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Influence of Frying Oil Type on Acrylamide Formation and Sensorial Quality of Potato Chips

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ABSTRACT

A significant role of carbonyl compounds derived from lipid oxidation in acrylamide formation has been recently proposed. The challenge of this study was to find suitable frying oil type to minimize acrylamide formation in potato chips while maintaining the expected product quality for the consumers. In this work, sesame oil and olive oil which are less prone to oxidation exhibited much lower acrylamide formation in potato chips compared to other frying oils examined and sesame oil induced lower formation compared to olive oil. But, panelists preferred sensorial qualities of potatoes fried in olive oil superior than sesame oil. These findings suggested olive oil as suitable frying oil for reducing acrylamide formation in potato chips with more desirable sensory characteristics in domestic deep-frying.

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INTRODUCTION

The compound 2-propenamide, commonly known as acrylamide, is an α-β unsaturated conjugate molecule with the structure H2C=CH-CONH2. Acrylamide's vinylic structure makes it a convenient tool in biochemical research to selectively modify thiol groups in compounds. Acrylamide is a synthetic monomer with a wide scope of industrial applications, mainly as a precursor in the production of several polymers, such as polyacrylamide. The main uses of polyacrylamide are in water and wastewater treatment processes, pulp and paper processing, and mining and mineral processing [1].

Acrylamide has been classified as a probable carcinogen by the International Agency for Research on Cancer [2] and exposure to high levels having been found to cause damage to nervous system [3]. The detection of surprisingly high levels of acrylamide in fried or toasted potato and cereal products in April 2002 provoked extensive international research, which progressed rapidly [4]. These processed foodstuffs are widely consumed and shown to be extremely susceptible to acrylamide formation by the Maillard reaction, mainly due to the abundant presence of the free amino acid asparagines and of reducing sugars [5]. In most foods, reducing sugars are the main carbonyl compounds reacting with free asparagines since their level is usually very high. Nevertheless, carbonyl compounds in foods may arise also from lipid oxidation, particularly during heating [6]. Lipid oxidation starts with the formation of hydroperoxides and proceeds via radical mechanisms. Lipid oxidation products are a huge family of relatively unstable compounds which may undergo further reactions resulting in a family of compounds of various molecular weight, flavor threshold and biological significance including aldehydes, ketones, alcohol, epoxydes, and hydrocarbons [7]. Although chemical structures of lipids and carbohydrates are quite different, both Lipid oxidation products and Maillard products comprise carbonyl compounds, thus, it is not surprising that some Lipid oxidation products may react with free asparagines to form acrylamide [8]. Zamora and Hidalgo [9] reported that some Lipid oxidation products can degrade asparagines to acrylamide. They proposed α, β, γ, δ-diunsaturated carbonyl compounds as the most reactive followed by hydroperoxides, likely because of their thermal decomposition upon heating. Capuano *et al*. [8] investigated the effect of lipid oxidation level on acrylamide formation by thermal treatment of differently formulated fat-rich model system. They showed that lipid oxidation positively influenced the formation of acrylamide. The authors stated that the effect was more evident in sugar-free system where lipid becomes the main sources of carbonyls. Catechins reduced acrylamide formation presumably by trapping carbohydrates and/or preventing lipid oxidation. They claimed that more acrylamide was formed in model system composed with sunflower oil than

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in those containing palm oil which is less susceptible to oxidation. Some authors determined the amount of acrylamide in potatoes fried in corn, soybean, and sunflower oil. They showed that samples fried in sunflower oil had the highest level of acrylamide formation and the least of that was formed in the samples for soybean oil. They claimed that the composition of each oil differs in triglyceride and contaminant content, it is possible the presence of certain molecules in the oil, whether from the original plant source or added or created during the refinement process could inhibit acrylamide formation [10]. Ehling *et al*. [11] showed that heating amino acids with dietary oils or animal fats at elevated temperatures produced various amounts of acrylamide. The amount of acrylamide formation corresponded to the degree of unsaturation of the oils and animal fats. They claimed that the decreasing order of acrylamide formation from dietary oils or animal fats with asparagine was sardine oil (642 μg/g asparagine) > cod liver oil (435.4 μg/g) > soybean oil (135.8 μg/g) > corn oil (80.7 μg/g) > olive oil (73.6 μg/g) > canola oil (70.7 μg/g) > corn oil (62.1 μg/g) > beef fat (59.3 μg/g) > lard (36.0 μg/g). Authors stated that Three-carbon unit compounds such as acrylic acid and acroleins, which are formed from lipids by oxidation, also produced acrylamide by heat treatment with amino acids, in particular with asparagine.

