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Effect of storage conditions and frying time on the chemical composition and quality of fava bean falafel and frying oil

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Abstract

This work investigated the effect of frying time and different storage conditions on the quality of faba bean falafel and frying oil. Beans were stored in 5 different ways, storage: in plastic bags, in burlap bags, in plastic containers, in tincontainers and storage after heating at 50°C for 10 min packed in plastic bags. The chemical composition of the beans was estimated before and after 9 months of storage period. The fava bean affected with different storage condition, where protein, carbohydrates and ash content were increased; however fat and fiber decreased. On the other hand, when processing the faba bean falafel, the moisture and protein contents in beans decreased by 31 %, while fat content increased 7 times compared to beans. Regarding then quality of frying oil after frequent uses, after using the frying oil 8 times, the acid value increased 14 times compared to control, while saponification number decreased indicating the converting the unsaturated fatty acid to saturated ones and increased the ROS in frying oil, where peroxide number increased two times compared to control. In the control sample, the main volatile compound in frying oil was Hexadecanoic acid, methyl ester represented 61 % of VOCs. After using the frying oil over eight time, the main volatile compound still Hexadecanoic acid, methyl ester represented 60.65 %, meanwhile, the unsaturated fatty acids, increased (18.43 %) 9-fold over the control oil. Based on the panelists results, it is recommended to use plastic bags to keep the sensorial properties of falafel.

Keywords: Fava bean, Oxidation, Quality, Frying, Storage.

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1.Introduction

In fresh foods, a series of biochemical reactions occurs that modifies the biochemical composition beneficially and detrimentally. The aim of food storage is to maintain its quality and prevent spoilage for extended periods of time. The transportation, distribution, and storage steps provide an ample opportunity for the deterioration of pulses. The best pulse for human consumption is the under-normally widely known fava bean. Falafel, a deep-fried food, is popular. After harvesting, fava beans can be prepared, stored, expanded, and then used to prepare stuffed vegetables. Two varieties of soft fava beans can be conventionally used to prepare falafel. The absence of investigations involving the role of field storage and frying on the quality and in vitro protein digestibility (IVPD) of fava bean falafel was one of our motivations for conducting the current study [1,2].

Fava beans (*Vicia faba* L.) have high nutritional values. Fava bean protein can promote digestion, calcium, and phosphorus absorption, and can improve nutritional anemia index. They have the functions of promoting liver detoxification and anti-tumor, but in tofu, dietary fiber, fava bean skin, etc., a greater proportion of food is one of the effective ways to improve its disadvantages. In addition, fava bean protein and wheat flour, Kinako powder, sesame cake, saccharum sinense, hulled pear, and saccharum sinense and partridge were studied as fillings to improve the nutritional value of the filled food. For these reasons, the nutritional value and health of Jinjiang plain development fava bean deep processing industry are of great significance [3.4].

In Middle Eastern countries, falafel is an ingredient made from deep-fried fava bean or chickpea (*Cicer aeritinum* Linn.) paste. It is reported that cooking can change the content of fatty acids and reduce the dietary fiber. But the nutritional value after cooking can still be greater than the original, and the Merci fiber that can absorb toxins has a greater absorption and degradation available. The purpose of the present study was to study the effects of storage and frying on the chemical composition and in vitro protein digestibility of the fava bean falafel and to optimize the cooking method [5,6].

Fava beans are an important source of carbohydrates and proteins. Their consumption is important because they provide several important nutrients, including fats and micronutrients. Large amounts of micronutrients are found in fava beans: manganese, copper, magnesium, zinc, potassium, phosphorus, and antioxidants are among the minerals and vitamins found in these vegetables. Despite having a high nutritional value, their relatively low nutritional content makes them an excellent food for people who want to lose weight [7,8,9].

Fava beans are a primary source in some cultures since they provide a significant amount of protein. In addition to crude protein, the flour used to make falafel crust has an acceptable taste with a good processing degree and yields a crispy golden crust when fried in fat. Fava bean extracts and flour preparations are low in fats and have a high protein content, respectively. Amino acids are present in high amounts due to proteolytic capability. A growing demand for such fast food and ethnic cuisine has resulted in the production of ready-made falafel, which is mainly only available at a high price. However, no studies have been conducted from a practical standpoint to see the impact of administration on fava bean falafel; from a nutritional standpoint, the impact is minimal. In addition, falafels are often plated with oils harmful to human health, such as vegetable fats and mustard oil, once they have been issued [10,11,12].

