Effect of Frying on Physicochemical and Sensory Properties of Potato Chips Fried in Palm Oil Supplemented with Thyme and Rosemary Extracts

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Abstract: Quality parameters of potato chips (flat and serrated) fried either in palm oil (PO) alone or containing natural (thyme (TPO) and rosemary (RPO) extracts) and synthetic BHT (BPO) antioxidants were evaluated during storage period. The free fatty acid and peroxide values of chips fried in PO (control) were found between 0.18 and 0.21% to 1.00 and 1.04 meqO₂/kg during the first storage month, respectively. However, these values were 0.07-0.10% and 0.55-0.90 meqO₂/kg for chips fried in TPO, respectively. The water contents increased when storage time increased from 1 to 7 month and their values changed between 0.49 and 1.95% (flat potato chips in BPO) and between 0.88 and 1.24% (serrated potato chips in TPO). The total trans-fat contents were 0.13% (serrated potato chips in BPO) and 0.35% (both flat and serrated potato chips in PO) at the start of storage. The total trans-fat content after 7 months were 0.13% (PO fried flat and serrated potato chips) and 0.17% (serrated potato chips fried in BPO, TPO and RPO). The acrylamide contents varied between 152 (serrated potato chips in PO) and 540 µg/kg (flat potato chips fried in RPO) at the beginning of storage. However, the acrylamide contents changed during 7th storage month and ranged from 182 (serrated potato chips in PO) to 518 µg/kg (flat potato chips in RPO). Among fatty acids, while palmitic acid are determined between 37.14 (flat chips in PO) and 41.60% (serrated chips in TPO), oleic acid varied between 30.0 (flat chips in RPO) and 33.00% (serrated chips in PO). Sensory evaluation showed that PO containing antioxidants showed better consumer preference for potato chips until the end of storage.

Key words: potato chips frying, BHT, rosemary and thyme extract, palm oil, free fatty acidity, peroxide value, acrylamide, fatty acids, sensory properties

1 Introduction

The use of vegetable oil is essential in different food processing processes such as frying1. There are changes in the physical, chemical, nutritional and emotional properties of the oil that affect frying performance in frying processes2. The most common fried food product are potato chips or French fries. The relevant quality parameters for fried potatoes are classified as physical and chemical properties, fat content, water content and some other properties3. Due to their chemical structure, oils can undergo chemical changes under the influence of many factors and become harmful to health. These factors are temperature, light, ventilation, metallic ions and enzyme activities. They may act alone or in a collective way and cause events called autoxidation, thermal polymerization and oxidation in oils. Because of a series of reactions in these events, a large number of reaction products may form, or rancidity of fats may occur4. Oil used during frying can be different origins and their physicochemical properties can affect the degree of oxidation and hydrolysis reactions. Stability of oils depends on their fatty acids and presence of natural antioxidants in addition to the frying temperature5. Re-use of fried oil can directly affect the quality of fried products due to the formation of harmful substances to an undesirable degree which not only deteriorate the sensory quality but also accelerates fat deterioration6. Degradation of oil can result in acrylamide and aldehydes formation which may accumulate into the food matrix7. Aldehydes, alcohols and
hydrocarbons are volatile compounds often formed during deep frying and some of them may negatively affect human health. These volatiles not only deteriorate the flavor but also result in certain toxic effects. Potatoes contain very small amount (0.1%) of fat and once fried, the frying oil penetrates into potato products thereby increasing the fat contents significantly. A limited number of studies have been conducted on some characteristics of potato chips oils and the content of acrylamide in the chips after frying in oils containing natural antioxidant enriched extracts such as from rosemary and thyme. Rosemary (Rosmarinus officinalis) is a small needle-tipped, leafy plant from Labiatae family. Aromatic plant 1-2 m in height does not shed its leaves in winter. It has a strong aroma resembling the smell of eucalyptus. The flowers that bloom in spring and summer are white, light blue and blue in color. The leaves taste bitter in spring. Its leaves and essential oil are used, due to their pleasant aroma arising from the essential oils in European and North American countries. Rosemary is used as an antioxidant or natural preservative in foods as well as soap, room fragrance, deodorant, perfume and lotion. Essential oil or extracts of rosemary are used in meat products, foods containing fat, against oxidation and rancidity in fats. Thyme (Thymus vulgaris) is a genus of Thymus from the family Lamiaceae and it grows in sunny and warm climates in rocky and mountainous regions where the soil temperature is high. Common properties of oregano species commonly used and traded include essential oils and the main components of these essential oils are thymol and carvacrol. These substances are phenolic compounds that give the oregano its own odor and antioxidant properties. These compounds constitute 78-82% of essential oils. For these reasons, the current study was designed to improve the quality of potato chips obtained after frying in oil supplemented with natural antioxidants. In this study, sensory and chemical analyses were carried out with the aim of increasing the taste of the chips, increasing their shelf life and preserving their freshness for the longer time.

2 Material and Method

2.1 Materials

The chips used in this study were produced from potatoes grown in Reyhanlı region of Hatay in Turkey. The oil used for frying was palm olein oil from Malaysia. The natural antioxidant sources used in this study (thyme and rosemary extracts) were obtained from aroma and oil companies operating in Turkey.

