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Impact of Sprouting Time of Chickpea on the Physicochemical, Textural, Sensory, and Total Phenolic Characteristics of Falafel Prepared from Sprouted Chickpea Flour

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Abstract

Falafel is considered as an inexpensive and nutritious product that contains various plant substances, vitamins, dietary fibers, and phenolic compounds. The aim of this research was to investigate the impact of sprouting time on the physicochemical characteristics of sprouted chickpea flour. Also, the effects of sprouting time on the physicochemical characteristics and sensory properties of falafel prepared from sprouted chickpea flour were examined. The finding of this research indicated that the sprouting process significantly increased the total phenolic content (from 284.17 to 720.98 µg gallic acid/g dry), antioxidant capacity (from 77.55% to 93.35%), and redness (from 7.65 to 11.39) of chickpea flour ($p<0.05$). While, it significantly decreased the lightness (from 70.81 to 57.07) and yellowness (from 43.71 to 25.62) of chickpea flour ($p<0.05$). The total phenolic content and antioxidant capacity of falafel prepared from flour of sprouted chickpea for two-days (48 hours) were significantly higher than those prepared from unsprouted chickpeas flour ($p<0.05$). The volume of falafel samples produced from unsprouted, one-day sprouted, and two-day sprouted chickpea flours was 18.75, 16.60, and 15.40 cm^3, respectively. The minimum oil uptake was observed in the sample prepared from chickpeas sprouted for two-days ($p<0.05$). The sprouting process did not have a significant impact on the firmness, cohesiveness, and chewiness of the falafel ($p>0.05$). In general, utilizing of one-day (24 hours) sprouted chickpea flour for the production of falafel is recommended due to the best flavor, the highest overall acceptance score, high content of phenolic compounds, high antioxidant capacity, and low oil absorption.

Keywords: Antioxidant capacity, Cohesiveness, Firmness, Oil absorption, Total phenolic

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Introduction

Legumes rank as the second most important crop globally, after cereals. In developing countries, a significant portion of people's dietary protein comes from various sources of legumes such as peas, green peas, mung beans, soybeans, beans, faba beans, and lentils. The protein content of legumes (20-50%) is relatively high compared to cereals and other starchy crops and roots (Elobuike *et al.*, 2021; Ghoshal & Kaushal, 2020; Salehi, 2023; Salehi *et al.*, 2024). Chickpeas (*Cicer arietinum* L.) are an excellent source of protein, carbohydrates, fiber, minerals (P, Mg, Ca, Fe, and K), and vitamins such as niacin, thiamin, riboflavin, B vitamins, and β-carotene (Bidkhori & Mohammadpour Karizaki, 2022; Doddamani *et al.*, 2014; Ghoshal & Kaushal, 2020).

The process of germination enhances legumes by changing their nutritional value, chemicals, and taste. This process is used to increase digestibility and improve nutritional value of legumes. During this process, the total phenolic content (TPC) and antioxidant capacity (AC) of legumes also increased (El-Adawy *et al.*, 2003; Karimi & Saremnezhad, 2020; Oghbaei & Prakash, 2016). The study conducted by Sofi *et al.* (2023) showed that the sprouting process increases the nutritional value, phenolic content, and AC of chickpea flour, and considerably improves the protein and starch digestibility of sprouted chickpea flour. Kim *et al.* (2022) also confirmed that germination of desi chickpeas led to increase TPC, total flavonoid content, antioxidant activity, and percentage of soluble proteins. The effect of addition sprouted mung bean flour at different levels (0-30%) on noodles properties was examined by Liu *et al.* (2018). Their findings confirmed that when more sprouted mung bean flour was added, the protein content of noodles increased.

Chickpeas are used as the main ingredient in ethnic and traditional Iranian foods such as Abgoosht, Ash, Shole, and falafel (Bidkhori & Mohammadpour Karizaki, 2022; Goharpour *et al.*, 2024). Falafel is considered as an inexpensive and nutritious product that contains various plant substances, various vitamins, dietary fibers, and bioactive components (Fikry *et al.*, 2021;Hojjati *et al.*, 2020). In a study by Goharpour *et al.* (2024) investigated the impacts of various drying methods of ground sprouted chickpeas on the quality, textural characteristics, and sensory properties of fried falafel, they found that fried falafel made from infrared drying of sprouted chickpeas scored the highest in terms of odor, flavor, and total acceptability.

During drying products, it is important to use the most suitable drying method and conditions (Khodadadi *et al.*, 2023). The most common method for dehydration agricultural crops is hot air drying (Khodadadi *et al.*, 2024).

The goal of this study was to estimate the impacts of sprouting time on the moisture content (MC), ash content, TPC, AC, color, and rehydration of sprouted chickpea flour. The effects of sprouting time on the physicochemical characteristics of falafel prepared from sprouted chickpea flour were also examined.

Materials and Methods

Sprouting Process

To conduct this research, packaged chickpeas were purchased from Sahar Company (Hamedan, Iran). After washing, the chickpeas were soaked in water at 25°C for 24 h. At this stage, one-third of the soaked peas were separated (Unsprouted sample). Afterwards, excess water was removed and chickpeas were sprouted in containers covered with thin towels at 25°C for 24 h (Day 1 sample) or 48 h (Day 2 sample) (Amin-Ekhlas *et al.*, 2024). Unsprouted and sprouted (after 24 and 48 h) chickpeas were ground (MK-G20NR, National, Japan) (Fig. 1).

Hot-air Drying

To dry the ground of unsprouted and sprouted (after 24 and 48 h) chickpeas, the samples were placed in a fan oven (Shimaz, Iran) at 70°C, until reached a constant weight (Amin-Ekhlas *et al.*, 2024).

Preparation of Falafel

The raw and fried falafels were prepared according to the approach described in our previous work (Goharpour *et al.*, 2024). The falafel recipe prepared included chickpea flour (70 g), water (100 g), salt (3.5 g, Toloo company, Iran), falafel spice (1.1 g), and baking powder (1 g, Bartar company, Iran). The prepared mixture was distributed evenly using a mold and placed in a deep fryer (Seven star, Model df02, Germany) at 150°C for 8 min.

