GRASAS Y ACEITES 66 (1)
January–March 2015, e065
ISSN-L: 0017-3495
doi: http://dx.doi.org/10.3989/gya.0713142

Properties and stability of deep-fat fried chickpea products

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Submitted: 08 July 2014; Accepted: 23 October 2014

SUMMARY: The aims of this study were to develop new snack foods prepared from deep frying whole chickpeas and evaluating the properties and storage stability of the new products. The most remarkable results found were: moisture content (3.48–9.19%), water activity (0.1833–0.5936), hardness (3243–4056 g), L (42.01–65.79), a* (10.56–19.24), b* (30.80–42.20), free fatty acidity (0.2195–0.3467%), peroxide value (3.167–5.25 meq $O_2 \cdot kg^{-1}$), total phenolic (22.34–37.34 mgGA·100g^{-1} chickpea), antioxidant capacity (6.53–31.61 mmol Trolox·100g^{-1} chickpea), absorbed fat (13.46–13.92%), and caloric value (453.17–488.49 kcal·100g^{-1} chickpea). Hexanal, 2,5-dimethylpyrazine, nonanal, benzaldehyde, *p*-cymene, and carvacrol were the major volatile compounds determined. The color, hardness, moisture content, water activity, free fatty acids, and peroxide value of the products were monitored for three months at room temperature. Consumer acceptance tests were conducted to reveal the changes which occurred during the storage period. All the products developed and evaluated in this study show potential in the market and industry, with the plain type being the preferred product.

KEYWORDS: *Aromatics; Chickpea; Composition; Frying; Snack; Storage*

RESUMEN: ***Propiedades y estabilidad de productos derivados de garbanzos fritos***. Los objetivos de este estudio fueron el desarrollo de nuevos aperitivos elaborados mediante fritura de garbanzos enteros y la evaluación de las propiedades y estabilidad de los nuevos productos durante el almacenamiento. Los resultados mas destacados fueron: contenido de humedad (3,48–9,19%), actividad de agua (0,1833–0,5936), dureza (3243–4056 g), L (42,01 a 65,79), a* (10.56–19,24), b* (30,80–42,20), ácidos grasos libres (0,2195–0,3467%), índice de peróxido (3,167 a 5,25 meq $O_2 \cdot kg^{-1}$), fenoles total (22,34–37,34 mgGA·100g^{-1} garbanzo), capacidad antioxidante (6.53– 31.61 mmol Trolox·100 g^{-1} garbanzos), grasa absorbida (13,46–13,92%), y el valor calórico (453,17 a 488,49 kcal·100 g^{-1} de garbanzos). Además, los componentes volátiles más importantes determinados son: hexanal, 2,5-dimetilpirazina, nonanal, benzaldehído, *p*-cimeno, y carvacrol. De igual forma, el color, la dureza, el contenido de humedad, la actividad de agua, la acidez libre, y el índice de peróxidos de los productos se controlaron durante tres meses de almacenamiento a temperatura ambiente. Además, se llevaron a cabo pruebas de aceptación de consumidores para determinar los cambios durante el período de almacenamiento. Todos los productos desarrollados y evaluados en este estudio tienen un nuevo e importante potencial en el mercado y la industria, siendo el producto más deseado y preferido el de tipo natural.

PALABRAS CLAVE: *Almacenamiento; Aroma; Composición; Fritura; Garbanzo; Snack*

Citation/Cómo citar este artículo: Bozdemir S, Güneşer O, Yılmaz E. 2015. Properties and stability of deep-fat fried chickpea products**.** *Grasas Aceites* **66** (1): e065. doi: http://dx.doi.org/10.3989/gya.0713142.

1. INTRODUCTION

The chickpea (*Cicer arietinum* L.) is an annual plant belonging to the *Fabaceae* family. The seeds of the plant which are colored from light yellow to brown, and even to black, are consumed as food. It has been cultivated in and around Anatolia for nearly 8000 years. Today, it is one the most commonly grown legumes in Turkey, Northern Africa, Mexico, India, Pakistan, and Spain. Being resilient to drought conditions it is produced in arid areas. It is consumed in large quantities and the world production yield was 9.7 billion tons in the year 2009. In the same vein, Turkey produced 560 thousand tons in the same year. The annual consumption ratio of chickpeas in Turkey is around 5–6 kg per person (Anonymous1, 2012).

As for its nutritional value, the basic nutritional composition of chickpeas was reported as 12.6–30.5% crude protein, 52.4–70.9% total carbohydrate, of which 41–50.8% is starch, and 5.2–19.4% crude fiber, with 3.8–10.2% total lipids (Singh, 1985). In another study (Thavarajah *et al*., 2012), the following nutritional features are identified: a micronutrient composition of ten chickpea varieties was determined as selenium (15.3–56.3 $\mu g \cdot 100g^{-1}$), iron (4.6–6.7 $mg \cdot 100g^{-1}$), zinc (3.7–7.4 $mg \cdot 100g^{-1}$), calcium (93.4–197.4 $mg \cdot 100g^{-1}$), magnesium (125.1–158.7 $mg \cdot 100g^{-1}$), potassium (732.2–1125.5 $mg \cdot 100g^{-1}$), copper (0.7–1.1 $mg \cdot 100g^{-1}$), phosphorus (2627–3703 $mg \cdot kg^{-1}$), xanthophyll (9.0–19.7 $mg \cdot 100g^{-1}$), and β-carotene (166–431 $\mu g \cdot 100g^{-1}$).