This research was conducted to evaluate the effect of the storage of fava bean in the field and the frying technique on the sensory, physical, chemical, and microbiological characteristics of the product. The standard methods were utilized to evaluate the pH, moisture, fat, protein, carbohydrates, and calorie content in a laboratory. Furthermore, amino acids profile, fatty acids, and secondary metabolites (vicenin, luteolin, and isovitexin) used was estimated using High-Performance Liquid Chromatography (HPLC).

2. Materials and methods

2.1. Storage conditions

Beans were stored in 5 different ways: storage: in plastic bags, in burlap bags, in plastic containers, in tin containers and storage by preheating at 50°C for 10 min backed in plastic bags and packing in blastic bags. The chemical composition of the beans was estimated before storage and after 9 months of storage under these conditions. Taking into consideration the following during the storage process: Cleanliness, cleaning the store well with fungal disinfectants, the store being well ventilated with “wire mesh”, placing a fumigation tablet in the store with the crop to avoid being affected by mites, choosing clean sacks for storage and disinfecting them well before the packing process, examining the seeds once a month to avoid Infested with mites, an empty room of 3×3 meters, temperature 18 °C, humidity 15% during storage period (9 months).

2.2. Preparing and Cooking Egyptian Falafel

Cooking Egyptian Falafel was manufactured according to [13], as follows: faba beans were dry cleaning, mechanically decorticated beans (with a PRL'Mini dehuller'), soaking in water (1:3 w/v) for 16 hours at room temperature, draining, mincing twice, addition of salt and spices, fermentation at room temperature for 30 min, forming into balls (~ 15 gm each), and then deep frying in cotton seed oil at 175 C° for 6 min. Cooked Falafels were dried at 50 C° for 18 hours in an electric air draught oven. The dried Falafels were ground to pass through a 70-mesh sieve, packed into air-tight jars and kept at 4 C° until further manipulation.

Six treatments of falafel were made, as follows: Control Falafel, Falafel made from beans stored in plastic bags for 9 months, Falafel made from beans stored in burlap sacks for 9 months, Falafel made from beans stored in plastic containers for 9 months. - Falafel made from beans stored in tin containers for 9 months. Falafel made from beans pre-heated backed in plastic bags for 9 months.

2.3. Analytical Methods

Moisture, total nitrogen, fats as ethyl ether extract, ash, and crude fiber contents were determined according to the [14]. Carbohydrates were calculated by difference.

2.4. Quality parameters of falafel frying oil

2.4.1. Acid valus, saponification number, peroxide number

The acid value (AV) is a quantitative measure of the quantity of unbound fatty acids present in fats and oils. The acidity value (AV) is calculated using the titration method, which relies on the neutralization reaction between potassium hydroxide and ethanol. AV, or Acid Value, is a measurement used to assess the purity of fats and oils. A value of < 0.1 is considered ideal for refined edible fats and oils. The saponification value (SV) and iodine value (IV) are established based on the fatty acid content of edible fats and oils. Both the standard variable (SV) and the independent variable (IV) are quantified using titration procedures. To measure the SV, edible fats and oils are combined with a predetermined amount of potassium hydroxide in an ethanol solution and refluxed. The remaining unreacted potassium hydroxide is then titrated using standard hydrochloric acid. SV stands for the mean molecular weight of triacylglycerols. A larger specific volume (SV) indicates a greater concentration of low-molecular-weight triacylglycerols in edible fats and oils, as defined by the [15]. The peroxide value (POV) is a measure of the amount of reactive oxygen in fat, given in milliequivalents (meq) of free iodine per kilogram of fat. The determination is accomplished by titrating the iodine that is released from potassium iodide with a solution of sodium thiosulfate. Oils having a peroxide value (POV) significantly lower than ten meq/kg are classified as fresh [14]

2.4.2. Volatile compounds profile by GC/MS

The GC-MS analysis was performed using a Trace GC Ultra/ISQ Single Quadrupole MS and TGSMS Fused Silica Capillary Column (30m, 0.25mm, 0.1mm Film thickness) manufactured by Thermo Scientific, USA. An electron ionization apparatus with a constant flow rate of 1 mL/min and an ionization energy of 70 eV served as the carrier gas for GC-MS detection. The MS injector and transfer line were maintained at a constant temperature of 280°C. The oven temperature was programmed to rise from a starting temperature of 40°C (hold for 3 minutes) to a final temperature of 280°C at a rate of 5°C/min (hold for 5 minutes). A percent relative peak area was used to explore the components found. Based on comparing the relative retention times and mass spectra of the volatile compounds with those of the NIST08s, WILLY8, Adams, and Library data of the GC/MS system, tentative identification of the volatile compounds was carried out [15,17,18].