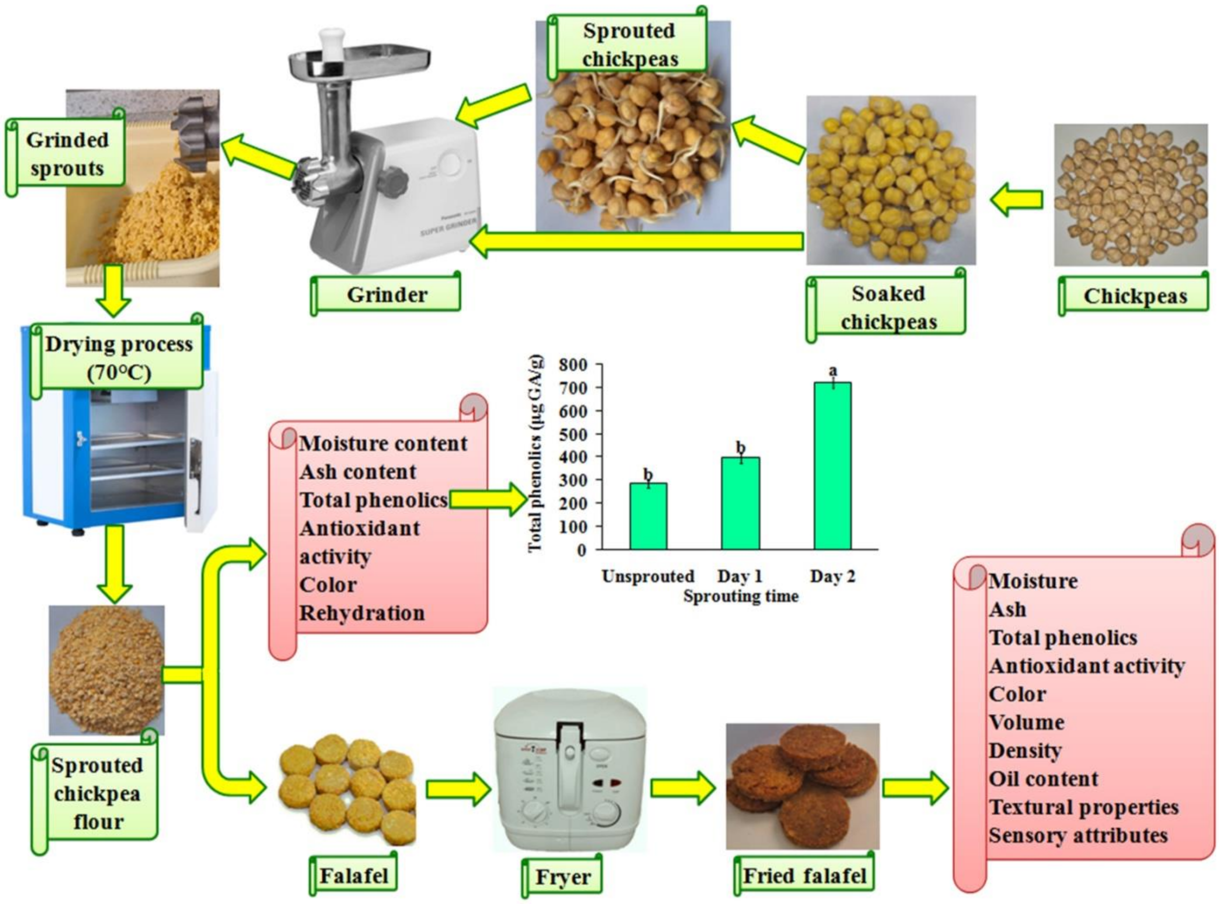

Fig. 1. Schematic of sprouted chickpea flour production and falafel making process

Moisture and Ash Contents

The MCs of chickpea flours (unsprouted and sprouted) and falafels were determined using an oven at 105°C for 5 h (Shimaz, Iran)(Amin-Ekhlas *et al.*, 2024). The ash contents of chickpea flours (unsprouted and sprouted) and falafels were determined using a laboratory electric furnace (Iran) at 550°C for 6 h (Goharpour *et al.*, 2024).

Total Phenolic Content

The TPCs of chickpea flours and falafels were determined according to the procedure described by Goharpour *et al.* (2024). The TPC of flours/falafels was calculated as Gallic acid equivalent (GA) using Folin-Ciocalteu's phenol reagent (Sigma-Aldrich, USA) and a UV-VIS spectrophotometer at 725 nm (XD-7500, Lovibond, Germany) (Salehi *et al.*, 2023a).

Antioxidant Activity

The AC of chickpea flours/falafels was determined as free radical scavenging activity using DPPH (2,2-Diphenyl-1-picrylhydrazyl, 0.1mM, Sigma-Aldrich, USA) and a UV-VIS spectrophotometer at 517 nm (XD-7500, Lovibond, Germany) (using Equation 1).

$$\text{DPPH} = \frac{\text{Absorbance of control - Absorbance of sample}}{\text{Absorbance of control}} \times 100 \quad (1)$$

Rehydration of Chickpea Flour

The rehydration test of chickpea flour was carried out in a water bath (R.J42, Pars Azma Co., Iran) at 50°C for 30 min (Salehi *et al.*, 2023b).

Color

Samples photos were taken with a scanner (HP Scanjet-300). The flour/falafel photos were converted from RGB color space to $L^*a^*b^*$color space using a computer software (ImageJ, V.1.42e, USA) and its color space conversion plugin (Eftekhari *et al.*, 2023).

Volume and Density of Falafels

The volume and density of falafels were measured following the method described by Goharpour *et al.* (2024).

Oil Content (Soxhlet Extraction)

Conventional soxhlet extraction was performed in a laboratory soxhlet extractor using 3 g of falafel and approximately 75 mL of n-Hexane (extra pure, Arman Sina, Iran) at 80°C for 5 h (Behr E4, Germany).

Textural Properties

Puncture test: A texture analyzer (STM-5, Santam, Iran) was used for measuring the surface hardness of falafels. Puncture tests were performed using a cylindrical probe with a diameter of 5 mm, at a speed of 1 mm/s, and a penetration depth of 10 mm.

TPA test: Texture profile analysis (TPA) of falafel samples were carried out using the texture analyzer equipped with a 5 cm diameter cylindrical probe, 50% deformation, and a test speed of 1 mm/s.

Sensory Assessment

The sensory assessment was carried out after the falafels samples were fried. Food engineering students and professors participated in the evaluation of the sensory attributes of the fried falafels.