Snack foods have been getting larger market shares day-by-day, as the world's population increases rapidly. Time is a more limiting factor now more than ever, and the hedonic preferences of consumers are more divergent and advanced than ever before. Snack foods can be described as foods to be consumed immediately after unpacking. And snacks are ready to eat, shelf stable, easy to carry, and store as well as consumable everywhere, and mostly nutritious foods. On the other hand, starchy materials and frying process are, by and large, used to produce most snacks on the market. Nevertheless, current consumer demands require more natural, less processed, fewer component snack foods which are expected to be various, tasty, diverse, and even functional (Gordon, 1991; Ibanoglu, 2006; Ozer, 2007).

In this context, it can be cited here that the databases show the existence of some studies on traditional fried-snack type products prepared from chickpeas and other cereal flours. The traditional Indian extruded-and-deep-fat fried product *sev* is prepared out of different cereal and legume flour mixtures. Oil absorption and water holding capacity were determined as a function of frying oil type and product formulations (Annapure *et al*., 1998). The study of Bhat and Bhattacharya (2001) was on another traditional Indian snack, called *boondi*, which is prepared from frying chickpea flour droplets in hot oil. The effects of using gellan gum and other hydrocolloids in the formulations of *sev* regarding oil uptake and product texture were investigated (Bajaj and Singhal, 2007). Additionally, rice and legume flours were used to prepare deep-fat fried snacks, and their properties were evaluated (Tiwari *et al*., 2011). The effects of total solid concentration of the chickpea batter in *boondi* on oil uptake and quality were studied. According to the test, the batter containing 40% solids was found more desirable in uniformity, crispness and fried-aroma (Ravi and Susheelamma, 2004). In another study (Ahamed *et al*., 2006), soy flour and corn, amaranth and chenopodium starches were fried into a noodle-like product, and, in accordance with the study, it was found that as starch content increases, oil absorption decreases.

The traditional products described above largely use chickpea flour and other legumes as well as cereal flour mixtures to prepare fried, snack foods. In a more recent study (Jauregui *et al*., 2012), whole soybeans were fried in different oils (sunflower and peanut oils) and then stored at 22 °C, and 40 °C for 112 days. During the storage period, the stability of fried soybeans was evaluated. To our knowledge, there is no study reported in the literature about fried, whole chickpeas, although exist some studies with legume flours.

The aim of this study is to develop whole chickpea-based deep-fat fried snack foods. Spice- and pepper coated types of a new product were also developed and evaluated. In addition, three months' storage durability of these new products in terms of sensory and physico-chemical quality was monitored.

2. MATERIALS AND METHODS

2.1. Materials

Large chickpeas (bigger than 10 mm) as a variety of Koçbaşı by the Kale Gıda Co. (Çanakkale, Turkey), and refined peanut oil by the Helvacızade Oil and Pharmaceuticals Co. (Konya, Turkey) were given as gifts for this study. Zippered-locked three layer laminated (12 μ PET + 9 μ Aluminum + 70 μ LDPE) snack bags were provided by the Yılmaz Offset Press and Packaging Co. (Izmir, Turkey). Red pepper, thyme and tomato powders were purchased from local stores. All chemicals and standards were of analytical grade, and bought from Merck (Darmstadt, Germany), and from Sigma (St. Louis, USA).

2.2. Frying

In order to optimize the process, a pre-study was carried out. Chickpeas were immersed in cold tap water, and left for 6, 12 and 24 hours. Immediately

after the time given, the chickpeas were removed from the water and fried in hot (180 °C) peanut oil. The samples of chickpeas were withdrawn from the fryer at 5, 10, and 15 minutes. Finally, five panelists scored the different fried products with the 5-point hedonic scale for their level of cooking, crispness, surface color, and flavor. After collecting and evaluating the data (not shown), the process parameters of 12 hours of cold water immersion, and 15 minutes frying time were selected. After 12 hours of water immersion, and then drainage, the moisture content of the chickpeas was measured at around 40–42%. In the end the same parameters were used in the aim to carry out the experiments.

There were three different types of products used in this study: (i.) In the 'plain' type, water-immersed chickpeas were immediately fried in peanut oil at 180 °C for 15 min. (ii.) The 'peppery' type, following immersion in cold water, wet chickpeas were rolled in a mixture composed of 98% red pepper-powder, and 2% fine salt. Then, they were fried regularly. (iii.) Similarly, the 'spicy' type was prepared by rolling the wet chickpeas in a mixture of thyme, and tomato powders (1:1) (49% of each, and 2% of fine salt), and then fried regularly.

The frying process was carried out in a 2.7 L Arnica Z27A type fryer (Arnica, Turkey). At the beginning of the frying process, 2 L of peanut oil were added, its temperature was adjusted to 180 °C, and frying period for each batch was 15 minutes. In each bath, 200 g of chickpeas were fried. On each frying day, 2.0 kg of chickpeas were fried in 10 consecutive batches, and all were collected and mixed to form a homogeneous lot. From the lot of each frying day (replicate), samples for the analyses were withdrawn randomly. For the storage study, separate frying sessions were carried out under the same experimental. The whole frying experiment was repeated twice. After frying each sample group, the fried chickpeas were filled into zippered-snack bags with a 200–250 g filling level. The air was removed by squeezing, and the bags were tightly zipped. The vapor and oxygen permeability of the bags were 0.01 $g \cdot m^{-2} \cdot 24$ h, and 3.6 $mL \cdot m^{-2} \cdot 24$ h, respectively. The samples were stored at room temperature in a dry and dim place for 3 months. During the storage, some analyses were carried out every 15 days. Consumer hedonic tests were done every 30 days. This storage action was also repeated twice.