2.2 Experimental plan

Chips samples used in this study included those fried (straight cut and serrated cut potato wedges) in butylated hydroxytoluene (BHT) containing palm olein oil (BPO), thyme extract containing palm olein oil (TPO), rosemary extract containing palm olein oil (RPO) and palm olein oil (PO). The samples were classified into eight groups. Samples the fatty acid composition were stored at room conditions for 7 months and analyses were carried out before and after frying. The analysis of acrylamide and trans fat were done at the beginning and end of shelf life. Oil content, free fatty acid, peroxide, moisture, salt values of samples were made on monthly basis. Whereas sensory analyses were made on weekly basis.

2.3 Preparation and storage of chips samples

Potato slices of 1.40 mm thickness for straight cut and 2.10 mm thickness for serrated wedges were prepared using the slicing machine and then fried in different oils as mentioned in previous section at 180°C followed by coating with 1.4-1.8% powder salt to give flavor. Then, samples were packed in metalized packages under nitrogen (99.9%), and stored for 7 months at room temperature at dry place.

2.4 Determination of moisture and salt

Salt amount % = \( \frac{(V \times N \times \text{mEq} \times F)}{\text{Sample wt}} \times 100 \)

where \( V \) is the amount of AgNO₃ spent (mL), \( N \) is normality of AgNO₃ solution (0.1N), \( F \) is the factor of AgNO₃ solution, mEq is the equivalent weight of spindle to NaCl (0.0585 g) and sample means sample amount (g).

2.5 Oil contents

About 10 g chip for each sample were weighed, and placed in Soxhlet cartriges and covered. Then, it was extracted for 8 hours using hexane solvent in a Soxhlet apparatus and hexane was removed by placing in oven. The containers removed from the oven were placed in the desiccator and allowed to cool to room temperature. For salt determination 5 g of each of the chips samples was mixed with 200 mL of distilled water and a few drops of 5% \( \text{K}_2\text{CrO}_7 \) indicator were dropped, and titrated with 0.1N AgNO₃ solution and titration was terminated when the tile color was formed.

\[ \text{Salt amount} \% = \frac{(V \times N \times \text{mEq} \times F)}{\text{Sample wt}} \times 100 \]

where \( V \) is the amount of AgNO₃ spent (mL), \( N \) is normality of AgNO₃ solution (0.1N), \( F \) is the factor of AgNO₃ solution, mEq is the equivalent weight of spindle to NaCl (0.0585 g) and sample means sample amount (g).

\[ \text{Oil amount} \% = \frac{(M_s - M_i)}{\text{Sample wt}} \times 100 \]

where \( M_s \) is the weight of final weighing balloon and \( M_i \) is

\[ \frac{M_2 - M_1}{V} = \frac{M_2 - M_1}{1000} \times \frac{F}{N} \]

where \( M_2 \) is the weight of final weighing balloon and \( M_1 \) is
the weight of first weighing balloon.

2.6 Determination of free fatty acids

The chip sample (100 g) was crushed, weighed, and filled with 250 mL of hexane and kept in the dark for 24 h followed by hexane evaporation in an oven at 103 ± 2°C for 8 h. 5 g of the oil samples were taken and dissolved in 30 mL of diethylether: ethanol (1: 1) and titrated with 0.1 N NaOH by adding a few drops of phenolphthalalein indicator. Filtration was terminated when persistent violet purple color was observed using spent NaOH (V) in mL according to following expression:

Free Fatty Acid % = V × 2.82 / sample quantity

2.7 Determination of peroxide number

About 100 g chip sample was crushed, filled with 250 mL of hexane and kept in the dark for 24 hours. Then, the hexane was evaporated by filtration with filter paper in an oven at 103 ± 2°C for 8 h. 2 g of the oil samples were taken and dissolved in 10 mL of chloroform and 15 mL of acetic acid was added and mixed. 1 mL of saturated KI solution was added and left in the dark for 10 min. Afterwards, 75 mL of pure water and 1 mL of starch solution was dropped and titrated with 0.002 N sodium thiosulfate color consumption was read according to following expression:

Peroxide numbers (meg/kg) = 2 × consumption / sample quantity

2.8 Trans-fat analysis

Oil sample was prepared by dissolving 1 g of each oil in 50 mL of n-hexane then was shaken strongly, and solution was filtered by using 0.45 μm membrane filter. Chips samples were analyzed for trans-fatty acid using following gas chromatography (GC) system and conditions in an accredited laboratory:

2.9.1 Working Conditions of GC System

Agilent 6890 N model GC Gas Chromatography device, using flame ionization detector (FID) and DB-23 (bonded 50% cyan propyl) (J & W Scientific, Folsom, CA, USA) capillary column (60 m × 0.25 mm id × 0.250 μ) it is made. Detector temperature of 280°C, injector temperature of 270°C, injection following split model, injector temperature of 260°C, split method of 1/50 ratio, carrier gas (helium)/flow rate was 0.5 mL/min (constant flow model), hydrogen gas flow was 30 mL/min, air flow was 300 mL/min, make up gas flow Helium @ 24.5 mL/min were the operating parameters for GC analyses for trans-fatty determination.

2.9 Acrylamide analysis

Chips samples were sent to an accredited laboratory where acrylamide analysis was accomplished following Pedreschi et al. method. About 4 g of homogenized potato were extracted with 40 mL water by an Ultra-turrax mixer. Each analytical batch included 1-2 spiked samples for recovery measurements. The samples were centrifuged for 10 min at 3500 rpm. Then, solution were filtered by Teflon filter.