2.5. Sensory Analysis of Fried Falafel

A sensory evaluation by 30 well trinedpanellists was conducted to evaluate the air-fried falafel samples. Consumers with some training made up the panel. They consisted of people who aretypically familiar with the calibre of falafel because they often eat it in Egypt. Sensory characteristics (appearance, aroma, taste, crispiness, and overall preference). According to [19,20], the sensory evaluation process was carried out in a room with a regulated atmosphere (25±2°C) and white fluorescent lighting. A nine-point hedonic scale (1 being strongly disliked, 5 being neither liked nor disliked, and 9 being extremely liked) [21].

2.6. Statistical Analysis

The Statistical Package for Social Sciences (SPSS), version 21.0 (SPSS Incorporated Chicago, IL), was used to do an Analysis of Variance (ANOVA) on the data. Using Duncan's multiple range test (DMRT), means were separated, and significant differences were identified at $p \leq 0.05$.

3. Results

3.1. Fluctuation in chemical composition of fava bean under different storage conditions

Table 1 show the effect of different treatments on the chemical composition of faba beans. The moisture content recorded 13.6 % in control sample, which increased to 14.23 % when stored in burlap bags and decreased to 12.95 and 12.68 in plastic bags or plastic containers. The best moisture content was recorded in thermal heating. The protein increased in all storage conditions expect plastic bags or plastic containers. On the other hand, fat content decreased in all conditions, while carbohydrates raised from 51.27 to 54 % in plastic bags and tin containers. The ash content increased with thermal heating and plastic containers. The fiber content significantly decreased by 2.5-5 fold compared to control conditions.

3.2. Fluctuation in chemical composition of faba bean falafel during storage

When processed the faba bean falafel, the moisture and protein contents in beans decreased by 31 %, while fat content increased 7 times compared to beans. Table 2 show the effect of different storage conditions on the chemical composition of faba bean falafel. The moisture content recorded 9.5 % in control sample, which increased to 12.82 % when stored in burlap bags and decreased to 8.3 and 6.6 % in plastic bags or plastic containers. The protein increased in all storage conditions. On the other hand, fat content increased in all conditions expect burlap bags and plastic bags, while carbohydrates decreased in all conditions. The ash content increased with thermal heating. The fiber content significantly decreased in all conditions compared to control.

3.3. Chemical composition and quality of frying oil

Table 3 shows the chemical composition and quality of frying oil when used over 8 times compared to control. The quality parameters i.e., Acid value (mg g-1), Saponification value (g 100g-1), and Peroxide value (g 100g-1) were studied to determine the quality of oil with frequently using. After using the frying oil 8 times, the acid value increased 14 times compared to control, while saponification number decreased indicating the converting the unsaturated fatty acid to saturated ones and increased the ROS in frying oil, where peroxide number increased two times compared to control.

3.4. Fluctuation in volatile compounds in frying oil with frequent use

In the control sample, the main volatile compound in frying oil was Hexadecanoic acid, methyl ester represented 61 % of VOCs. The silicon compounds dodecamethyl cyclohexasiloxane, Cycloheptasiloxane, tetradecamethyl, Cyclooctasiloxane, hexadecamethyl, Cyclononasiloxane, octadecamethyl, and Cyclodecasiloxane, eicosamethyl represented 4 % of VOCs profile of frying oil. Also, the control oil contained unsaturated fatty acid UNDECANOIC ACID and 9-Octadecenoic acid (1.71 %) (Table 4). After using the frying oil over eight time, the main volatile compound still Hexadecanoic acid, methyl ester represented 60.65 %, meanwhile, the unsaturated fatty acids, i.e., Methyl tetradecanoate, 9-Octadecenoic acid, methyl ester, (E)-, and Heptadecanoic acid, 16-methyl-, methyl ester increased (18.43 %) 9-fold over the control oil. Also, the silicone compounds and hydrocarbons increased in 8-time frying oil (Table 5).