In addition, some analyses were done on raw chickpeas as shown in Table 1. The physical, chemical, instrumental, and sensory analyses of other groups were also carried out for the three different types of new fried-chickpea products. Moreover, the storage stability of the new products was evaluated in accordance with selected analytical criteria i.e., instrumental color, consumer hedonic test, moisture content along with water activity, hardness value, free fatty acidity, and peroxide value.

2.3. Physical analysis

Dimensions of the chickpeas were measured by a digital caliper (CD-15CP, Mitutoyo Ltd, Andover, UK). Seed weight was measured by a lab scale (Sartorius Extend ED 224S, Germany). The ash content of the chickpeas was measured according to the the AOAC method 923.03 (AOAC, 1990).

2.4. Chemical analysis

The absorbed oil content of the chickpeas was measured by the Soxhlet technique following the AOAC method 920.39 (AOAC, 1984). Total nitrogen and protein contents of the products were determined by the Kjeldahl technique with the AOAC method 920.87 (AOAC, 1990). The free fatty acid of the samples was monitored by the Ca5a-40 method (AOCS, 1998), and similarly, the peroxide value of the products was monitored by the Cd8-53 method (AOCS, 1998). The total phenolic contents of the raw and fried-chickpea samples were measured according to the criteria of Chotimarkorn *et al*. (2008). For the phenolic extraction from the samples, 1:1 = sample: solvent (water/methanol, 60/40 v/v) mixture was vortexed vigorously and centrifuged at 1615 g at 4 °C for 10 min. After removing the methanolic phase, the process was repeated, and all of the supernatants were collected. The same extract was also used for the antioxidant capacity measurement according to Re *et al*. (1999).

2.5. Instrumental analysis

The moisture of the fried-chickpea products was measured by the Ohaus MB-45 moisture analyzer (Ohaus, Pine Brook, USA). The water activity of the samples was determined by the AquaLab 4TE (Decagon Inc. US). The hardness of the fried chickpea products was measured with the TA-XTPlus Texture Analyzer (Stable Micro Systems Co., UK) with a 3 mm cylindrical probe and 3 mm/s velocity and 5 mm penetration depth and calculated as a gram force. The color of the samples was determined with the Minolto CR-300 reflectance colorimeter (Osaka, Japan). The combustion caloric values of the new products were measured with a Leco AC350 type (Leco Corp, St. Joseph, US) calorimeter.

2.6. Analysis of volatile compounds

The volatile compounds of the fried chickpea products were isolated using the solid phase microextraction (SPME) technique (Pawliszyn, 2001) and determined by gas chromatography and mass spectrometry. For this purpose, 3 g of ground sample were weighed into a 40 ml amber SPME vial (Supelco, Bellfonte, US), and 1 g of NaCI and 2 μL internal standard (containing 0.1 μL of 2-methyl

TABLE 1. The physical and chemical properties of raw chickpeas and deep-fat fried chickpea samples at the beginning of the storage (Mean±SE)

				Deep-fried chickpea		
Properties	**Raw chickpea**	**Properties**		**Plain**	**Peppery**	**Spicy**
Seed weight (g)	0.6313±0.0142	Seed width (mm) (p>0.05)		10.692±0.254[a]	10.834±0.158[a]	10.714±0.174[a]
Seed width (mm)	8.30±0.11	Seed height (mm) (p>0.05)		13.302±0.286[a]	13.326±0.263[a]	13.642±0.232[a]
Seed height (mm)	11.72±0.28	Moisture (%) (p≤0.05)		6.200±0.472[c]	8.160±0.135[b]	9.798±0.472[a]
Ash (%)	2.57±0.01	Water activity (p≤0.05)		0.4230±0.0449[b]	0.5643±0.0152[a]	0.6446±0.0285[a]
Moisture (%)	11.07±0.05	Texture (g) (p>0.05)		3293±216[a]	3466±154[a]	2861±282 [a]
Water activity (a_w)	0.5428±0.0021	Calorie value (kcal·100 g^{-1} chickpea) (p>0.05)		488.49±1.81[a]	453.17±1.02[a]	469.3±13.7[a]
Total nitrogen (%N)	3.31±0.02	Fat (%) (p>0.05)		13.468±0.241[a]	13.530±0.099[a]	13.92±1.76[a]
Protein (%)	20.50±0.11	Total phenolic content (mg GA·100 g^{-1} chickpea) (p≤0.05)		22.34±1.04[c]	32.63±1.44[b]	37.34±0.893[a]
Calorie value (kcal·100 g^{-1} chickpea)	417.81±1.56	Antioxidant capacity (mmol Trolox·100 g^{-1} chickpea) (p≤0.05)		6.53±0.08[c]	31.61±0.62[a]	23.58±0.61[b]
Color L	35.19±2.47	Color	L (p≤0.05)	65.78±1.11[a]	41.35±0.75 [b]	33.44±3.02[c]
a*	6.42±0.99		a*	8.55±0.29[c]	20.94±0.52[a]	17.22±0.92[b]
b*	13.31±1.07		b*	40.59±1.17[a]	35.15±1.01[a]	23.63±3.87[b]
Antioxidant capacity (mmol Trolox/100g chickpea)	14.75±0.49					

[a–c]Means in the same row with different superscript letters show significant differences among products. SE: Standard Error.