2.10 Fatty acid composition analysis

One drop of the oil was dissolved in 1 mL of n-heptane, 50 µg of sodium methylate was added, and the closed tube was agitated vigorously for 1 min at room temperature. After addition of 100 µL of water, the tube was centrifuged at 4500 g for 10 min and the lower aqueous phase was removed. The esterification of the samples was carried out according to the method of ISO 5509 using n-hexane and methanolic KOH. Fatty acid methyl esters were determined using a flame ionization detector (FID) and capillary column (Teknokroma TR CN100, P / N TR 882162 fused silica column, 60 m × 0.25 mm × 0.20 μm) in gas chromatography apparatus (Shimadzu GC 2010) (Matthäus and Ozcan, 2006). Operating conditions of the device included: detector temperature of 260°C, injection block temperature of 260°C, nitrogen as mobile phase, total flow rate was 80 mL/min, flow rate of nitrogen was 1.51 mL/min, split rate was 1/40 mL/min, temperature program included holding at 90°C for 7 min and increasing by 5°C/min to 240°C and kept for 15 min at this temperature.

2.11 Sensory analysis

Hedonic test was chosen for sensory evaluation. For this purpose, 8 people were selected in the taste test. In order to determine the sensory properties of chips samples, 8 semi-educated panelists were asked to specify numerical values. Color, taste, odor, brittleness and general acceptability were examined and panelists were asked to evaluate the samples separately for each. Each group of samples was presented to the panelists simultaneously and with the same presentation and they were asked to score (1 = very bad, 2 = bad, 3 = moderate, 4 = good, 5 = very good).

2.12 Statistical analyses

Data obtained from all analysis were calculated as mean ± standard deviation using MSTAT C software.

3 Results and Discussion

3.1 Free fatty acids and peroxide values of potato chips

Potato chips samples fried (straight cut and serrated cut potato wedges) in palm olein oil (BPO) containing butylated hydroxytoluene (BHT), thyme (TPO) and rosemary extract (RPO) and palm olein oil (PO) (control) are given in Table 1. In general, both free acidity and peroxide values of chips fried in BPO, TPO and RPO were found lower than that of...
control group (fried in PO) in the first month of storage. During first storage month, free fatty acid and peroxide values of flat and serrated potato chip oils change between 0.07-0.21% and 0.55-1.04 meqO₂/kg, free fatty acid and peroxide values of flat and serrated potato chip oils were determined between 0.07-0.34% and 0.80-2.14 meqO₂/kg during 7th month of storage, respectively. Peroxide value (1.50 meqO₂/kg) of serrated potato chips fried in TPO was higher than control group only in the second month of storage. Towards the end of storage, the free fatty acid and peroxide values of all chips samples increased partially. As in the first month of storage, BHT, thyme and rosemary extracts were effective on reducing free fatty acid and peroxide values compared to control groups in the 7th month.

The free acidity value of sunflower oil used in frying potato chips ranged from 0.33, 0.28 and 0.15mg KOH/g, respectively. During first storage month, free fatty acid and peroxide values of flat and serrated potato chip oils were between 2.25 meq/kg and 17.56 meq/kg for the free acidity values change between 2.25 meq/kg and 17.56 meq/kg.

Free fatty acids are formed of mono and diglycerides in the medium, glycerol and free hydrolysis of triglycerides and ultimately the combination fatty acids are converted to these products in the course of degradation. Depending on the type of diet, fats are consumed in various ways. Of these, most are used for frying purposes and vegetable oils are preferred in this process. High polyunsaturated fatty acids in the structure can reduce the shelf life of both oil and fried products in frying oils. Therefore, fried vegetable oils can become harmful to human health. In addition, due to their chemical structure, fats can undergo chemical changes under the influence of many factors and become harmful to health.

**Table 1** Free fatty acid and peroxide values of chips oils fried in palm olein added synthetic and natural antioxidant.

| Chips Samples          | Peroxide (meqO₂/kg) | Free fatty acid (%oleic acid) |
|------------------------|---------------------|------------------------------|
| Flat potato chips PO   | 0.07 ± 0.08         | 0.00 ± 0.00                  |
| Serrated potato chips PO | 0.21 ± 0.08        | 0.00 ± 0.00                  |
| Flat potato chips BPO  | 0.07 ± 0.08         | 0.00 ± 0.00                  |
| Serrated potato chips BPO | 0.21 ± 0.08        | 0.00 ± 0.00                  |
| Flat potato chips TPO  | 0.07 ± 0.08         | 0.00 ± 0.00                  |
| Serrated potato chips TPO | 0.21 ± 0.08        | 0.00 ± 0.00                  |
| Flat potato chips RPO  | 0.07 ± 0.08         | 0.00 ± 0.00                  |
| Serrated potato chips RPO | 0.21 ± 0.08        | 0.00 ± 0.00                  |

*Means ± standard deviation, PO: Palm oil, BPO: BHT containing palm oil, TPO: thyme containing palm oil, RPO: rosemary containing palm oil*
3.2 Moisture and salt contents of potato chips