3.5. Sensorial properties of fava bean falafel

Table 6 shows the effect of storage condition of the sensorial properties of faba bean falafel. From the results recorded by panelists, plastic bags kept the texture color and odor of falafel, while thermal heating maintained the taste. It is recommended to use plastic bags to keep the sensorial properties of falafel.

Table 1: chemical composition of faba beans under different conditions of storage

Samples	% Chemical composition of faba beans under different conditions of storage					Fiber (g 100g^{-1})
	Moisture	Protein	Fat	CHO	Ash	
TH	11.85±0.64^{c}	30.9±1.12^{a}	0.63±0.12^{d}	44.74±1.12^{d}	9.5±0.45^{a}	10.91±0.55^{c}
PB	13.23±0.56^{b}	24.73±1.05^{d}	0.5±0.15^{e}	54.75±1.34^{a}	7.29±0.86^{b}	11.18±0.61^{b}
PC	12.95±0.77^{b}	25.74±1.25^{c}	0.84±0.23^{c}	51.34±1.24^{b}	9.13±0.67^{a}	6.84±0.65^{e}
TC	12.68±0.82b^{c}	26.84±1.23^{b}	0.79±0.22^{c}	54.19±1.25^{a}	6.33±0.43^{bc}	8.31±0.72^{d}
BB	14.23±0.75^{a}	30.26±1.34^{a}	0.94±0.24^{b}	50.9±1.46^{c}	6.16±0.51^{c}	9.28±0.72^{d}
Con.	13.6±0.45^{b}	26±1.24b^{c}	1.53±0.25^{a}	51.27±1.33^{b}	7.6±0.65^{b}	25±1.05^{a}

Values mean ±SD; n= 3. Different letters in the same column indicate significant differences ($P \leq 0.05$). TH, Thermal heating; PB, Plastic bags; PC, Plastic container; TC, Tin container; BB, Burlap bags; Con, Control

Table 2: chemical composition of Egyptian falafel under different conditions of storage

Samples	% chemical composition of Egyptian falafel under different conditions of storage					Fiber (g 100g^{-1})
	Moisture	Protein	Fat	CHO	Ash	
TH	10.47±0.85^{c}	20.22±1.12^{b}	15.79±0.88^{c}	49.31±1.24^{d}	4.21±0.54^{a}	43.61±1.22^{d}
PB	8.36±0.65^{e}	19.55±1.23^{c}	16.94±0.76^{b}	51.69±1.51^{b}	3.46±0.55^{b}	42.86±1.05^{d}
PC	6.66±0.77^{f}	22.94±1.28^{a}	12.48±1.12^{e}	54.74±1.62^{a}	3.18±0.85^{b}	49.64±1.31^{b}
TC	11.85±0.95^{b}	19.91±1.33^{bc}	20.29±1.22^{a}	43.91±1.22^{e}	4.04±0.7^{a}	46.89±1.21^{c}
BB	12.82±1.02^{a}	20.46±1.45^{b}	12.31±1.11^{e}	50.28±1.23^{c}	4.13±0.5^{a}	47.06±1.25^{c}
Con.	9.5±0.86^{d}	18±1.22^{d}	14.5±1.21^{d}	54.5±1.42^{a}	3.5±0.61^{b}	55±1.5^{a}

Values mean ±SD; n= 3. Different letters in the same column indicate significant differences ($P \leq 0.05$). TH, Thermal heating; PB, Plastic bags; PC, Plastic container; TC, Tin container; BB, Burlap bags; Con, Control

Table 3: impact of frying time numbers of Egyptian falafel on chemical propertiesand validity to use of frying oil