valeric acid, and 0.6 µL of 2-methyl-3-heptanone in 1 mL) were added. The vial was closed and vortexed for 1 min. Then, the vial was placed in a water bath (GFL, Germany) held at 40 °C for 20 min to equilibrate volatiles in the headspace. Then, the SPME (2 cm to 50/30 µm DVB/Carboxen/PDMS, Supelco, Bellafonte) needle was inserted into the vial. The SPME fiber was exposed to a depth of 2 cm in the headspace of the vial for 20 minutes at 40 °C in a water-bath. Then, the fiber collected volatiles were injected into the GC/MS (Agilent 6890N/Agilent 5875C mass spectrometer, Agilent technologies, Wilmington, US), immediately. The separation of the volatiles was achieved in a non-polar HP-5 MS column (30 m × 0.25 mm i.d × 0.25 µm film thickness, J&W Scientific, Falsom, CA). The GC/MS conditions were determined according to the method of Lasekan *et al*. (2011) with minor modifications. The helium carrier gas flow rate was 1.2 mL·min^{-1}. Oven programming: start temperature 40 °C, Ramp 1: 1 °C·min^{-1} to 70 °C, Ramp 2: 5 °C·min^{-1} to 200 °C, Ramp 3: 50 °C·min^{-1} to 230 °C, and a final temperature of 230 °C for 5 min. The MSD conditions were as follows: capillary direct interface temperature, 280 °C; ionization energy, 70 eV; mass range, 35 to 350 amu; scan rate, 4.45 scans/s. The identification of volatiles was based on the comparison of the m/z ratio of compounds with those in the National Institute of Standards and Technology (NIST, 2008), the Wiley Registry of Mass Spectral Data, 7th Edition (WILEY, 2005) databases. The quantities of the volatile compounds were calculated from the relative abundance of the volatile compounds positively from the equation below (Avsar *et al*., 2004). 2-Methyl valeric acid for acidic compounds and 2-methyl-3-heptanone for basic/neutral compounds were used as internal standards (IS).

$$\text{Mean relative abundance } (\mu g \cdot kg^{-1} \text{ chickpea}) = \frac{\text{concentration of IS} \times \text{peak area of compound}}{\text{peak area of the IS}} \quad \text{(Eq. 1)}$$

2.7. Sensory analysis

The consumer acceptance test of the three different fried-chickpea products were carried out on fresh (first day) products, and once a month on stored products. There were 100 voluntary consumers (aged from 20 to 45; faculty, staff and students) for each test day. Approximately 5–10 g of each sample were placed on a separate plate coded with three digit numbers to serve to the consumers together with water and an expectoration cup for consumers to clean their palate after each sample. The evaluation was completed following a 5-point hedonic scale (1-dislike extremely to 5-like extremely). The product sensory attributes of appearance/color, hardness, crispness, taste/flavor, smell/aroma, and general appreciation were measured.

2.8. Statistical analysis

The analysis of variance (the ANOVA test) was conducted to determine the differences among the three types of fried chickpea products. The Tukey Honestly Significant differences (HSD) test was used for mean separation. The non-parametric Kruskall Wallis test was applied to determine the differences among the fried chickpea products in terms of sensory properties. The Dunn's test was conducted for average separations. The package programs of the Minitab ver. 16.1. (Minitab, 2010) and SPSS ver. 10.1 (SPSS, 1994) were used in the statistical analyses. The minimum confidence level was at least 95% in all statistical analyses.

3. RESULTS AND DISCUSSION

Some physical and chemical properties of the Koçbaşı variety of raw chickpeas are given in Table 1. In general, the values of seed weight and dimensions were found to be in agreement with the literature (Sotelo *et al*., 1987; Khan *et al*., 1995). In 8 different Mexican chickpeas (Sotelo *et al*., 1987), the total ash was 3.1% in raw and 2.4% in cooked samples. The protein content of the samples was reported as 16.9–20.7% in the same study. Similarly, the total caloric value of raw chickpeas in that study was indicated as 422.4 kcal·100 g^{-1} sample. Ravi and Susheelamma (2004) have reported average protein contents of chickpeas to be around 22.6% in India. Our measurements are mostly in agreement with the findings reported in the literature. Some information pertinent to the literature is also provided Table 1.

The three new fried whole chickpea products were presented in Figure 1. The different colors of the products are mainly due to the different coatings (red pepper and spice mixture) and cooking. The physical and chemical properties of the plain, peppery and spicy types of new fried chickpea products are also given in Table 1. It was observed that there were no significant differences among the samples in terms of seed dimensions, hardness value, absorbed fat content, and caloric value. The moisture level was the highest in the spicy samples. This result might be attributed to the spicy coating of chickpeas which creates a barrier for water vaporization during frying. The water activity measures are in good agreement with the moisture level. Compared to raw chickpeas, the fried samples showed an increase of around 8–17% in caloric value due to the absorbed fat (Table 1).

The total phenolic content was at its highest in the spicy samples, but the antioxidant capacity was highest in the peppery samples. Both values were significantly higher in the spicy and peppery samples than those in the raw and fried plain chickpea samples. It was emphasized that antioxidant capacities are high for red pepper, thyme and tomato by Brewer (2011). Obviously, coating of the samples had changed their visual, chemical, sensorial, and nutritional composition. Significant differences were determined for the L, a* and b* color values of the three samples ($p \leq 0.05$). Both colors of the coating materials and the Maillard products formed at the surface by frying might have created the differences in color values of the food products. As one can observe from Figure 1, plain fried chickpeas had the highest L value compared to the other samples. A higher a* value in the peppery samples indicated more redness which presumably was due to red pepper pigments. The highest b* value measured in the plain samples indicated more yellowness in the product, which is the natural color of chickpeas.