On the other hand, studies about the effects on acrylamide formation of the antioxidant compounds present in the oil were scarce. Becalski *et al*. [12] found that acrylamide could be reduced when adding rosemary herb to the oil used for frying potato slices. Napolitano *et al*. [13] investigated the relationship between virgin olive oil phenol compounds and the formation of acrylamide in potato crisps. Results demonstrated that acrylamide concentration in crisps increased during frying time, but the formation was faster in the oil having the lowest concentration of phenolic compounds. Moreover, the olive oil having the highest concentration of ortho-diphenolic compounds is able to efficiently inhibit acrylamide formation in crisps from mild to moderate frying conditions.

In a recent paper, Arribas-Lorenzo *et al*. [14] investigated the effect of the oil oxidation level as well as the oil phenol profile on acrylamide formation in cookies. The authors claimed that lipid oxidation products can be regarded as an important factor in acrylamide formation in fat-rich, dry foods and that the amount and the type of antioxidant compounds of oil clearly affect acrylamide concentrations after baking.

Since 2002 till now, wide researches were done about the useful ways to reduce the amount of acrylamide formation in fried carbohydrate-rich foods especially potato chips [15,16] But, the major challenge in frying of potatoes is to achieve a substantial reduction of acrylamide while keeping desirable product attributes such as color, flavor, texture, and taste [17]. Because, for consumers, the perceivable sensory attributes are the deciding factors in food acceptance [18]. Sensory evaluation is considered to be an important analytical tool in the present day competitive corporate environment. Measuring the sensory properties, and determining the importance of these properties, as a basis for predicting acceptance by the consumer represent major accomplishments for sensory evaluation [19]. It has been reported that edible oils have different characteristics of stability and sensory factors [20] as seen by Abdulkarim *et al*. [21] who showed that sensory attributes of banana chips fried in palm olein were significantly better than sesame oil.

In this work it has been tried to investigate the effect of frying oil type on acrylamide formation and sensorial characteristics of potato chips to find suitable frying oil type to minimize acrylamide formation in potato chips while maintaining the expected product quality for the consumers.

MATERIAL AND METHODS

Materials:

For this research 10 kg of potatoes (Solanum tuberosum L.), variety Agria, were purchased from Seed and Plant Improvement Institute of Iran and stored at $10^{℃}$ until preparing chips. For frying potatoes, four different kinds of edible oil of original plant were used in this research. Refined, bleached and deodorized olive oil, palm olein, sesame oil, and canola oil void of synthetic antioxidants were purchased from Behshahr factory. All chemicals and solvents used were purchased from Merck (Darmstadt, Germany).

Methods:

Laboratorial production of potato chips:

Potatoes were washed and after peeling, slices with a thickness of 1/5 mm were prepared by using a mechanical slicer (Italimport SRL, Model 90915, China). Slices were soaked in cold water for 1 minute to eliminate superficial starch and then dried with paper towel. 100 g of slices were fried in an electric deep fryer with a capacity of 3 Lit of oil at $180^{℃}$ for 4/15 minutes in olive oil, palm olein, sesame oil, and canola oil. After frying, the samples were dried to remove excess oil and were frozen at $-18^{℃}$ till used for acrylamide analysis.

Determination of acrylamide:

Method of measuring acrylamide by Gas Chromatography which is equipped with an electron capture detector (ECD) is based on extraction of the acrylamide from defatted sample with sodium chloride and derivatization of acrylamide with bromine and then tracking it by an electron capture detector (ECD).