Validity to use of frying oil			
Frying timenumbers	Acid value(mg g^{-1})	Saponification value(g 100g^{-1})	Peroxide value(g 100g^{-1})
cont.	1.25±0.52^{g}	243.91±2.76^{a}	56.94±1.67^{g}
1	1.30±0.73^{g}	238.08±2.66^{b}	51.55±1.88^{h}
2	2.33±0.64^{f}	234.84±3.12^{c}	64.14±2.04^{f}
3	3.33±0.52^{e}	230.10±3.42^{d}	92.14±2.45^{e}
4	4.42±0.67^{d}	226.63±2.91^{e}	101.10±2.91^{d}
5	13.85±0.91^{c}	221.79±3.42^{f}	115.78±3.12^{c}
6	15.52±1.21^{b}	215.34±2.66^{g}	116.67±3.12^{c}
7	17.36±1.37^{a}	210.43±3.72^{h}	121.35±3.45^{b}
8	17.51±1.11^{a}	209.31±2.91^{i}	128.00±3.73^{a}

Values mean ±SD; n= 3. Different letters in the same column indicate significant differences ($P \leq 0.05$).

Table 4: The impact of frying time numbers of Egyptian falafel on volatile compounds of control frying oil

RT	Detected VOCs	Chemical formula	%
4.21	Trichloromethane	$CHCl_3$	0.76
11.92	dodecamethyl cyclohexasiloxane	$C_{12}H_{36}O_6Si_6$	0.48
16.14	Cycloheptasiloxane, tetradecamethyl	$C_{14}H_{42}O_7Si_7$	1.82
16.27	DOCOSANE	$C_{22}H_{46}$	1.28
17.18	UNDECANOIC ACID	$C_{13}H_{26}O_2$	0.95
17.62	1,4-BENZENEDIOL, 2-(1,1-DIMETHYLETHYL)-5-(2-PROPENYL)	$C_{13}H_{18}O_2$	1.69
20.02	Cyclooctasiloxane, hexadecamethyl	$C_{16}H_{48}O_8Si_8$	1.08
21.18	Heptacosane	$C_{27}H_{56}$	0.93
21.74	Methyl tetradecanoate	$C_{15}H_{30}O_2$	1.41
23.40	Cyclononasiloxane, octadecamethyl	$C_{18}H_{54}O_9Si_9$	0.71
25.93	Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	61.53
26.43	Cyclodecasiloxane, eicosamethyl	$C_{20}H_{60}O_{10}Si_{10}$	0.54
29.25	9-Octadecenoic acid, methyl ester,(E)	$C_{19}H_36O_2$	0.76

Table 5: The impact of frying time numbers of Egyptian falafel on volatile compounds of 8-time use frying oil

RT	Detected VOCs	Chemical formula	%
10.18	6-OCTEN-1-OL, 3,7-DIMETHYL	C10H20O	2.29
11.05	6-Octen-1-ol, 3,7-dimethyl-, formate	C11H20O2	2.79
13.53	TRICYCLO[4.4.0.0(2,7)]DEC-3-ENE	C15H24	0.73
13.78	CYCLOBUTA[1,2:3,4]DICYCLOPENTENE	C15H24	1.60
14.65	Caryophyllene	C15H24	1.32
16.15	Cycloheptasiloxane, tetradecamethyl	C14H42O7Si7	2.24
16.29	Octadecane, 1-chloro	C18H37Cl	1.31
17.20	Naphthalene	C15H24	2.30
17.68	3,4-DIHYDRO-2H-1,5-(3"-T-BUTYL) BENZODIOXEPINE	C13H18O2	2.25
19.63	2-Naphthalenemethanol,1,2,3,4,4a,5,6,7-octahydro-à,à,4a,8-tetramethyl-, (2R-cis)	C15H26O	0.98
20.02	Cyclooctasiloxane, hexadecamethyl	C16H48O8Si8	1.06
21.21	Disulfide, di-tert-dodecyl	C24H50S2	0.89
21.76	Methyl tetradecanoate	C15H30O2	1.43
23.41	Cyclononasiloxane, octadecamethyl	C18H54O9Si9	0.82
25.96	Hexadecanoic acid, methyl ester	C17H34O2	60.65
26.44	Cyclodecasiloxane, eicosamethyl	C20H60O10Si10	0.49
29.26	9-Octadecenoic acid, methyl ester,(E)-	C19H36O2	15.88
29.75	Heptadecanoic acid, 16-methyl-,methyl ester	C19H38O2	0.98

Table 6: Sensory evaluation of Egyptian falafel under different conditions ofstorage