The volatile compounds of the fried chickpea products are shown in Table 2. A total of 57 volatile compounds were determined in the samples. Some of the compounds were determined only in the plain, spicy, or peppery samples individually, but some of them were identified on the whole. These results may be related to the coating materials which are naturally aromatic, and also during frying some heat-generated aromatics were also formed. The fourteen aromatics, including acetone, 2-methyl butanal, 2,4-pentanedione, hexanal, 2,5-dimethyl pyrazine, α-pinene, benzaldehyde, 2,2,4,6,6-pentamethyl heptane, p-cymene, benzeneacetaldehyde, 3-ethyl-2,5-dimethyl pyrazine, nonanal, maltol, and carvacrol were common in all three types of the samples. In general, the aromatics associated with fatty, nutty, floral, grassy, fried and fruity sensations were dominant in the samples. Acetone, 2,4-pentanedione, nonanal and 2,4-decadienal are responsible for the fried/fatty aroma, while hazelnut, or nutty aroma is caused mostly by 3-methyl butanal, 2,5-dimethyl pyrazine, and 2-ethyl-5-methyl-pyrazine. Planty or spicy sensations are produced by dimethyl disulfide, p-cymene, benzeneacetaldehyde, 3,5-dimethyl-2-vinylpyrazine and 4-carvomenthenol. Similarly, a fruity characteristic is usually associated with the 3-hexanone, isoamyl octanoate, 2-ethyl butanal, farnesane and α-terpineol. Since frying of the chickpea products was achieved in peanut oil, the aromatics associated with peanut sensation like 2,5-dimethyl pyrazine and 2-ethyl-5-methyl pyrazine were also determined in the samples (Anonymous 2, 2012). In general, these new, fried snack foods were very aromatic, and smell like all other fried products. There is no knowledge in the literature on similar fried snack foods.

For the storage stability study of the new products, another batch of products was produced and measurements were carried out periodically. The changes in the moisture contents of the samples are shown in the Figure 2A. There was a significant difference among the fried chickpea products in terms of moisture ($p = 0.000$), while product type by storage time interactions ($p = 0.630$) and storage time

FIGURE 1. The types of the new fried chickpea products.

($p = 0.221$) were not significant in terms of moisture content. Similar results were observed in water activity values, as presented in Figure 2B. The peppery samples had higher moisture than the other two types. Most likely, the pepper coating created a stronger barrier to the disposal of water during the frying process. During 90-days' storage, the moisture content of the samples did not change significantly. It was indicated that moisture absorption during the storage of snack foods caused hydrolytic rancidity in chips, crackers and popcorns, and crispness in the products was lost significantly (Katz and Labuza, 1981). The samples in this study were quite stable in terms of moisture level, and water activity.

The change in hardness values of the samples was also monitored during the storage phase on every fifteenth day (Table 3). It was observed that the product type according to storage time interactions ($p = 0.559$), and the storage time ($p = 0.207$) were not significant with regards to hardness value; however, there was a significant difference among the fried chickpea products in terms of hardness ($p = 0.009$). The highest hardness value was in the peppery type in which the moisture level was also the highest. It is obvious that the pepper coating created a more rigid surface than the others, and due to the same reason more moisture was retained inside the seeds after frying.

The changes in the color values of the products were monitored during storage on every fifteenth day and the results are shown in Table 3. It was determined that the effect of storage time according to product type interactions ($p = 0.998$) and the storage time ($p = 0.256$) on the L values were not significant; however, the effect of product type itself was significant ($p = 0.000$). The plain samples were lighter than the other two types. Coating of the chickpea surface with pepper and spices, and darkening occurring during frying caused the L value to decrease, as expected. Similarly, the a* value was only significantly different among the three product types ($p = 0.000$). The plain samples had the lowest a* value. Only product type-dependent differences were present for the b* ($p = 0.000$) values. The surface of the plain samples was more yellow than the coated samples which can also be observed in Figure 1. No significant changes in color values in the three types of chickpea products were observed during the storage period. This situation can be evaluated as "good" in terms of product stability and acceptability.

The free fatty acid (FFA) in fried snack foods is a very important quality and stability parameter. It defines the product's taste and acceptability as well. When free fatty acid exceeds 1%, most products become unacceptable (Ericson and Frey, 1994; Tiwari *et al.*, 2011). The days of storage ($p = 0.608$)