The moisture and salt contents of potato chips fried in BPO, TPO, RPO and PO are given in Table 2. While moisture and salt analysis of chips fried in palm olein added synthetic and natural antioxidant vary between 0.49-0.88% and 1.30-1.75% at the first month of storage, moisture and salt analysis of chips fried in palm olein added synthetic and natural antioxidant changed between 1.24-1.95% and 1.47-1.70% at the end of storage, respectively. The salt content of the chips did not show much variation from start until end of the storage. However, it was observed a partial increase in water contents towards the end of storage, which, may have resulted to the absorption of moisture from air. In the first month of storage, the water content of potato chips fried in BPO, TPO and RPO stayed within 0.49 (flat potato chips fried in BPO) and 0.88% (serrated potato chips fried in TPO). The water content increase to 1.24 in serrated potato chips fried in TPO and 1.95% in plain potato chips fried BPO. The data in Table 2 reveals that the water contents of chips fried in TPO and RPO were in general higher than that of the PO (control group), which may be due to the fact that the vegetable extracts may absorb more moisture due to their fibrous nature. The moisture content for all types of chips varied between 1.0 and 1.3%.[22] In the first month of storage, the salt content of potato chips varied between 1.30 (flat potato chips fried in RPO) and 1.75% (serrated potato chips fried PO). Whereas after 7th month of storage, the salt content increase to 1.47 (serrated potato chips fried in BPO) - 1.70% (flat potato chips fried in RPO). The reason for the difference in salt values is due to the homogeneous distribution on the slices during the sample preparation stage. The number of peroxides of olive oil and vegetable shortening used repeatedly in potato chips production has changed.[23] However, it has been observed that peroxides do not show a constant increase in ketones, aldehydes, hydrocarbons and alcohols in constant deep frying and are not stable.[11][24] Oil peroxide value increased from 0.6 meqO₂/kg to 6.5 meqO₂/kg.[25] The peroxide value of all oils obtained from potato chips was below the value determined by the Codex Alimentarius Commission (15 meqO₂/kg for extra virgin and cold press olive oil, max. 10 meqO₂/kg for other oils).[26]

3.3 Trans-fat contents in potato chips

Trans oil analysis results of potato chips fried in palm olein oil containing BHT, thyme and rosemary extracts are illustrated in Table 3. Initially, total trans fatty acid contents were 0.30 (serrated potato chips fried in BPO) to 0.35% (serrated potato chips fried in PO), however at the end of storage it was 0.13 (flat potato chips fried in either oil)-0.17% (serrated potato chips fried in ether). Initially, the total trans-fat contents of the plain and serrated potato chips with thyme and rosemary extracts were found to be

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Table 2: Moisture and salt analysis of chips fried in palm olein added synthetic and natural antioxidant.

| Chip samples                  | 1 month | 2 month | 3 month | 4 month | 5 month | 6 month | 7 month |
|------------------------------|---------|---------|---------|---------|---------|---------|---------|
| Flat potato chips fried in BPO| 0.003± 0.006* | 0.12 | 0.15 | 0.008 | 0.012 | 0.009 | 0.008 |
| Serrated potato chips fried in BPO | 0.014± 0.003 | 0.016 | 0.018 | 0.012 | 0.014 | 0.011 | 0.010 |
| Flat potato chips fried in TPO | 0.014± 0.003 | 0.016 | 0.018 | 0.012 | 0.014 | 0.011 | 0.010 |
| Serrated potato chips fried in TPO | 0.014± 0.003 | 0.016 | 0.018 | 0.012 | 0.014 | 0.011 | 0.010 |
| Flat potato chips fried in RPO | 0.014± 0.003 | 0.016 | 0.018 | 0.012 | 0.014 | 0.011 | 0.010 |
| Serrated potato chips fried in RPO | 0.014± 0.003 | 0.016 | 0.018 | 0.012 | 0.014 | 0.011 | 0.010 |

* = ± standard deviation. PO: Palm oil, BPO: BHT containing palm oil, TPO: thyme extract containing palm oil, RPO: rosemary extract containing palm oil.
partially lower than the control group, but these values gradually increased after storage. This difference may be due to the instability observed in high temperature frying oils. This instability might have triggered the impurities found in the extracts. Trans oleic acid was initially detected in the oil without antioxidants whereas it was not detected in those containing natural antioxidants. Initially, the total amount of trans fat was measured in a higher amount in oil without antioxidant. At the end of the shelf life, the total amount of trans fat in oil without antioxidant was relatively lower than that of oils containing antioxidant.

3.4 Acrylamide contents in potato chips

Acrylamide contents of flat and serrated potato chips fried in PO containing synthetic (BHT) and natural (thyme and rosemary extract) antioxidants were determined, and results are presented in Table 4. The initial acrylamide contents of chips samples change between 152 (serrated potato chips in PO) and 540 µg/kg (flat potato chips in RPO), acrylamide contents of chips samples in the last of frying changed between 182 (serrated potato chips fried in PO) and 518 µg/kg (flat potato chips fried in RPO). It was observed a partially increase in acrylamide contents of chip samples toward of the end of frying. Coconut oil was the second most common form of acrylamides in palm olein oil. The fried potatoes quality is dependent on the structure, chemical and physical properties of raw potatoes and these attributes are related to the type of food matrix and the processing techniques applied to them. The most important physical attribute of fried potatoes include color, mechanical properties, porosity, volume and smoothness. Whereas among chemical quality attributes, fat and moisture content of fried potatoes play important and basic role\(^{26 - 29}\). The potatoes fried at 150, 170 and 190 \(^\circ\)C had an acrylamide content of 287, 1338 and 2128 µg/kg, respectively. At low frying temperatures (70 \(^\circ\)C), the acrylamide content may decrease to 342 µg/kg (fried for 10 min) and 538 µg/kg (fried for 80 min)\(^{30}\). Thus, acrylamide is formed as a result of heat reaction of potato components when the

