	9.00 ± 0.00^{Aa}	8.50 ± 0.70^{Ab}	8.00 ± 0.00^{Bb}
T2	7.60 ± 0.69^{Acd}	2.10 ± 0.99^{Be}	$7.600. \pm 51^{Abc}$	2.00 ± 1.08^{Bd}	7.50 ± 0.70^{Ab}	2.50 ± 0.85^{Bd}	8.00 ± 0.00^{Aa}	8.00 ± 0.94^{Ab}	7.40 ± 0.51^{Ad}	1.80 ± 0.42^{Bd}
T3	8.10 ± 0.31^{Bbc}	9.00 ± 0.00^{Aa}	8.80 ± 0.42^{Ba}	9.00 ± 0.00^{Aa}	8.60 ± 0.51^{Aa}	8.00 ± 0.00^{Bb}	8.00 ± 0.00^{Ba}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}
T4	8.10 ± 0.31^{Bbc}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Bb}	8.90 ± 0.31^{Aa}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Ba}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}
T5	8.00 ± 0.00^{Bbc}	8.00 ± 0.00^{Ab}	8.00 ± 0.00^{Ab}	8.00 ± 0.00^{Aab}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Ba}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Ac}	8.00 ± 0.00^{Ab}
T6	7.10 ± 0.31^{Bcd}	8.00 ± 0.00^{Ab}	7.20 ± 0.42^{Bcd}	7.90 ± 0.56^{Aab}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Ba}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Ac}	8.90 ± 0.31^{Ba}
T7	9.00 ± 0.00^{Aba}	3.10 ± 0.87^{Bd}	9.00 ± 0.00^{Aa}	4.50 ± 1.78^{Bc}	8.83 ± 0.84^{Aa}	7.10 ± 0.31^{Bc}	8.00 ± 0.00^{Ba}	9.00 ± 0.00^{Aa}	8.90 ± 0.31^{Aab}	4.00 ± 0.81^{Bc}
T8	9.00 ± 0.00^{Aba}	7.10 ± 0.87^{Bc}	8.90 ± 0.31^{Aa}	7.30 ± 1.05^{Bb}	8.70 ± 0.48^{Aa}	8.60 ± 0.51^{Aa}	8.00 ± 0.00^{Ba}	9.00 ± 0.00^{Ba}	8.90 ± 0.31^{Aab}	7.50 ± 1.08^{Bb}
T9	9.00 ± 0.00^{Aba}	8.00 ± 0.00^{Bb}	8.00 ± 0.00^{Ab}	8.20 ± 0.42^{Aab}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Ba}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}
T10	8.00 ± 0.00^{Abc}	8.00 ± 0.00^{Ab}	7.10 ± 0.31^{Bd}	7.90 ± 0.56^{Aab}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Ba}	9.00 ± 0.00^{Aa}	8.00 ± 0.00^{Ac}	8.00 ± 0.00^{Ab}

T1: without oleoresin and fried in palm oil. T2: without oleoresin and fried in rapeseed oil .T3, T4, T5, and T6: fried in palm oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. T7, T8, T9, and T10: fried in rapeseed oil and contain 0.1, 0.25, 0.5, and 0.75% turmeric oleoresin, respectively. Results are presented as a mean value ± SD. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) in each identical column and row, respectively.

4-Conclusion

In this study, the effect of turmeric oleoresin on improving the oxidative stability of fried instant noodles and their physicochemical and sensory properties was investigated. The addition of turmeric oleoresin to noodles fried in rapeseed or palm oil improved the oxidative stability, total phenolic content, and antioxidant activity, while no significant changes were observed in physicochemical properties. The peroxide value, anisidine value, TBA value, acid value, conjugated diene content, and induction period depended on the type of frying oil used in the noodles and the concentration of oleoresin, and increasing the oleoresin concentration enhanced oxidative resistance. It should be noted that turmeric oleoresin, particularly at higher concentrations of 0.5 and 0.75% in instant noodles fried in rapeseed oil, caused similar or even better oxidative stability than the control noodle fried in palm oil. Therefore, given the challenges in supplying palm oil used for frying noodles in Iran, palm oil can be replaced with rapeseed oil, and turmeric oleoresin can be added to produce a product with appropriate oxidative stability and acceptable physicochemical and sensory properties.