Statistical Analysis

A statistical analysis was performed to compare the average responses (using the Duncan's multiple range test), revealing significant differences with a 95% confidence level (employing the SPSS 21 software).

Results and Discussion

Sprouted Chickpea Flour Properties

The moisture and ash content of fresh chickpeas (unsoaked) were 6.89% and 3.40%. Table 1 shows the influence of sprouting time on the MC, ash content, AC, and rehydration of sprouted chickpea flour. The MC of unsprouted, sprouted after one-day, and sprouted after two-day samples was 9.13%, 7.77%, and 8.43%, respectively. The ash content of unsprouted, sprouted after one-day, and sprouted after two-day samples were 2.38%, 2.28%, and 2.22%, respectively. The results showed that there was no significant change in the ash content of sprouted chickpea flour during the sprouting process.

Table 1- Effect of sprouting time on the moisture, ash, antioxidant capacity, and rehydration of sprouted chickpea flour

Sprouting time	Moisture content (%)	Ash content (%)	Antioxidant capacity (%)	Rehydration ratio (%)
Unsprouted	9.13±0.05 a	2.38±0.12 a	77.55±3.72 b	366.47±16.45 a
Day 1	7.77±0.19 c	2.28±0.15 a	88.46±2.07 a	353.53±17.37 a
Day 2	8.43±0.12 b	2.22±0.10 a	93.35±1.32 a	341.73±1.67 a

Different letters within each column represent significance difference ($p<0.05$)

In this research, the TPC of fresh chickpea (unsoaked) was 254.37 µg GA/g dry. Sprouting of chickpeas increases the amount of phenolic compounds. Fig. 2 shows the effects of sprouting time on the total phenolics of sprouted chickpea flour. The total phenolics of unsprouted, sprouted after one-day, and sprouted after two-day samples were 284.17, 395.38, and 720.98 µg GA/g dry, respectively. The results showed that there was a significant change in total phenolics of sprouted chickpea flour during the sprouting process. The increase in TPC after sprouting could be due to the enzymatic degradation of kernel structure of the samples, which helps in the more extraction of phenolic compounds (Kumar *et al.*, 2020). Goharpour *et al.* (2024) studied the impacts of different drying methods of ground sprouted chickpeas on the TPC of dried samples. Their findings showed that the TPC of hot air, infrared, and microwave dried samples were 463.42 µg GA/g dry, 766.20 µg GA/g dry, and 470.82 µg GA/g dry, respectively. In addition, Amin-Ekhlas *et al.* (2024) reported that the process of sprouting of wheat improves the TPC, and as a result, the flour made from the sprouts also had higher TPC.

Sprouting is a slow natural biochemical process that happens at low temperatures. It alters the metabolic activity and carbohydrate digestibility, and increases protein content, antioxidant activity, and nutrients bioavailability (Kumar *et al.*, 2020). During the sprouting process, the TPC of chickpea increased, which led to an increase in the AC of the product. In this study, the AC of unsprouted, one-day sprouted, and two-day sprouted chickpeas flours were 77.55%, 88.46%, and 93.35%, respectively. The sprouting process decreased the rehydration rate of the flours. As shown in the Table 1, as the sprouting time increased, the rehydration rate of sprouted chickpea flours was decreased from 366.47% to 341.73% ($p>0.05$).Gan *et al.* (2017) reported that hot-air dehydration not only enhanced the TPC and AC of sprouted mung beans, but also changed their color to brown. Kumar *et al.* (2020) studied the of sprouting on the TPC and AC of black chickpea. Their results showed that the effect of sprouting on TPC was positive but non-significant.

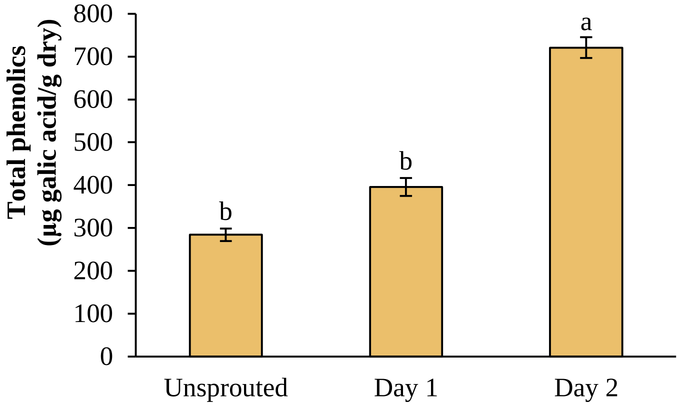

Fig. 2. Effect of sprouting time on the total phenolics of sprouted chickpea flour
Different letters above the columns indicate significant difference ($p<0.05$)

In this study, the lightness (L^*), redness (a^*), and yellowness (b^*) of fresh chickpea powder (unsoaked) were 60.79, 7.67, and 31.49 respectively. Table 2 shows the effects of sprouting time on the color parameters of sprouted chickpea flour. The sprouting process decreased the L^* and b^* indexes of the sprouted chickpea flours, while the a^* index of flours was increased. As shown in this table, as the sprouting time increased, the L^* and b^* indexes of sprouted chickpea flours significantly decreased from 70.81 to 57.07, and from 43.71 to 25.62, respectively ($p<0.05$). While, as the sprouting time increased, the a^* index of sprouted chickpea flours significantly increased from 7.65 to 11.39 ($p<0.05$). Reduction in color parameters in sprouted samples might be due to the change in carbohydrates and protein structure (Tian *et al.*, 2010). Ozturk *et al.* (2014) reported that sprouted wheat flour was darker in color than unsprouted wheat flour. In addition, Javaheripour *et al.* (2022) reported that the addition of sprouted wheat flour to sponge cake formulations darkened the color of the samples and reduced the L^* parameter. This is likely due to the enhanced activity of the enzymes and the increased value sofreducing sugars in the sprouted grains. The study of Kumar *et al.* (2020) showed that sprouting process improved the physical and pasting properties of black chickpea (*Cicer arietinum*), whereas roasting improved the functional properties. The L^* index of sprouted grains considerably enhanced as compared with the dark color of roasted sample.