| Chip samples                      | The first of frying | The last of frying |
|----------------------------------|---------------------|-------------------|
|                                  | Trans Linoleic Acid + Linolenic Acid | Trans Oleic Acid | Total Trans Oil | Trans Linoleic Acid | Trans Oleic Acid | Total Trans Oil |
| Flat potato chips fried in PO     | 0.30                | 0.05              | 0.35            | 0.13              | 0                | 0.13            |
| Serrated potato chips fried in PO| 0.30                | 0.05              | 0.35            | 0.13              | 0                | 0.13            |
| Flat potato chips fried in BPO    | 0.31                | 0                 | 0.31            | 0.15              | 0                | 0.15            |
| Serrated potato chips fried in BPO| 0.30                | 0                 | 0.30            | 0.17              | 0                | 0.17            |
| Flat potato chips fried in TPO    | 0.31                | 0                 | 0.31            | 0.17              | 0                | 0.17            |
| Serrated potato chips fried in TPO| 0.31                | 0                 | 0.31            | 0.17              | 0                | 0.17            |
| Flat potato chips fried in RPO    | 0.32                | 0                 | 0.32            | 0.17              | 0                | 0.17            |
| Serrated potato chips fried in RPO| 0.32                | 0                 | 0.32            | 0.17              | 0                | 0.17            |

PO: Palm oil, BPO: BHT containing palm oil, TPO: thyme extract containing palm oil, RPO: rosemary extract containing palm oil

| Chip samples                      | The first of frying (µg/kg) | The last of frying (µg/kg) |
|----------------------------------|-----------------------------|---------------------------|
| Flat potato chips fried in PO     | 460 ± 120*                  | 409 ± 48                  |
| Serrated potato chips fried in PO| 152 ± 46                    | 182 ± 21                  |
| Flat potato chips fried in BPO    | 347 ± 92                    | 342 ± 40                  |
| Serrated potato chips fried in BPO| 356 ± 95                    | 380 ± 44                  |
| Flat potato chips fried in TPO    | 354 ± 94                    | 287 ± 33                  |
| Serrated potato chips fried in TPO| 265 ± 72                    | 321 ± 37                  |
| Flat potato chips fried in RPO    | 540 ± 140                   | 518 ± 60                  |
| Serrated potato chips fried in RPO| 316 ± 85                    | 409 ± 48                  |

* mean ± standard deviation; PO: Palm oil, BPO: BHT containing palm oil, TPO: thyme extract containing palm oil, RPO: rosemary extract containing palm oil
moisture level is low. The formation of acrylamide in potato slices is a critically controlled point during processing and their formation is controlled by monitoring the reaction rate and time. The reaction critique refers to the rate limiting steps in chemical reactions and are also referred to as the checkpoints. Therefore, the understanding of rate limiting steps and the factors that control them for acrylamide formation may help in controlling their contents in food products. Many factors such as precursors, their rate, heating temperature, processing process, and pH and water activity of the product are effective on the formation of acrylamide in potato fries. In general, color-dipping potato chips without dipping into the potato chips more reducing sugar and asparagine produces, resulting in the resulting French fries lower acrylamide occurs. A significant factor that may determine the final fat content in fried potato strips, can be the frying temperature. For instance, a higher frying temperature may result in less oil absorption by the fried product, however, on the other hand, it may trigger the acrylamide formation due to temperature influence on reaction kinetics.

3.5 Oil contents of potato chips

The oil content of flat and serrated potato chips fried in palm olein oils containing synthetic and natural antioxidant are shown in Table 5. Generally, the oil contents of the samples were close to each other depending on the storage time. But there have been partial fluctuations. These fluctuations in the results have probably changed depending on the microstructural property of the potato strips and the amount of dry matter in the strips. While the amount of fat absorbed by chips at the beginning of storage change between 34.40 (flat potato chips fried in PO) and 38.35% (serrated potato chips fried in BPO), the amounts of fat absorbed by chips at the end of storage were determined between 35.19 (flat potato chips fried in PO) and 38.03% (serrated potato chips fried in BPO), respectively. The fat content of chips fried in BPO, TPO and RPO was partially higher in comparison to control group (chips fried in PO). This is probably due to the fact that both BHT and thyme and rosemary extracts resulted in more oil uptake by chips. In general, it is seen that serrated chips have a higher fat content than flat chips. The fat content of fried potato chips in coconut, soybean, olive oil and vegetable shortening was found to be between 22.1-25.9%, 22.4-27.6%, 22.1-28.0% and 19.7-26.1%, respectively.

3.6 Fatty acid composition of potato chips

Fatty acid compositions of oils extracted from potato chip samples fried in four types of oils (BPO, TPO, RPO and PO) were analyzed by gas chromatography. The results are presented in Table 6. The fatty acids composition of these samples may be attributed to the frying media. While the palmitic acid contents of the chips samples range from

Table 5. Oil contents of chips fried in palm olein added synthetic and natural antioxidant.