Table 2. The volatile compound composition of deep-fat fried chickpea samples

RI[a]	Volatile compounds	Aroma Quality	Amount of volatile compounds (µg/kg chickpeas)		
			Plain	Peppery	Spicy
<600	Acetone	Fatty	279.55±104.40	459.38±96.72	216.72±0.01
601	Ethyl acetate	Fruity, solvent	Nd.	Nd.	6.97±0
641	3-methyl butanal	Nutty, herbal	Nd.	19.63±1.24	14.44±0.01
648	2-methyl butanal	Nutty, malty	102.96±0.01	28.44±7.78	20.28±0.01
736	3-methyl-1-butanol (isoamyl alcohol)	Malty, musty	42.33±0.01	Nd.	Nd.
742	Dimethyl disulfide	Cabbage	Nd.	Nd.	16.52±0.01
743	1-methylpyyrole	Amine like	Nd.	66.44±16.13	0.33±0.01
781	2,4-pentanedione	Buttery	33.45±3.22	52.22±3.91	472.96±456.63
799	Hexanal	Cut grass, fishy	164.11±15.48	85.42±19.60	33.66±0.01
806	Dihydro 2 methyl-3(2H)furanone	Sweet, nutty, buttery	Nd.	79.52±13.14	Nd.
818	3-hexanone	Fruity	Nd.	21.71±9.10	20.37±9.36
849	Isoamyl octanoate	Fruity	0.87±0.23	Nd.	Nd.
857	Furfural alcohol	Burnt sugar	Nd.	24.83±5.70	55.49±47.69
880	2-ethyl-2-hexanal	–	8.83±2.11	9.09±2.82	Nd.
890	2-heptanone	Cheesy	18.93±1.82	Nd.	Nd.
900	Heptanal	Rancid, cheesy	Nd.	21.18±6.46	Nd.
901	5-methyl hexanal	–	22.20±1.57	Nd.	Nd.
908	2,5-dimethyl pyrazine	Nutty	12.82±14.6	126.60±108.71	415.63±275.62
909	γ-butyrolactone	Creamy	Nd.	75.79±0.01	Nd.
910	Methoxy-phenyl-oxime	Honey like	41.33±0.01	Nd.	Nd.
926	α--phellandrene	Fruity, mint	Nd.	Nd.	11.38±0.01
931	α- pinene	Fruity, piney, mint	1.52±0.42	48.57±9.13	32.87±1.61
957	Benzaldehyde	Peppery, almond	26.90±2.25	34.08±10.10	14.22±0.01
963	5-methyl-2-furancarboxaldehyde	Caramellic	Nd.	Nd.	34.80±0.01
972	β- pinene	Turpentine	Nd.	33.21±0.01	25.93±0.01
990	2,2,4,6,6-pentamethyl heptane	–	3160.88±586.3	3356.34±830.5	2609.79±109.95
998	2-ethyl-5-methyl-pyrazine	Nutty, coffee	Nd.	Nd.	2.07±0.01
1011	α-Terpinolene	Piney	Nd.	Nd.	65.36±0.01
1012	α- terpinene	Mushroom, mouldy	Nd.	Nd.	21.81±0.01
1021	p-cymene	Woody, herbal	17.04±8.09	22.57±0.79	75.81±34.99
1040	Benzeneacetaldehyde	Cut grass, honey	11.64±1.64	14.96±3.22	19.55±3.72
1056	γ-terpinene	Citrus	Nd.	6.71±0.01	41.17±17.28
1059	2-ethyl butanal	Fruity	Nd.	Nd.	7.89±0.01
1061	2-Acetylpyrrole	Popcorn	Nd.	Nd.	5.40±0.01
1078	3-ethyl-2,5-dimethyl pyrazine	Earthy, roasted nutty	1.26±0.05	38.96±11.17	45.48±11.84
1085	4-methyl nonane	–	Nd.	Nd.	20.45±4.94
1092	3- methyl decane	–	Nd.	3.18±0.01	Nd.
1093	3,5-dimethyl-2-vinylpyrazine	Herbal	Nd.	Nd.	2.65±0.01
1095	Farnesane	Fruity	4.58±0.01	Nd.	96.23±20.55
1103	Nonanal	Fried, fatty	18.14±2.16	19.64±5.54	16.88±4.64
1107	Maltol	Caramel, sweet	2.81±0.01	4.71±0.01	11.42±1.23
1147	2,3-dihydro-3-5-dihydroxy-6-methyl-4H-pyran-4-one	Caramel, sweet	Nd.	0.20±0.01	8.13±0.01
1161	2,4-dimethyl heptane	–	4.78±1.76	Nd.	Nd.
1176	3,8- dimethyl decane	–	Nd.	7.42±0.76	Nd.
1177	3-methyl undecane	–	0.84±0.82	Nd.	Nd.

TABLE 2 (*Continued*)

RI[a]	Volatile compounds	Aroma Quality	Amount of volatile compounds (µg/kg chickpeas)		
			Plain	Peppery	Spicy
1178	4- carvomenthenol	Pepper, woody	Nd.	Nd.	16.94±1.67
1189	α- terpineol	Floral,fruity	Nd.	Nd.	0.10±0.01
1241	2-(tetradecyloxy) ethanol	–	2.60±0.93	Nd.	Nd.
1245	2-methoxy- p-cymene	Herbal, spice	Nd	1.42±1.02	22.20±1.06
1275	Nonanoic acid	Fatty	Nd.	Nd.	404.98±77.91
1288	4-methyl piperidine	–	Nd.	0.02±0.03	Nd.
1292	2,4-decadienal	Fatty	0.48±0.59	Nd.	0.88±1.25
1298	Carvacrol	Herbal,spicy	0.14±0.20	48.66±17.97	124.98±23.11
1315	(E,E)-2,4-decadienal	Fried oil	3.23±0.37	Nd.	Nd.
1419	Trans-caryophyllene	Herbal	Nd.	2.60±3.69	5.88±0.15
1455	α-humulene	Herbal	Nd.	Nd.	0.62±0.88
1967	Hexadecanoic acid	Fruity	Nd.	44.15±62.44	Nd.