Manner of extraction:

The samples were prepared for acrylamide analysis using a procedure described by Lehotay and Mastovska [22]. In the first stage, 5/6 g of the homogeneous sample were mixed with 500 ng/g of meta acrylamide as an internal standard, 5 mL of hexane solution and distilled water and acetonitrile in the equal ratio by vortex mixer for 15 minutes. Then, 5 g of sodium sulfate anhydrous and sodium chloride were added to it. The mixture was centrifuged at 4500 rpm for 5 minutes and after using ultrasonic for 30 minutes, the acetonitrile layer was separated completely.

Manner of derivatization:

The collected acetonitrile layer was brominated based on a procedure described by Tareke and Rydber [23]. For this aim, potassium bromide, hydrobromic acid and saturated bromine water were used. Obtained solution was kept in the refrigerator at 4℃ for a day. Then, the excess of bromine became colorless by adding some drops of sodium thiosulfate solution and this solution was extracted twice with 65 mL of ethyl acetate. The obtained organic phase was dried with 1 g of sodium sulfate and transferred in to rotary vacuum evaporator. Then the solution was concentrated under the nitrogen gas till a volume of 250 µL. Finally, 1 µL from each of prepared samples was injected into the capillary column (30 m × 0/25 mm × 0/25 µm) of GC/ECD. Four standard solutions of acrylamide were prepared with volumes of 10, 15, 20, 25 mL and were extracted and brominated on the basis of procedure described for the samples. The calibration curve was generated by injecting 1 µL from each of acrylamide standards into the GC/ECD and acrylamide concentration formed in the samples was determined by using this curve Figure1).

Table 1: GC-ECD Device Parameters.

GC-ECD Parameters	
Column temperature	80-240 Ċ
Injection temperature	250 Ċ
Detector temperature	280 Ċ
Injection volume	1 µL

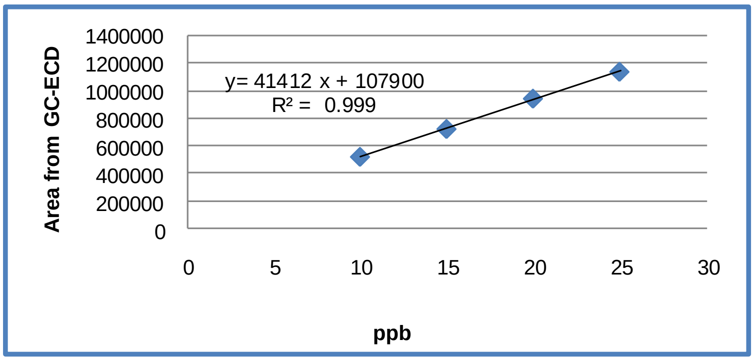

Fig. 1: GC-ECD Calibration Curve.

Sensory Evaluation:

Peeled Agria potatoes approximately 1/5 mm in thickness were sliced using a mechanical slicer (Italimport SRL, Model 90915, China). Three liter of each oil examined (including sesame oil, olive oil, palm olein and canola oil) was used as frying medium to fry potato chips (batches of 100g) at 180℃ for 4/15 minutes. The potato chips kept at room temperature for 5 min, placed on kitchen Rolland paper towels to remove surplus oil and later stored in an air tight glass bottles and labeled. The sensory quality of the potato chips was evaluated based on their crispness, aroma, flavor and overall acceptability by using 10-point hedonic scale, where 1= dislike extremely and 10= like extremely by 50 untrained panelists.

Statistical Analysis:

The experiments were carried out in the completely randomized design (CRD) in triplicates. The average was compared with each other by Duncan method. Analysis of variance (ANOVA) and comparison of averages was done by SPSS 16.0 software.

RESULTS AND DISCUSSION

Results of Testing Acrylamide:

Regarding to the significant role of potato variety [24], properties of cultivar and fertilization [25], storage conditions of potatoes [26], temperature and frying time [27] and pretreatment procedures [28] on the amount of acrylamide formation in final product, in this study it has been tried to attribute the observed changes in the amount of acrylamide concentration in samples to the effect of frying oil types by fixing others mentioned effective factors.