Table 2- Effect of sprouting time on the color parameters of sprouted chickpea flour

Sprouting time	Lightness	Redness	Yellowness
Unsprouted	70.81±1.42 ^{a}	7.65±0.14 ^{b}	43.71±0.66 ^{a}
Day 1	67.01±2.49 ^{b}	8.09±0.18 ^{b}	37.38±2.97 ^{b}
Day 2	57.07±2.52 ^{c}	11.39±0.45 ^{a}	25.62±2.52 ^{c}

Different letters within each column represent significance difference ($p<0.05$)

Moisture and Ash Contents of Falafel

Fig. 3 (a) displays the influence of sprouting time on the MC of falafel samples. The MC of falafel samples made from unsprouted, sprouted after one-day, and sprouted after two-days chickpea flours were 19.73%, 26.27%, and 24.80%, respectively. The MC of falafel made from sprouted chickpea flour was considerably higher than unsprouted chickpea flour ($p<0.05$). Serdaroglu (2006) used fat and oat flour in the production of beef patties. Their results confirmed that the addition of oat flour enhanced the baking properties of patties. Furthermore, adding oat flour reduced the water content of raw patties, whereas oat flour increased the water content of baked patties.

Fig. 3 (b) displays the influence of sprouting time on the ash content of samples. There was no considerable difference in ash content between falafel made from sprouted and unsprouted chickpea flour ($p>0.05$). The ash content of falafel samples prepared from unsprouted, sprouted after one-day, and sprouted after two-days chickpea flours were 5.19%, 5.40%, and 5.93%, respectively.

Total Phenolic Content and Antioxidant Capacity of Falafel

During the sprouting process, the amount of chickpea phenolic compounds increased, which led to an increase in the TPC and AC of the prepared falafel samples. Fig. 4 (a) and 4 (b) demonstrate the influence of sprouting time on the TPC and AC of falafel samples, respectively. The TPC of samples made from unsprouted, one-day sprouted, and two-days sprouted chickpea flours were 154.47, 245.73, and 264.23 μg GA/g dry, respectively. Also, the AC of samples made from unsprouted, sprouted after one-day, and sprouted after two-days chickpea flours were 71.88%, 78.89%, and 87.35%, respectively. The TPC and AC of falafel made from two-days sprouted chickpeas flours were considerably higher than falafel prepared from unsprouted chickpea flours ($p<0.05$).

Color of Falafel

The effect of sprouting time on the surface and core color parameters of falafel prepared from sprouted chickpea flours was reported in Table 3. The sprouting process did not have a considerable influence on the surface color of the falafel ($p>0.05$). The L^*, a^*, and b^* values of the falafel's surface were between 45.41 and 46.59, 14.95 and 15.57, and 29.62 and 32.12, respectively. The L^*, a^*, and b^* values of the falafel's core were between 55.18 and 60.65, 2.32 and 4.46, and 37.04 and 41.61, respectively. Goharpour *et al.* (2024) results showed that the L^*, a^*, and b^* values of the fried falafel's core were between 57.37 and 59.29, 3.66 and 6.88, and 40.50 and 43.31, respectively.

Volume

Fig. 5 displays the effect of sprouting time on the volume of falafel prepared from sprouted chickpea flours. The use of sprouted chickpeas to prepare falafel reduced the volume of falafel. The lowest volume was related to the sample made from the two-days sprouted chickpea. The volume of samples made from unsprouted, one-day sprouted, and two-day sprouted chickpea flours were 18.75, 16.60, and 15.40 cm^3, respectively. The results of this study showed that the use of sprouted chickpea flours did not have a considerable effect on the density of the falafel (p>0.05) and the density of falafel was between 886.86kg/$m^3$and 889.81 kg/m^3.

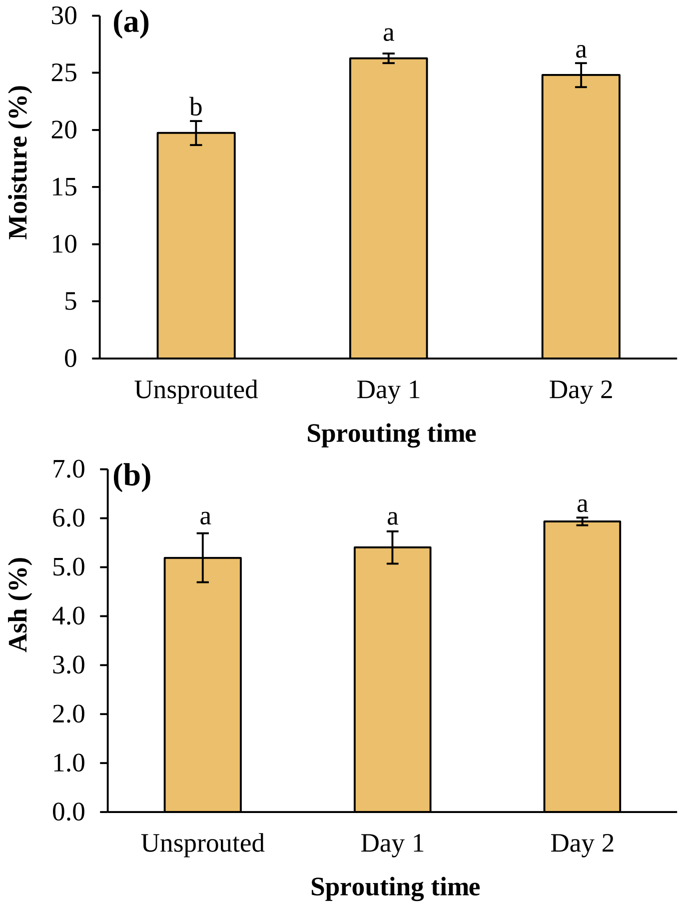

Fig. 3. Effect of chickpea sprouting time on the moisture (a) and ash (b) contents of falafels

Different letters above the columns indicate significant difference (p<0.05)

Table 3- Effect of chickpea sprouting time on the color parameters of falafels

Sprouting time	Surface color indexes			Core color indexes		
	Lightness	Redness	Yellowness	Lightness	Redness	Yellowness
Unsprouted	45.41±2.75 [a]	15.57±0.93 [a]	30.17±3.27 [a]	55.91±0.51 [b]	3.43±0.43 [b]	37.04±0.77 [a]
Day 1	45.98±1.40 [a]	15.44±0.47 [a]	29.62±4.32 [a]	60.65±0.91 [a]	2.32±0.42 [c]	41.61±1.94 [a]
Day 2	46.59±0.25 [a]	14.95±0.22 [a]	32.12±4.32 [a]	55.18±1.71 [b]	4.46±0.07 [a]	39.66±3.65 [a]