| Chips samples          | 1 month | 2 month | 3 month | 4 month | 5 month | 6 month | 7 month |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| Flat potato chips fried in PO | 34.40 ± 0.12* | 36.59 ± 0.16 | 36.50 ± 0.24 | 36.51 ± 0.60 | 36.50 ± 0.15 | 36.69 ± 0.17 | 36.30 ± 0.25 |
| Serrated potato chips fried in PO | 38.35 ± 0.12 | 36.59 ± 0.16 | 36.50 ± 0.24 | 36.51 ± 0.60 | 36.50 ± 0.15 | 36.69 ± 0.17 | 36.30 ± 0.25 |
| Flat potato chips fried in TPO | 35.28 ± 0.51 | 36.59 ± 0.16 | 36.50 ± 0.24 | 36.51 ± 0.60 | 36.50 ± 0.15 | 36.69 ± 0.17 | 36.30 ± 0.25 |
| Serrated potato chips fried in TPO | 37.28 ± 0.51 | 36.59 ± 0.16 | 36.50 ± 0.24 | 36.51 ± 0.60 | 36.50 ± 0.15 | 36.69 ± 0.17 | 36.30 ± 0.25 |
| Flat potato chips fried in RPO | 36.50 ± 0.51 | 36.59 ± 0.16 | 36.50 ± 0.24 | 36.51 ± 0.60 | 36.50 ± 0.15 | 36.69 ± 0.17 | 36.30 ± 0.25 |
| Serrated potato chips fried in RPO | 37.58 ± 0.51 | 36.59 ± 0.16 | 36.50 ± 0.24 | 36.51 ± 0.60 | 36.50 ± 0.15 | 36.69 ± 0.17 | 36.30 ± 0.25 |

*mean ± standard deviation; PO: Palm oil, BPO: BHT containing palm oil, TPO: thyme extract containing palm oil, RPO: rosemary extract containing palm oil.
37.14 (PO) to 41.60% (TPO), the oleic acid contents were determined between 30 (RPO) and 33% (serrated potato chips in PO). In addition, the oleic acid content of the oils extracted from PO-fried serrated chips and the BPO-fried plain potato chips were found partly similar. The highest palmitic acid contents were found in chips fried in TPO (41.60%) and RPO (41.42%), respectively. The palmitic acid content (37.14%) of PO fried chips was lower than that of BPO, TPO and RPO fried samples. Probably this may be due to the relative reduction in the amount of unsaturated fatty acids and in part due to the effect of temperature during frying. In addition, the stearic acid contents of the fried oils extracted from the chips samples varied between 3.48 (serrated chips in BPO) and 4.02% (serrated potato chips in TPO). In addition to these fatty acids, lauric, myristic, elaidic, behenic and arachidonic acid contents of the control group (PO) and BPO, TPO and RPO containing antioxidant varied [22]. Potato chip fried in vegetable shortening depended on the reuse of oil (1 to 80 times) for their fatty acid profile, and samples contained 3.0-2.4% lauric, 2.6-0.7% myristic, 47.1-49.0% palmitic, 3.8-3.7% stearic, 29.4-29.3% oleic and 9.7-8.4% linoleic acids. The same researchers found that the 1st and 80th fried oils of the fried potato chips fried in the coconut oil contained 47.1-46.4% lauric, 15.5-16.1% myristic, 7.6-7.8% palmitic, 1.3-1.0% stearic, 4.8-4.6% oleic and 1.6-1.6% linoleic acids [22]. Partial differences were also observed in the fatty acid contents of chips samples in relation to oil reuse [22]. Various modified canola oils used in frying contained 3.5-4.8% palmitic, 2.0-5.5% stearic, 57.4-78.3% oleic, 8.5-23.6% linoleic and 1.8-2.3% linolenic acids. Warner et al. [22] reported that the oil of the best delicious potato chips fried in modified canola oil contained 68% oleic, 20% linoleic, and 3% linolenic acids. The researchers stated that the stability of the frying oil increases with the decrease in the linolenic acid content of the frying oil [22, 32]. Foods such as high-linoleate fried potato chips are not stable to oxidation [22]. Rancid taste is an important sensory measure in potato chips. It is well known whether the properties of the fat to be used before frying are suitable for frying. Particularly the type of oil to be used and the time of use (recurrence) is important in frying. Sunflower oil with high oleic acid has been reported to give better results compared to soy, corn and peanut oils and these can be related to good thermal and oxidative stability during the traditional frying process [33-36]. The ratio of polyunsaturated fatty acids and monounsaturated fatty acids was very important in fried oils. It has been reported that fats with high polyunsaturated fatty acid content are more reactive and have low oxidation stability [33, 37, 38]. In comparison to the relative aspect of fatty acids during frying, the decrease in polyunsaturated fatty acids in sunflower oil (high oleic acid) was significantly higher with TBHQ (synthetic antioxidant) addition in in sunflower oil [39].

3.7 Sensory analysis of potato chips

Sensory analysis values of flat and serrated potato chips fried in palm oil (PO) and containing thyme extract (TPO), rosemary extract (RPO) and BHT (BPO) are shown in Table 7. In general, synthetic and natural antioxidant sources showed positive effects on the sensory properties of chips during storage. In the first month of storage, color values of chips were between 4.25 (flat potato chips in BPO and serrated potato chips in RPO) and 4.65 (flat potato chips in RPO). In addition, the odor values of chips increased from 3.33 (flat potato chips in RPO) to 4.63 (serrated potato chips in BPO). The chips had appearance values of 4.20 (serrated potato chips in PO) and 4.73 (flat potato chips in BPO). In the 7th month of storage, while the color values of chips are found between 4.13 (BPO) and 4.71 (TPO), the taste values of chips were evaluated between 3.88 (flat potato chips in PO and TPO) and 4.13 (serrated potato chips in BPO). Moreover, in the 7th month of storage, the odor values of the chips ranged from 3.43 (serrated potato chips in TPO) to 4.38 (serrated potato chips in BPO) while appearance values are evaluated between 4.13 (plain potato chips in PO) and 4.71 points (serrated potato chips in TPO). Also, crispness values of chips in the 7th month of storage changed between 4.13 (flat and serrated potato chips in PO) and 4.85 (serrated potato chips in TPO).