During frying, complicated changes such as physical, chemical and organoleptical properties (taste and odor) were occurred in oil that have a direct effect on quality and health of food [29,30].

According to the obtained results the samples of potato chips had significantly ($p< 0.05$) difference with each other for the amount of acrylamide formation (Figure 2). These findings suggested that type of frying oil could become a relevant factor for acrylamide formation in potato chips. The obtained results were similar to previous finding [8,11,31].

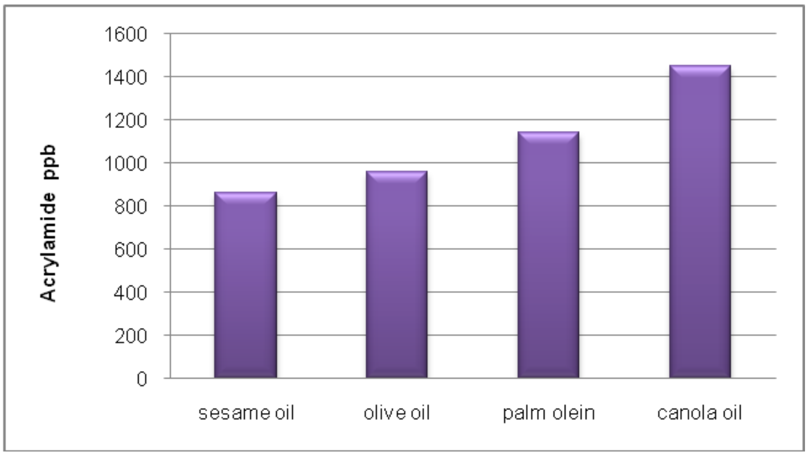

Fig. 2: Average ppb of acrylamide found in the tested oils.

A likely possibility for influencing the formation of acrylamide may lie in the inherent compositions of the oils themselves before and after heating. Because the composition of each oil differs in triglyceride, it is possible the presence of certain molecules in the oils, whether from the original plant source or added or created during the refinement process could affect acrylamide formation [10].

Fats and oils have different compounds which are present in low concentrations. Some of these trace materials, including tocoferols, phospholids, carotenoids and sterols increase oil stability during frying [32]. Sesame seed and its oil contains substantial amounts of unique components called lignans (sesamin sesamolin), which play an important role in promoting health. Sesamin and sesamolin have been reported to have many bioactive properties, e.g. antioxidant activity, antiproliferative activity, lowering cholesterol levels, and showing antihypertensive effects and neuro protective effects against hypoxia or brain damage [33]. Apart from sesame lignans, sesame seed and oil also contain other important biologically active compounds, such as vitamin E (tocopherol homologues) [34]. Tocopherol has many beneficial properties, such as antiproliferative effects in human cancer cells. Anti-inflammatory activity and partial prevention of age-associated transcriptional changes in heart and brain of mice [33]. The sesame oil is very stable due to the presence of the previously mentioned antioxidants; therefore, it has a long shelf-life and can be blended with less stable vegetable oils to improve their stability and longevity [35].

Also, about olive oil, it has been reported that this oil is rich in natural antioxidants such as phenolic compounds which is very effective in protecting the oil from oxidation [36, 37]. However, it has been stated that thermo oxidative stability of sesame oil is significantly ($p< 0.05$) higher than olive oil [38].

As shown in figure 2, sesame oil generated the least concentration of acrylamide, while canola oil generated the highest. According to this recommendation that the formation of acrylamide by oils is due to the reaction between carbonyl compounds derived from lipid thermoxidation products with free asparagine of potato [8,39], so, the reason of the least formation of acrylamide concentration in fried potatoes in sesame oil can likely depend on its high thermo oxidative stability. It has already been demonstrated that sesame oil is more stable to the thermoxidation than the other vegetable oils due to the presence of unique and powerful mentioned antioxidants called lignin compounds such as sesamin, sesamolin, sesaminol, sesangolin, 2-episalatin [40, 41] which they exist just in sesame oil [32].