Different letters within each column represent significance difference (p<0.05)

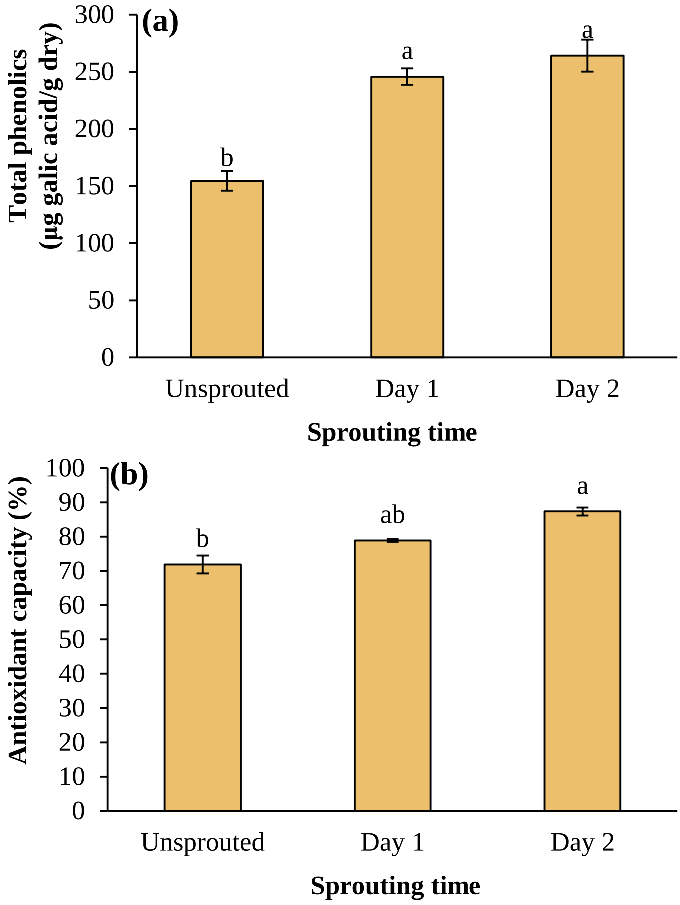

Fig. 4. Effect of chickpea sprouting time on the total phenolics content (a) and antioxidant capacity (b) of falafels
Different letters above the columns indicate significant difference ($p<0.05$)

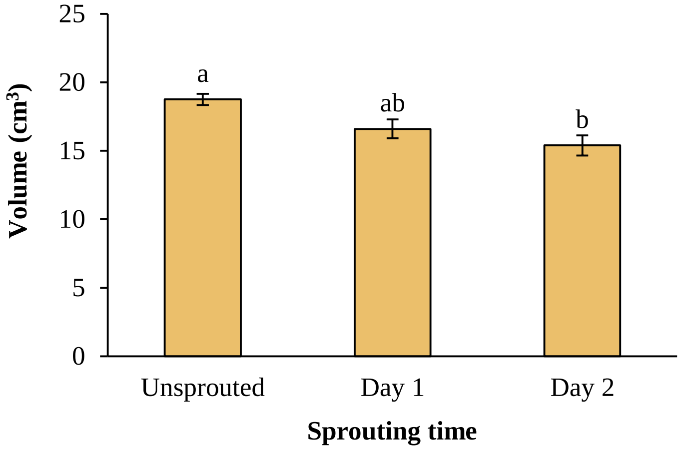

Fig. 5. Effect of chickpea sprouting time on the volume of falafels
Different letters above the columns indicate significant difference ($p<0.05$)

Oil Content of Falafel

Today, people are looking for low-fat content of food products (Daraei Garmakhany *et al.*, 2011). Fig. 6 displays the effect of sprouting time on the oil content of falafel prepared from sprouted chickpea flours. The use of sprouted chickpeas to prepare falafel reduced the oil absorption by falafel. The minimum oil uptake was related to falafel made from the two-day sprouted chickpea ($p<0.05$).

The oil content of samples made from unsprouted, one-day sprouted, and two-day sprouted chickpea flours were 22.56%, 21.67%, and 17.00%, respectively.

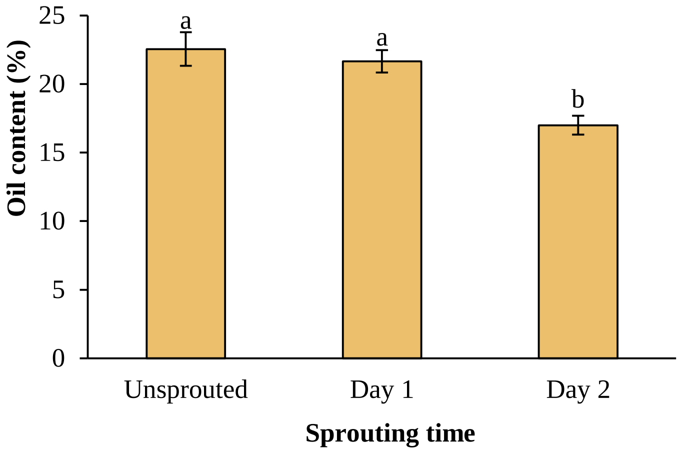

Fig. 6. Effect of chickpea sprouting time on the oil content of falafels
Different letters above the columns indicate significant difference (p<0.05)

Textural Properties of Falafels

Chickpea flour is commonly used as the main ingredient in falafel. Fig. 7 shows the effect of sprouting time on the texture hardness (puncture test) of falafel made from sprouted chickpea flours. The sprouting process did not have a considerable effect on the hardness of falafel (p>0.05). The hardness of falafel samples prepared from unsprouted, one-day sprouted, and two-days sprouted chickpea flours were 7.65 N, 8.94 N, and 7.47 N, respectively.