During storage, the odor values of chip samples were found similar but slightly lower than other sensory properties. Furthermore, the crispiness scores of the chips during storage were found at the highest level compared to other properties and maintained these values until the end of storage. Synthetic (BHT) and natural antioxidant sources (oregano or thyme and rosemary extracts) were partially effective on these properties. In general, while the highest scores are obtained by chips in BPO, the lowest scores were established in chips fried in PO alone.

4 Conclusions

In this study, the sensory and physicochemical properties of potato chips were determined after frying them in palm oil containing antioxidants sources and results were compared to those in samples fried in palm oil only. In our study, no significant differences were observed in the moisture values of the chips, including the control group, in the salt values and the brittleness. This difference did not occur due to frying and packaging at the same temperatures and times. The free fatty acid and peroxide values showed the highest increase in the control group fried chips samples that is palm oil without antioxidants supplementation. The least increase was observed in chips fried in frying oil with BHT. When compared with respect to fat content, it was seen that the serrated cut chips did not cause a significant change in antioxidant additions and had
| Oil samples                              | Lauric      | Myristic    | Palmitic    | Elaidic | Stearic    | Oleic      | Behenic | Arachidonic |
|------------------------------------------|-------------|-------------|-------------|---------|------------|------------|---------|-------------|
| Palm olein oil                           | 0.17 ± 0.011* | 0.72 ± 0.024 | 37.14 ± 0.037 | 0.00    | 3.66 ± 0.016 | 31.0 ± 0.005 | 0.06 ± 0.001 | 0.21 ± 0.004 |
| Serrated potato chip after frying        | 0.25 ± 0.126 | 0.69 ± 0.035 | 38.23 ± 0.583 | 0.03 ± 0.001 | 3.91 ± 0.048 | 33.0 ± 0.009 | 0.07 ± 0.003 | 0.19 ± 0.007 |
| Flat potato chip after frying            | 0.17 ± 0.011 | 0.70 ± 0.003 | 38.16 ± 0.431 | 0.00    | 3.83 ± 0.032 | 32.0 ± 0.013 | 0.34 ± 0.393 | 0.16 ± 0.007 |
| Palm olein oil added with BHT            | 0.35 ± 0.018 | 0.87 ± 0.020 | 38.21 ± 0.209 | 0.00    | 3.97 ± 0.022 | 32.0 ± 0.010 | 0.06 ± 0.002 | 0.20 ± 0.003 |
| Serrated potato chip after frying        | 0.27 ± 0.010 | 0.73 ± 0.036 | 36.09 ± 0.838 | 0.00    | 3.48 ± 0.067 | 31.0 ± 0.016 | 0.06 ± 0.005 | 0.19 ± 0.010 |
| Flat potato chip after frying            | 0.31 ± 0.173 | 0.80 ± 0.488 | 38.44 ± 0.255 | 0.00    | 3.90 ± 0.103 | 31.0 ± 0.003 | 0.06 ± 0.002 | 0.19 ± 0.005 |
| Palm olein oil added with thyme extract   | 0.18 ± 0.015 | 0.76 ± 0.035 | 39.80 ± 0.099 | 0.00    | 3.83 ± 0.006 | 31.0 ± 0.002 | 0.06 ± 0.004 | 0.17 ± 0.004 |
| Serrated potato chip after frying        | 0.18 ± 0.007 | 0.76 ± 0.018 | 41.60 ± 0.588 | 0.00    | 4.02 ± 0.071 | 32.0 ± 0.014 | 0.06 ± 0.003 | 0.15 ± 0.002 |
| Straight potato chip after frying         | 0.20 ± 0.001 | 0.80 ± 0.005 | 39.19 ± 0.339 | 0.00    | 3.71 ± 0.032 | 31.0 ± 0.005 | 0.06 ± 0.001 | 0.14 ± 0.002 |
| Palm olein oil added with rosemary extract| 0.18 ± 0.009 | 0.80 ± 0.037 | 41.42 ± 0.705 | 0.00    | 3.61 ± 0.064 | 30.0 ± 0.013 | 0.05 ± 0.002 | 0.15 ± 0.001 |
| Serrated potato chip after frying        | 0.16 ± 0.006 | 0.72 ± 0.009 | 38.68 ± 0.064 | 0.05 ± 0.001 | 3.75 ± 0.019 | 31.0 ± 0.008 | 0.06 ± 0.003 | 0.15 ± 0.012 |
| Straight potato chip after frying         | 0.16 ± 0.010 | 0.72 ± 0.039 | 38.70 ± 0.406 | 0.00    | 3.64 ± 0.334 | 31.0 ± 0.002 | 0.06 ± 0.003 | 0.09 ± 0.005 |

*mean ± standard deviation; PO: Palm oil, BPO: BHT containing palm oil, TPO: thyme extract containing palm oil, RPO: rosemary extract containing palm oil
## Table 7  Sensory analysis of chips fried in palm olein added synthetic and natural antioxidant.