Results of this study demonstrated that concentration of acrylamide in potatoes fried in olive oil is much lower than palm olein. This result confirm previous findings by Napolitano *et al*. [13] who reported that olive oil is rich in natural antioxidants which are able to efficiently inhibit acrylamide formation in potato chips.

The usage of sesame and olive oils as natural antioxidants have been already reported [42,43] and according to the obtained results of this study both sesame and olive oils leaded to produce less acrylamide comparing to palm olein and canola oil. These results confirm previous finding by Becalski *et al*. [12] and Arribas- Lorenzo *et al*. [14] who found that the presence of natural antioxidants in the oil can markedly reduce the amount of acrylamide in the final products. Therefore, it is possible that the minor oil components (such as natural antioxidants) can influence acrylamide formation during the exposure of the potatoes at high temperatures [13].

It has been already reported that palm olein is more saturated than canola oil and therefore is less prone to thermoxidation [44]. Regarding to the obtained results of this study, the amount of acrylamide concentration in the samples for palm olein was significantly ($p<0.05$) lower than canola oil (Figure 2). This result confirm previous finding that products containing saturated fats, which are less prone to thermoxidation, will likely produce less acrylamide [8, 11].

However, there is still some confusion about the influence of the heating medium on acrylamide formation as seen by Matthaus *et al*. [15] and Williams [45] that could not find any significant effect of the oil type.

Results of Sensory Evaluation:

Results of this study showed that significant ($p< 0.05$) differences occurred in the sensory characteristics of potato chips fried in the different oil types.

During frying, oil is not only act as a heat transfer, but also it interacts with proteins and carbohydrates in the food matrix and induces favorable odor and taste. Also, brownish color of food makes donate the suitable appearance to foods which promote the appetite [18].

According to the obtained results of this study the samples for canola oil had the weakest scores for crispness, aroma, flavor and overall acceptability (Figures 3, 4, 5 and 6).

As seen in Figures 3 and 4, the samples of palm olein had the highest scores in aroma and flavor while olive oil had the highest scores for crispness and overall acceptability (Figures 5 and 6). Moreover, for four attributes (crispness, aroma, flavor and overall acceptability), scores for the samples fried in sesame oil were significantly ($p< 0.05$) lower than palm olein and olive oil (Figures 3, 4, 5 and 6). These results confirm previous finding by Waghray and Gulla [20] and Abdulkarim *et al*. [21].

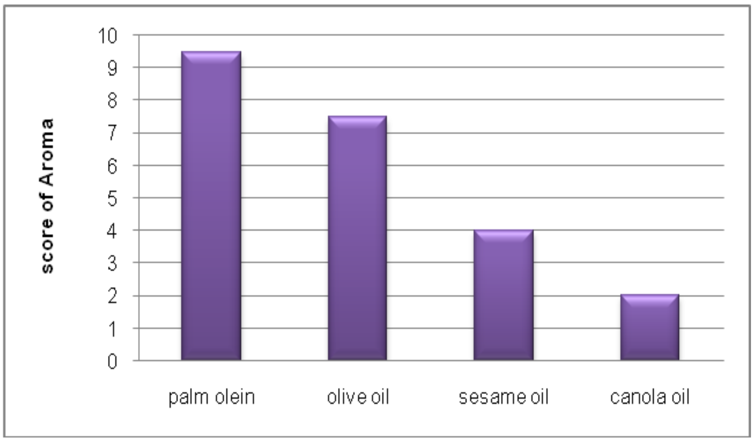

Fig. 3: Average of aroma in the tested oils.