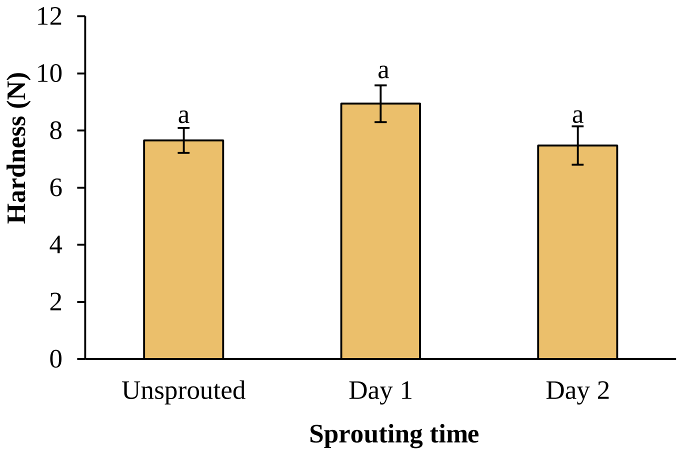

Fig. 7. Effect of chickpea sprouting time on the texture hardness (puncture test) of falafels
Same letters above the columns indicate no significant difference between means (p>0.05)

The texture is one of the main quality attributes of foods. Texture analysis tests are very useful in examining the texture of various foods and show a high correlation with sensory evaluation (Caine *et al.*, 2003). The firmness, cohesiveness, springiness, and chewiness values of falafel were between 45.90 N and 55.73 N, 0.60 and 0.72, 0.61 and 0.75, and 21.88 N and 25.14 N, respectively (Table 4). Goharpour *et al.* (2024) findings showed that the firmness, cohesiveness, springiness, and chewiness of the fried falafel were between 38.17 N and 91.56 N, 0.29 and 0.44, 0.48 and 0.58, and 5.38 N and 17.24 N, respectively.

Table 4- Effect of chickpea sprouting time on the textural properties (TPA test) of falafels

Sprouting time	Firmness (N)	Cohesiveness	Springiness	Chewiness (N)
Unsprouted	49.06±3.92 [a]	0.72±0.08 [a]	0.71±0.01 [a]	25.14±4.61 [a]
Day 1	55.73±2.19 [a]	0.70±0.21 [a]	0.61±0.05 [b]	24.44±8.74 [a]
Day 2	45.90±6.76 [a]	0.60±0.19 [a]	0.75±0.04 [a]	21.88±9.16 [a]

Different letters within each column represent significance difference (p<0.05)

Texture firmness is considered to be the maximum force observed in the for ceversustime graph (first cycle) during the TPA test. There is no considerable difference between falafel samples concerning firmness (p>0.05).

The TPA test is advice method that imitates the first two stages of chewing food and analyzes the texture of the product (Nishinari *et al.*, 2019). The cohesiveness parameter is a measure of the internal bond strength of the product. To estimate it, the ratio of the second cycle is at the first cycle in the TPA test graph was calculated. The use of sprouted chickpea flour to prepare falafel reduced the cohesiveness of falafel samples.

Springiness is the value or ratio at which a food samples returns to their original size/shape after being partially compressed among the tongue and palate (Meullenet *et al.*, 1998). Also, the springiness parameter or elastic describes the springiness state of a sample after the compressive force is removed. To calculate the springiness parameter, the ratio of the compression period of the second cycle to the first cycle in the TPA test graph is considered. The findings of this research demonstrated that the mean values of the springiness of falafel were between 0.61 and 0.75.

Chewiness describes the value of work required to chew the food products until it is swallowed (Meullenet *et al.*, 1998) and it is equal to firmness × cohesiveness × springiness. The findings of this research showed that the sprouting process did not have a significant effect on the chewiness of falafel (p>0.05). Off course, adding sprouted chickpeas flour to the falafel formulation decreases the cohesiveness of the texture, as well as, decreases the energy required for chewing falafel.

Sensory Evaluation of Falafel

The sprouting process greatly influences nutritional, biochemical, and sensory characteristics by improving chickpea quality and increasing its digestibility. Table 5 shows the effect of sprouting time on the sensory attributes of falafel made from sprouted chickpea flours. The sprouting process did not have a considerable influence on the surface brightness and core brightness of falafel (p>0.05). The appearance, odor, flavor, firmness, texture, and overall acceptance of falafel made from two-days sprouted chickpea flours were considerably lower than samples made from unsprouted flour (p<0.05). The highest texture acceptance score was related to falafel prepared from unsprouted chickpea flour. Falafel, made from one-day sprouted chickpeas, received the highest marks in terms of flavor and overall acceptance.

Conclusion

Various products such as falafel are made from ground and dried sprouted chickpea. In this work, the effect of sprouting time on the physicochemical characteristics of sprouted chickpea flour was examined. In addition, the effects of sprouting time on the physicochemical characteristics of falafel made from sprouted chickpea flour were studied. Sprouting of chickpea improves the TPC, so the flour made from the sprouts has a higher TPC and the highest AC. The sprouting process did not have a considerable effect on the ash content and rehydration rate of the sprouted chickpea flour (p>0.05). The TPC and AC of falafel made from two-day sprouted chickpea flours were considerably higher than falafel prepared from unsprouted chickpea flours (p<0.05). The sprouting process did not have a significant impact on the firmness, cohesiveness, and chewiness of falafel (p>0.05). Using sprouted chickpea to prepare falafel reduced the cohesiveness and chewiness of falafel samples. It is recommended to use sprouted chickpea in the preparation of various food products. In addition, due to the highest sensory score, high TPC, high AC, high MC, and low oil absorption, it is recommended to use one-day sprouted chickpea flour for the production of falafel.

Table 5- Effect of chickpea sprouting time on the sensory attributes of fried falafels

Sprouting time	Surface brightness	Core brightness	Appearance acceptance	Odor acceptance	Flavor acceptance	Firmness	Texture acceptance	Overall acceptance
Unsprouted	7.40±0.80 [a]	7.90±1.30 [a]	8.00±0.45 [a]	8.20±0.75 [a]	7.20±1.25 [a]	7.30±0.78 [a]	8.10±0.54 [a]	7.70±0.46 [a]
Day 1	6.60±0.92 [a]	7.20±1.25 [a]	7.60±0.80 [a]	7.10±1.04 [b]	7.50±1.12 [a]	6.80±0.75 [a]	7.30±0.46 [b]	8.00±0.89 [a]
Day 2	6.80±1.83 [a]	6.90±1.22 [a]	6.90±0.70 [b]	4.70±1.27 [c]	4.60±1.02 [b]	5.10±0.70 [b]	4.90±1.22 [c]	5.40±1.11 [b]

Different letters within each column represent significance difference (p<0.05)

Author Contributions

Kimia Goharpour: Data curation, Formal analysis, Investigation, Software, Writing–original draft. **Fakhreddin Salehi**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Writing–original draft, Writing–review and editing. **Amir Daraei Garmakhany**: Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing – original draft.