| Chip samples                  | 1. month | 2. month | 3. month | 4. month | 5. month | 6. month | 7. month |
|-------------------------------|----------|----------|----------|----------|----------|----------|----------|
|                               | color    | taste    | odor     | appearance | hardness | color    | taste    | odor     | appearance | hardness | color    | taste    | odor     | appearance | hardness | color    | taste    | odor     | appearance | hardness | color    | taste    | odor     | appearance | hardness |
| Flat potato chips fried in PO | 4.38 ± 0.527 | 3.75 ± 0.717 | 3.50 ± 0.535 | 4.50 ± 0.535 | 4.18 ± 0.518 | 4.25 ± 0.463 | 4.13 ± 0.353 | 4.13 ± 0.353 | 4.63 ± 0.517 | 4.50 ± 0.534 | 4.43 ± 0.518 | 3.71 ± 0.463 | 3.86 ± 0.354 | 4.58 ± 0.518 | 4.43 ± 0.518 |
| Serrated potato chips fried in PO | 4.38 ± 0.517 | 3.88 ± 0.835 | 3.88 ± 0.641 | 4.20 ± 0.533 | 4.38 ± 0.353 | 4.25 ± 0.463 | 4.18 ± 0.353 | 4.13 ± 0.353 | 4.50 ± 0.534 | 4.38 ± 0.518 | 4.13 ± 0.353 | 4.00 ± 0.535 | 4.50 ± 0.517 | 4.58 ± 0.518 | 4.38 ± 0.518 |
| Flat potato chips fried in BPO | 4.25 ± 0.463 | 4.13 ± 0.353 | 4.48 ± 0.518 | 4.73 ± 0.535 | 4.63 ± 0.518 | 4.63 ± 0.463 | 4.47 ± 0.535 | 4.37 ± 0.535 | 4.71 ± 0.535 | 4.37 ± 0.517 | 4.05 ± 0.835 | 4.18 ± 0.641 | 4.50 ± 0.535 | 4.38 ± 0.518 | 4.38 ± 0.518 |
| Serrated potato chips fried in BPO | 4.43 ± 0.535 | 4.63 ± 0.518 | 4.63 ± 0.518 | 4.50 ± 0.535 | 4.40 ± 0.354 | 4.50 ± 0.535 | 4.44 ± 0.518 | 4.25 ± 0.463 | 4.13 ± 0.353 | 4.63 ± 0.517 | 4.50 ± 0.534 | 4.63 ± 0.517 | 4.63 ± 0.534 | 4.63 ± 0.534 | 4.63 ± 0.534 |
| Flat potato chips fried in TPO | 4.10 ± 0.463 | 4.00 ± 0.353 | 4.38 ± 0.518 | 4.30 ± 0.535 | 4.50 ± 0.535 | 4.00 ± 0.535 | 3.86 ± 0.535 | 4.25 ± 0.707 | 4.38 ± 0.518 | 4.25 ± 0.463 | 3.88 ± 0.835 | 3.63 ± 0.518 | 4.50 ± 0.535 | 4.63 ± 0.534 | 4.63 ± 0.534 |
| Serrated potato chips fried in TPO | 4.90 ± 0.535 | 4.00 ± 0.535 | 3.86 ± 0.354 | 4.25 ± 0.707 | 4.38 ± 0.518 | 4.37 ± 0.517 | 3.88 ± 0.355 | 4.38 ± 0.518 | 4.25 ± 0.535 | 4.20 ± 0.535 | 4.00 ± 0.535 | 3.86 ± 0.354 | 4.25 ± 0.707 | 4.38 ± 0.518 | 4.38 ± 0.518 |
| Flat potato chips fried in RPO | 4.65 ± 0.414 | 4.43 ± 0.535 | 3.33 ± 0.353 | 4.25 ± 0.488 | 4.00 ± 0.378 | 4.25 ± 0.463 | 3.72 ± 0.831 | 3.63 ± 0.518 | 4.50 ± 0.535 | 4.63 ± 0.518 | 4.17 ± 0.517 | 3.88 ± 0.535 | 3.55 ± 0.707 | 4.00 ± 0.517 | 4.48 ± 0.501 |
| Serrated potato chips fried in RPO | 4.25 ± 0.517 | 4.00 ± 0.353 | 4.38 ± 0.717 | 4.43 ± 0.518 | 4.70 ± 0.535 | 4.38 ± 0.517 | 3.88 ± 0.645 | 3.80 ± 0.441 | 4.00 ± 0.530 | 4.38 ± 0.707 | 3.75 ± 0.707 | 3.55 ± 0.544 | 4.46 ± 0.530 | 4.38 ± 0.517 | 4.38 ± 0.517 |

*mean ± standard deviation; PO: Palm oil, BPO: BHT containing palm oil, TPO: thyme extract containing palm oil, RPO: rosemary extract containing palm oil
a statistically higher oil content than plain cuts. When compared with the results of trans fat and acrylamide, the amount of trans fat was found to be highest in chips fried in palm olein oil in the initial analysis. When the acrylamide results were examined, the initial results were higher in all straight cut chips than the results at the end of shelf life. At these days, fried food products have an important place in food industry due to increasing consumption. However, factors such as exposure to high temperatures, oxygen from the external environment and the degree of unsaturation of the oil lead to various degradation reactions in the oil. Changes in oils in terms of physical chemical and sensory properties are seen. In order to avoid any negative effects on oil used for frying and to improve the quality and acceptability of products, natural antioxidants can be effectively used in place of synthetic ones that may be deleterious to human health.

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