[a]RI: Retention Index based on HP 5 MS column, Nd: not detected.

and storage time according to product type interaction ($p = 0.999$) did not affect the FFA values of the chickpea products, while product type affected the FFA values significantly ($p = 0.000$) (Figure 2C). The highest FFA value was present in the peppery group throughout the storage period, and the lowest value was in the plain product. It might be possible that the pepper coating enhances free fatty acids by retaining higher moisture levels in the product to facilitate oil hydrolysis. In general, during the 90 days storage, the FFA value did not increase significantly in all three products, indicating good storage stability. Also, all measured FFA values were well below 0.4% level (Figure 2C). Another important stability parameter in fat containing foods is the peroxide value (PV). Storage time ($p = 0.031$) and product type ($p = 0.009$) were significant factors for measuring the peroxide value (Figure 2D), but their interactions were unimportant ($p = 0.118$). There was a steady increase until 60 days, then a slight decrease, and towards 90 days, a slight increase in peroxide values was observed. The initially formed and accumulated peroxides might probably have degraded to cause a decline in PV after 60 days, and then new peroxides might have formed to enhance it again. All measured values were below the 10 meq $O_2 \cdot kg^{-1}$ sample level. In this study, the samples were filled into zipped storage bags without a vacuum, or neutral

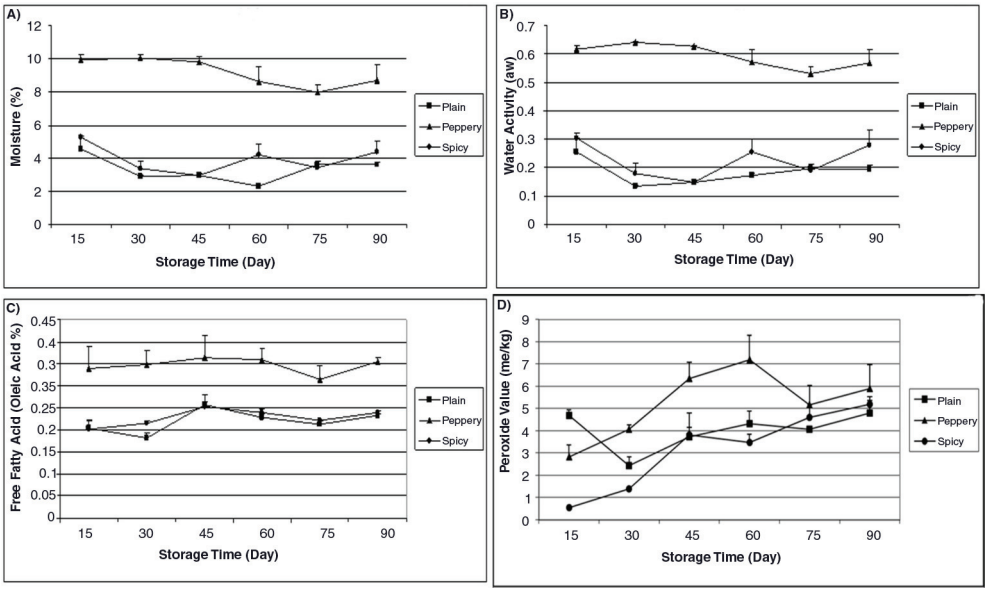

FIGURE 2. The moisture, water activity, free fatty acid and peroxide values of the chickpea samples during storage.

TABLE 3. The instrumental color and hardness values of deep-fat fried chickpea samples during storage

Storage time (Day)	Plain	Peppery	Spicy
		L value	
15	64.67±0.49	46.47±2.01	42.78±1.18
30	60.63±1.27	45.90±2.14	36.81±2.51
45	63.87±0.85	47.08±1.89	40.84±1.23
60	69.67±0.74	51.88±2.26	44.40±2.86
75	70.83±0.58	48.25±0.77	45.56±0.94
90	64.87±0.42	48.83±1.45	41.66±1.94
Overall	65.79±1.11[a]	48.07±1.47[b]	42.01±1.80[b]
		a* value	
15	10.207±0.230	18.953±0.859	19.699±0.385
30	11.465±0.616	19.026±0.657	17.987±0.523
45	10.604±0.470	18.982±0.728	18.798±0.325
60	10.639±0.294	19.347±0.933	18.618±0.396
75	10.157±0.222	20.887±0.387	20.008±0.281
90	10.281±0.347	18.285±0.719	18.959±0.328
Overall	10.559±0.227[b]	19.247±0.616[a]	18.845±0.269[a]
		b* value	
15	43.367±0.836	39.210±1.760	33.230±1.130
30	40.357±0.917	39.580±2.120	25.690±2.980
45	41.303±0.643	40.880±1.400	31.720±1.250
60	43.877±0.756	39.990±2.070	30.760±2.800
75	43.915±0.868	38.909±0.623	32.877±0.882
90	40.390±1.180	39.589±0.957	30.520±2.030
Overall	42.202±0.514[a]	39.690±1.170[b]	30.800±1.840[c]
		Hardness (g force)	
15	3770±285	4570±467	4209±247
30	3223±280	3429±299	3542±277
45	3824±125	3560±118	2932±206
60	2504±132	3951±248	3772±222
75	2760±186	3735±138	3525±202
90	3424±140	4222±138	3516±133
Overall	3250±218[a]	3911±175[b]	3582±169[c]

[a–c]Means in the same row with different superscript letters show significant differences among the products (P≤0.05).

gas atmosphere, and kept at room temperature. After 3 months, the level of oxidation is not very high, and the sensory evaluations have also not identified any rancidity problems. If the products were stored under vacuum or gas atmosphere, the peroxide value would be much lower. Tiwari *et al.* (2011) studied fried cereal and legume flour products and pointed out that the peroxide value was under 5 meq $O_2 \cdot kg^{-1}$ during the 30 days of storage; and the products were acceptable in terms of sensory properties. According to another study, (Jauregui *et al.*, 2012) peroxide values higher than 10 meq $O_2 \cdot kg^{-1}$ were measured after 23 days when soybeans were fried in sunflower oil, 223 days in high-oleic sunflower oil, and 159 days in peanut oil. This study indicates that the type of oil is very important for peroxide value changes in fried snacks. According to the Turkish vegetable oils codex regulations, the maximum allowable peroxide value for edible vegetable oils is 10 meq $O_2 \cdot kg^{-1}$ oil (TFC, 2012). Hence, these new products are still acceptable after 90 days and kept in room temperature storage.