Founding Source

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References

1. Amin-Ekhlas, S., Pajohi-Alamoti, M., & Salehi, F. (2024). Effect of ultrasonic and infrared treatments on microbial population, physicochemical properties, and total phenols of sprouted wheat powder. *Innovative Food Technologies*, *11*(3), 197-210. https://doi.org/10.22104/ift.2024.6712.2166
2. Bidkhori, P., & Mohammadpour Karizaki, V. (2022). Diffusion and kinetic modeling of water absorption process during soaking and cooking of chickpea. *Legume Science*, *4*(1), e116. https://doi.org/10.1002/leg3.116
3. Caine, W.R., Aalhus, J.L., Best, D.R., Dugan, M.E.R., & Jeremiah, L.E. (2003). Relationship of texture profile analysis and Warner-Bratzler shear force with sensory characteristics of beef rib steaks. *Meat Science*, *64*(4), 333-339. https://doi.org/10.1016/S0309-1740(02)00110-9
4. Daraei Garmakhany, A., Aghajani, N., & Kashiri, M. (2011). Use of hydrocolloids as edible covers to produce low fat French fries. *Latin American Applied Research*, *41*(3), 211-216.
5. Doddamani, D., Katta, M.A., Khan, A.W., Agarwal, G., Shah, T.M., & Varshney, R.K. (2014). CicArMiSatDB: the chickpea microsatellite database. *BMC Bioinformatics*, *15*(1), 212. https://doi.org/10.1186/1471-2105-15-212
6. Eftekhari, A., Salehi, F., Gohari Ardabili, A., & Aghajani, N. (2023). Effects of basil seed and guar gums coatings on sensory attributes and quality of dehydrated orange slices using osmotic-ultrasound method. *International Journal of Biological Macromolecules*, *253*, 127056. https://doi.org/10.1016/j.ijbiomac.2023.127056

7. El-Adawy, T.A., Rahma, E.H., El-Bedawey, A.A., & El-Beltagy, A.E. (2003). Nutritional potential and functional properties of germinated mung bean, pea and lentil seeds. *Plant Foods for Human Nutrition*, *58*(3), 1-13. https://doi.org/10.1023/B:QUAL.0000040339.48521.75
8. Elobuike, C.S., Idowu, M.A., Adeola, A.A., & Bakare, H.A. (2021). Nutritional and functional attributes of mungbean (*Vigna radiata* [L] Wilczek) flour as affected by sprouting time. *Legume Science*, *3*(4), e100. https://doi.org/10.1002/leg3.100
9. Fikry, M., Khalifa, I., Sami, R., Khojah, E., Ismail, K.A., & Dabbour, M. (2021). Optimization of the frying temperature and time for preparation of healthy falafel using air frying technology. *Foods*, *10*(11), 2567. https://doi.org/10.3390/foods10112567
10. Gan, R.-Y., Lui, W.-Y., Chan, C.-L., & Corke, H. (2017). Hot air drying induces browning and enhances phenolic content and antioxidant capacity in mung bean (*Vigna radiata* L.) sprouts. *Journal of Food Processing and Preservation*, *41*(1), e12846. https://doi.org/10.1111/jfpp.12846
11. Ghoshal, G., & Kaushal, K. (2020). Extraction, characterization, physicochemical and rheological properties of two different varieties of chickpea starch. *Legume Science*, *2*(1), e17. https://doi.org/10.1002/leg3.17
12. Goharpour, K., Salehi, F., & Daraei Garmakhany, A. (2024). Effects of different drying techniques of ground sprouted chickpeas on quality, textural properties, and sensory attributes of fried falafel. *Food Science & Nutrition*, *12*(9), 6328-6337. https://doi.org/10.1002/fsn3.4240
13. Hojjati, M., Mehrnia, M.A., Kakaaghazadeh, A., & Feghhi, S. (2020). Effects of edible hydrocolloids on quality characteristics of the fried falafels emphasize on decreases in oil uptakes. *Iranian Journal of Nutrition Sciences and Food Technology*, *14*(4), 77-88.
14. Javaheripour, N., Shahsoni Mojarad, L., Mahdikhani, S., & Inanloo, Y. (2022). The effect of adding quinoa flour and germinated wheat flour on the physicochemical ،microbial and sensory properties of sponge cake. *Journal of Food Science and Technology (Iran)*, *18*(119), 375-392. https://doi.org/10.52547/fsct.18.119.375
15. Karimi, A.S., & Saremnezhad, S. (2020). The effect of germination process on some functional properties of Iranian lentil cultivars. *Journal of Food Science and Technology (Iran)*, *17*(101), 167-176. https://doi.org/10.52547/fsct.17.101.167
16. Khodadadi, M., Masoumi, A., & Sadeghi, M. (2024). Drying, a practical technology for reduction of poultry litter (environmental) pollution: methods and their effects on important parameters. *Poultry Science*, *103*(12), 104277. https://doi.org/10.1016/j.psj.2024.104277
17. Khodadadi, M., Masoumi, A., Sadeghi, M., & Moheb, A. (2023). Optimization of drying specification and protein losses of poultry litter during drying process using response surface methodology. *Thermal Science and Engineering Progress*, *43*, 101958. https://doi.org/10.1016/j.tsep.2023.101958
18. Kim, S.M., Aung, T., & Kim, M.J. (2022). Optimization of germination conditions to enhance the antioxidant activity in chickpea (*Cicer arietimum* L.) using response surface methodology. *Korean Journal of Food Preservation*, *29*(4), 632-644.
19. Kumar, Y., Sharanagat, V.S., Singh, L., & Mani, S. (2020). Effect of germination and roasting on the proximate composition, total phenolics, and functional properties of black chickpea (*Cicer arietinum*). *Legume Science*, *2*(1), e20. https://doi.org/10.1002/leg3.20
20. Liu, Y., Xu, M., Wu, H., Jing, L., Gong, B., Gou, M., Zhao, K., & Li, W. (2018). The compositional, physicochemical and functional properties of germinated mung bean flour and its addition on quality of wheat flour noodle. *Journal of Food Science and Technology*, *55*(12), 5142-5152. https://doi.org/10.1007/s13197-018-3460-z
21. Meullenet, J.-F., Lyon, B.G., Carpenter, J.A., & Lyon, C.E. (1998). Relationship between sensory and instrumental texture profile attributes. *Journal of Sensory Studies*, *13*(1), 77-93. https://doi.org/10.1111/j.1745-459X.1998.tb00076.x