5- Acknowledgements

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Data availability

Data will be made available upon request from the corresponding author.

Conflict of Interest

The authors hereby declare that Dr. Afshin Jafarpour, one of the authors, has a professional relationship with Golestan Company, the manufacturer of the product investigated in this study (noodles). The results of the present research are currently being utilized in the company's industrial process. The remaining authors declare no conflict of Interest. This research was conducted in accordance with the principles of scientific integrity and impartiality.

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Author Contributions

Paniz Kabiri: Investigation, Resources, Data curation. Samar Mansouripour: Conceptualization, Methodology, Project administration, formal analysis, Validation, Writing-review & editing. Afshin Jafarpour: Conceptualization, Methodology, Resources, Writing-review & editing.

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بررسی اثر اولئورزین زردچوبه بر بهبود پایداری اکسایشی نودل فوری سرخ شده و ویژگی‌های فیزیکوشیمیایی و حسی آن

پانید کبیری[1]، ثمر منصوری پور[1و2*]، افشین جعفرپور[3]

۱- گروه علوم و مهندسی صنایع غذایی، واحد علوم پزشکی تهران، دانشگاه آزاد اسلامی، تهران، ایران.

۲- مرکز تحقیقات علوم تغذیه و صنایع غذایی، واحد علوم پزشکی تهران، دانشگاه آزاد اسلامی، تهران، ایران.

۳- گروه علوم و صنایع غذایی، واحد گرمسار، دانشگاه آزاد اسلامی، گرمسار، ایران.

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* مسئول مکاتبات:

Sa.mansouripour@iau.ac.ir

چکیده

با توجه به مشکلات موجود در تأمین روغن پالم برای سرخ کردن نودل در ایران و استفاده از روغن کلزا، هدف از این مطالعه افزایش پایداری اکسایشی نودل سرخ شده در روغن کلزا با افزودن اولئورزین زردچوبه می‌باشد. دو گروه نودل با روغن پالم و یا کلزا سرخ گردید. سپس اولئورزین زردچوبه روی نودل‌ها اسپری شد و ویژگی‌های کیفی در طول ۱۲۰ روز ارزیابی گردید. نمونه‌های حاوی اولئورزین نسبت به شاهد خود با روغن سرخ کردنی یکسان، اندیس پراکسید و آنیزیدین پایین تری را نشان دادند. پس از ۱۲۰ روز، نمونه‌های سرخ شده در روغن کلزا که دارای ۰/۵ و ۰/۷۵ درصد اولئورزین بودند (T9 و T10) نسبت به نمونه سرخ شده در روغن پالم بدون الئورزین (T1)، اندیس پراکسید و آنیزیدین کمتری داشتند($P<0.05$). با افزایش غلظت اولئورزین روند کاهشی در تیوباربیتوریک اسید مشاهده شد. همچنین اندیس اسیدی و دی ان کونژوگه نمونه‌های T8 (۰/۲۵ درصد اولئورزین و سرخ شده در کلزا)، T9 و T10 نسبت به T1 یا کمتر و یا غیرمعنادار بود. در انتهای دوره نگهداری، زمان القاء (IP) در نمونه T1 از نمونه T10 کمتر بود و اختلاف معناداری باT9 نداشت. با افزایش میزان اولئورزین، روند افزایشی معناداری در محتوی فنل و فعالیت آنتی‌اکسیدانی مشاهده شد($P<0.05$). از نظر مقبولیت کلی، در پایان دوره نگهداری اختلاف معناداری بین T10 با T1 وجود نداشت و حتی امتیاز نمونه T9 از آن بالاتر بود. بنابراین جایگزین نمودن روغن پالم با روغن کلزا همراه با افزودن اولئورزین زردچوبه به نودل به ویژه در غلظت‌های بالاتر (۰/۵ و ۰/۷۵ درصد) پیشنهاد می‌گردد.