The consumer acceptance test was carried out with the aim of determining the sensory properties of the products at each month, and the results obtained from the test are presented in Table 4. Every month, each product was evaluated by 100 consumers. The hedonic scale of 1 for dislike extremely to 5 for like extremely was used. The measured sensory attributes were appearance/color, hardness, crispiness, taste/flavor,

TABLE 4. The sensory properties of deep-fat fried chickpea samples during storage (1-dislike extremely, 5-like extremely)

Sample	Appearance/color	Hardness	Crispiness	Taste/flavor	Smell /aroma	General liking
			Beginning of storage			
Plain	3.66±0.06[a]	3.67±0.06[a]	3.73±0.06[a]	3.49±0.06[a]	3.41±0.05[a]	3.69±0.05[a]
Peppery	3.32±0.07[b]	3.14±0.07[b]	3.10±0.07[b]	2.94±0.08[b]	3.02±0.07[b]	3.10±0.06[b]
Spicy	2.22±0.07[c]	2.71±0.07[c]	2.65±0.07[c]	2.33±0.07[c]	2.47±0.07[c]	2.37±0.06[c]
			30th day of storage			
Plain	3.86±0.06[a]	3.82±0.06[a]	3.93±0.06[a]	3.71±0.06[a]	3.64±0.06[a]	3.81±0.05[a]
Peppery	3.09±0.07[b]	2.31±0.07[c]	2.19±0.06[c]	2.63±0.07[c]	2.75±0.07[b]	2.59±0.06[c]
Spicy	2.40±0.07[c]	3.27±0.07[b]	3.42±0.07[b]	2.94±0.08[b]	2.91±0.07[b]	3.01±0.06[b]
			60th day of storage			
Plain	3.85±0.08[a]	4.01±0.08[a]	3.95±0.10[a]	3.73±0.09[a]	3.61±0.09[a]	3.82±0.07[a]
Peppery	3.58±0.10[a]	3.03±0.10[b]	2.99±0.10[c]	3.06±0.10[b]	3.12±0.10[b]	3.22±0.09[b]
Spicy	2.22±0.11[b]	3.30±0.10[b]	3.48±0.10[b]	2.97±0.12[b]	2.85±0.10[b]	3.04±0.10[b]
			90th day of storage			
Plain	4.11±0.06[a]	3.94±0.08[a]	3.98±0.08[a]	3.61±0.10[a]	3.60±0.09[a]	3.96±0.08[a]
Peppery	3.41±0.11[b]	2.45±0.11[c]	2.38±0.11[c]	2.88±0.11[b]	2.83±0.09[c]	2.84±0.10[b]
Spicy	2.47±0.12[c]	3.43±0.11[b]	3.43±0.11[b]	3.09±0.10[b]	3.15±0.10[b]	3.11±0.10[b]

[a–c]Means in the same column with different superscript letters show significant differences in each property within the same product throughout the storage period.

smell/aroma, and general appreciation. Generally, most of the hedonic scores were higher than 3, indicating a good level of consumer acceptance. There were some differences among the product types for each property, and the plain product was more preferred than the other two products. In the peppery products, after 30 days, there appeared to be a loss in crispness due to higher moisture causing scores of a lower level. Similarly, in spicy products, the appearance/color values were lower due to the darkening of the surface after the frying process. In all measured properties throught the entire storage period, the plain products had higher sensory scores. During 3 months' storage with the aforementioned storage conditions, most of the attribute scores were not considerably changed (Table 4). Thus, it could be stated that the product sensory properties were also stable enough during the storage time, and that these products can be commercialized without any sensory defects.

4. CONCLUSIONS

With the processes of Globalization and of commodification of lifestyles in the "Global Village", snack foods have become more and more the favorite "fast meals" of the masses at every age for time-tight social gatherings, schools, vacations, and entertainment purposes. Therefore, the composition, quality and stability of such products are globally and saliently important. With the development of food technology and the availability of natural ingredients, healthier, safer, more nutritious and even more functional snack foods can be produced to satisfy consumer demands. The nutritional benefits of legumes and chickpeas have already been discussed. This study provides the first data for a snack food which is based on fried whole chickpeas. All quality parameters measured for these new products were quite acceptable. The shelf-life was excellent under the limited storage conditions. On the basis of these considerations, other types of fried chickpea snacks can also be developed. There was no chemical addition or harsh treatment of raw chickpeas other than just immersing them in tap water. All of the nutrients were retained in chickpeas, and also some oil is absorbed to enhance its energy value. Finally, the production of such a snack products does not require any special equipment, and it is easy to produce. In conclusion, the results of this study indicate the possible commercialization of new fried chickpea snack foods.

ACKNOWLEDGMENTS

The authors would like to thank the Kale Gida Co. (Çanakkale, Turkey), the Helvacızade Oil and Pharmaceuticals Co. (Konya, Turkey) and the Yılmaz Offset Press and Packaging Co. (İzmir, Turkey). This article is prepared from the M.Sc. Thesis of Seda Bozdemir.

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