22. Nishinari, K., Fang, Y., & Rosenthal, A. (2019). Human oral processing and texture profile analysis parameters: Bridging the gap between the sensory evaluation and the instrumental measurements. *Journal of Texture Studies*, *50*(5), 369-380. https://doi.org/10.1111/jtxs.12404
23. Oghbaei, M., & Prakash, J. (2016). Effect of primary processing of cereals and legumes on its nutritional quality: A comprehensive review. *Cogent Food & Agriculture*, *2*(1), 1136015. https://doi.org/10.1080/23311932.2015.1136015
24. Ozturk, I., Sagdic, O., Tornuk, F., & Yetim, H. (2014). Effect of wheat sprout powder incorporation on lipid oxidation and physicochemical properties of beef patties. *International Journal of Food Science & Technology*, *49*(4), 1112-1121. https://doi.org/10.1111/ijfs.12407
25. Salehi, F. (2023). Effects of ultrasonic pretreatment and drying approaches on the drying kinetics and rehydration of sprouted mung beans. *Legume Science*, *5*(4), e211. https://doi.org/10.1002/leg3.211
26. Salehi, F., Amiri, M., & Ghazvineh, S. (2024). Effect of ultrasonic pretreatment on textural properties and sensory attributes of cooked faba beans. *Ultrasonics Sonochemistry*, *110*, 107040. https://doi.org/10.1016/j.ultsonch.2024.107040
27. Salehi, F., Ghazvineh, S., & Inanloodoghouz, M. (2023a). Effects of edible coatings and ultrasonic pretreatment on the phenolic content, antioxidant potential, drying rate, and rehydration ratio of sweet cherry. *Ultrasonics Sonochemistry*, *99*, 106565. https://doi.org/10.1016/j.ultsonch.2023.106565
28. Salehi, F., Razavi Kamran, H., & Goharpour, K. (2023b). Effects of ultrasound time, xanthan gum, and sucrose levels on the osmosis dehydration and appearance characteristics of grapefruit slices: process optimization using response surface methodology. *Ultrasonics Sonochemistry*, *98*, 106505. https://doi.org/10.1016/j.ultsonch.2023.106505
29. Serdaroglu, M. (2006). The characteristics of beef patties containing different levels of fat and oat flour. *International Journal of Food Science & Technology*, *41*(2), 147-153. https://doi.org/10.1111/j.1365-2621.2005.01041.x
30. Sofi, S.A., Rafiq, S., Singh, J., Mir, S.A., Sharma, S., Bakshi, P., McClements, D.J., Mousavi Khaneghah, A., & Dar, B.N. (2023). Impact of germination on structural, physicochemical, techno-functional, and digestion properties of desi chickpea (*Cicer arietinum* L.) flour. *Food Chemistry*, *405*, 135011. https://doi.org/10.1016/j.foodchem.2022.135011
31. Tian, B., Xie, B., Shi, J., Wu, J., Cai, Y., Xu, T., Xue, S., & Deng, Q. (2010). Physicochemical changes of oat seeds during germination. *Food Chemistry*, *119*(3), 1195-1200. https://doi.org/10.1016/j.foodchem.2009.08.035

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تأثیر زمان جوانه‌زدن نخود بر ویژگی‌های فیزیکوشیمیایی، بافتی، حسی و فنل کل فلافل تهیه شده از آرد نخود جوانه‌زده

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چکیده

فلافل یک محصول ارزان‌قیمت و مغذی است که حاوی مواد گیاهی مختلف، ویتامین، فیبرهای غذایی و ترکیبات فنلی است. هدف از این مطالعه بررسی تأثیر زمان جوانه زدن بر ویژگی‌های فیزیکوشیمیایی آرد نخود جوانه‌زده بود. همچنین اثرات زمان جوانه زدن بر ویژگی‌های فیزیکوشیمیایی و خصوصیات حسی فلافل تهیه شده از آرد نخود جوانه‌زده مورد بررسی قرار گرفت. یافته‌های این تحقیق نشان داد که فرآیند جوانه زدن به‌طور معنی‌داری مقدار فنل کل (از ۲۸۴/۱۷ به ۷۲۰/۹۸ میکروگرم اسید گالیک در گرم خشک)، ظرفیت آنتی‌اکسیدانی (از ۷۷/۵۵ در صد به ۹۳/۳۵ در صد) و قرمزی (از ۷/۶۵ به ۱۱/۳۹) آرد نخود را افزایش می‌دهد ($p<0.05$). در حالی‌که روشنایی (از ۷۰/۸۱ به ۵۷/۰۷) و زردی (از ۴۳/۷۱ به ۲۵/۶۲) آرد نخود به‌طور معنی‌داری کاهش یافت ($p<0.05$). محتوای فنل کل و ظرفیت آنتی‌اکسیدانی فلافل‌های تهیه شده از آرد نخود جوانه‌زده به مدت دو روز (۴۸ ساعت) به‌طور معنی‌داری بیشتر از فلافل تهیه شده از آرد نخود جوانه نزده بود ($p<0.05$). حجم نمونه‌های فلافل تهیه شده از آرد نخود جوانه نزده، جوانه‌زده به‌مدت یک روز و جوانه‌زده به‌مدت دو روز به‌ترتیب برابر ۱۸/۷۵، ۱۶/۶۰ و ۱۵/۴۰ سانتی‌متر مکعب بود. کمترین مقدار جذب روغن مربوط به نمونه تهیه شده از نخود جوانه‌زده به‌مدت دو روز بود ($p<0.05$). فرآیند جوانه زدن تأثیر معنی‌داری بر سفتی، انسجام و قابلیت جویدن فلافل‌ها نداشت ($p>0.05$). در مجموع، استفاده از آرد نخود جوانه‌زده به‌مدت یک روز (۲۴ ساعت) برای تولید فلافل به‌دلیل بهترین طعم، بیشترین امتیاز پذیرش کلی، محتوای بالای ترکیبات فنلی، ظرفیت آنتی‌اکسیدانی بالا و جذب کمتر روغن، توصیه می‌شود.

واژه‌های کلیدی: انسجام، جذب روغن، سفتی، ظرفیت آنتی‌اکسیدانی، فنل کل

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