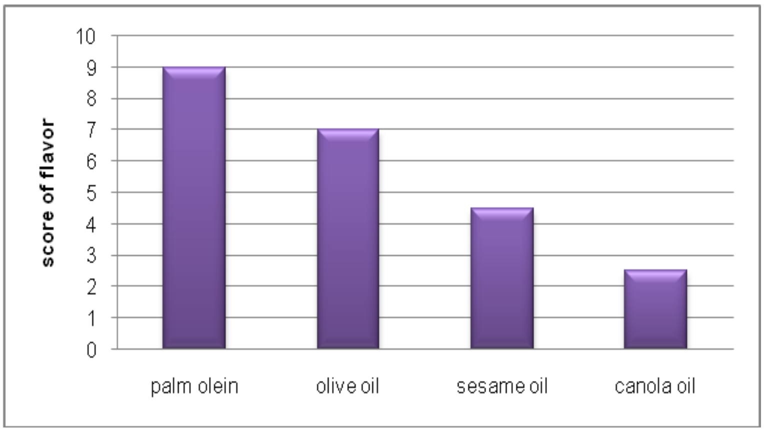

Fig. 4: Average of flavor in the tested oils

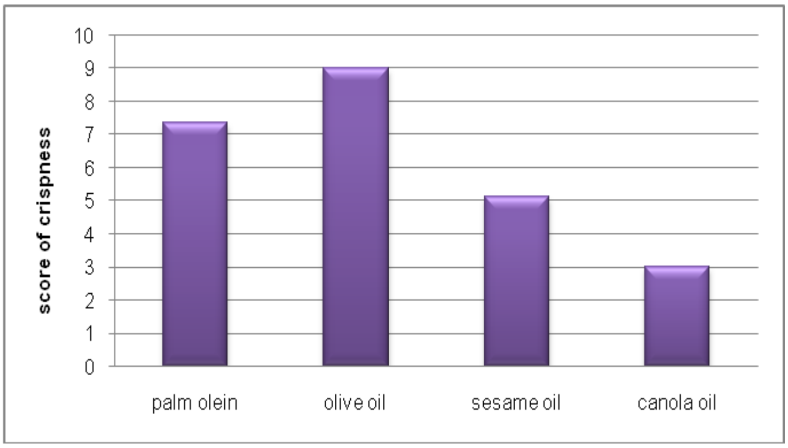

Fig. 5: Average of crispness in the tested oils.

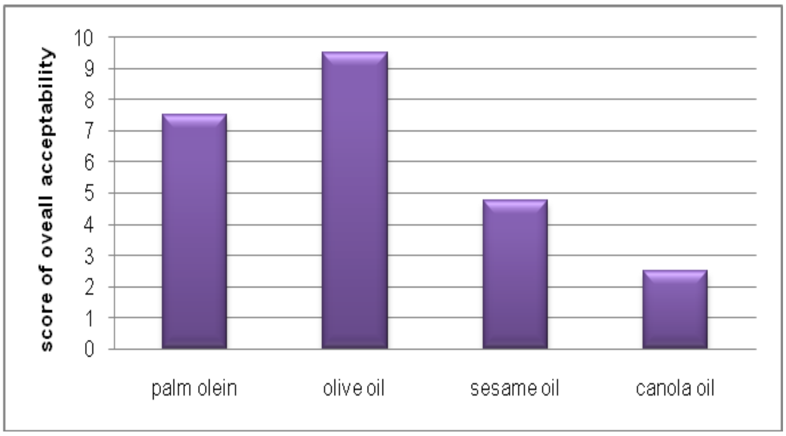

Fig. 6: Average of overall acceptability in the tested oils.

Conclusion:

It was concluded that type of frying oil could become a relevant factor for acrylamide formation in potato chips and the choice of suitable frying oil that has naturally high thermo oxidative stability can be proposed as a reliable mitigation strategy to reduce acrylamide formation in potato chips. But, for consumers, the perceivable sensory attributes are the deciding factors in food acceptance. In this work, sesame oil and olive oil which are less susceptible to oxidation exhibited much lower acrylamide formation in potato chips compared to other frying oils examined and sesame oil induced lower formation compared to olive oil. But, panelists preferred sensorial qualities of potatoes fried in olive oil superior than sesame oil. These findings suggested olive oil as suitable frying oil for reducing acrylamide formation in potato chips with more desirable sensory characteristics. However, frying using olive oil cannot be proposed for industrial use, but it is a common practice in domestic deep-frying in all Mediterranean countries, which could be exported to other areas of the world.

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