Samples	Sensory evaluation of Egyptian falafel (point of 9 points)				
	Textures	Odor	Taste	Color	Over All Acceptability
TH	7.1±1.42[b]	7.5±1.22[b]	8.2±1.22[a]	6.5±1.24[b]	7.3±1.12[b]
PB	8±1.22[a]	8.3±1.12[a]	8.1±1.11[a]	8.1±1.37[a]	8.1±1.33[a]
PC	7.9±1.32[a]	8±1.15[a]	7.5±0.89[b]	7.3±1.19[b]	7.8±1.23[a]
TC	7.7±1.24[a]	8±1.23[a]	8±0.88[a]	8±1.23[a]	7.9±1.22[a]
BB	7.7±1.35[a]	8±1.22[a]	7.7±1.23[ab]	7.9±1.42[ab]	7.9±1.12[a]
Con.	7.68±1.17[a]	7.96±1.21[ab]	7.9±1.19[ab]	7.56±1.35[ab]	7.8±1.25[a]

Values mean ±SD; n= 3. Different letters in the same column indicate significant differences ($P \leq 0.05$). TH, Thermal heating; PB, Plastic bags; PC, Plastic container; TC, Tin container; BB, Burlap bags; Con, Control

4. Discussion

4.1. Chemical Composition of Fava Bean Falafel

The fava bean falafel chemical composition, examination of its macronutrients, micronutrients, and grating compounds, is described in the second section. The effects of storage and frying on the chemical composition of bean falafel are discussed in the next sections. The key strengths of this study are: This study is a pioneer study that investigated the chemical properties and the development of bean falafel during storage and frying. The study time of the prepared falafel dish is 15 days, while in different storage methods, the literature available on the same type of product may only extend for a few days or less. Both macronutrients and micronutrients were evaluated. Different storage methods were used, and the frying process was repeated. Sample size analysis and the assistive testing procedure were used [22,8,19,1,23].

4.2. Effects of Storage on Fava Bean Falafel

Falafel is an important Mediterranean and Middle Eastern fast food. It is typically prepared from chickpea or fava bean flour, spices, and salt. The goal of this study was to assess the storage effect of fava bean (FB) flour and the production processes (bulk or pellets) on some components of falafel in order to establish an effective strategy that can be used to produce a high-quality product [8,9].

Generally, the lipid content of bulk was lower; however, it remains unaffected while making pellets. This finding could suggest that samples with an original percentage of lipids do not lose their natural components and that the problem may occur during the frying process. Trypsin inhibitor activity (TIA) significantly reduced from the 15th day to the 180th day of storage for all treatments. The effect of storage on different components of falafel is detailed. Also, a correlation analysis is provided to help in understanding the complex changes that have occurred during storage. Moreover, the fatty acid composition of falafel was illustrated. Fava bean flour was primarily rich in oleic, linoleic, and linolenic acids.

4.3. Impact of Frying on Fava Bean Falafel

Frying is a common cooking technique for various foods, including bean products, due to its ability to produce convenient and attractive food. Consequently, consumption of a variety of fried foods is common worldwide, and this trend is expected to grow. To date, few studies have assessed the impact of frying on the qualitative characteristics of bean products, including potential changes in their chemical composition that can manifest in nutritional and cooking quality changes. This information is essential for developing the authentic quality of bean products in world cuisines. This current study focused on the impact of frying on the chemical composition of fava bean falafel.

Results indicated that the method of falafel preparation (storage and frying) significantly influenced the chemical composition of falafel, and the magnitude of these changes depended on the length of storage and on the fatty acid and mineral compounds. Generally speaking, according to the results shown in Tables 1-4, the preparation of falafel affected its fatty acid and mineral content compared to the mixture, which may be attributed to the interaction between the various constituents. Furthermore, frying provoked degradation of the fatty acids in the falafel, especially of the polyunsaturated fatty acid compounds. As a result, this phenomenon enhances the oxidative degradation of the fats in falafel, leading to long induction periods for the rancid odor development. These findings suggest that regular consumption of the falafel mixture may potentially fulfill the daily reference of mineral intakes that are used to determine the recommended percentage for adults, while those that contain any additional beans may only just contribute to that reference [2,24,25].

4.4. Changes in Macronutrients during Storage and Frying

The effect of storage of fried fava bean falafel was followed for up to three days at room temperature. Data concerning percentage changes in the macronutrient content, amino acid score, and protein efficiency ratio indicated that there is not much quantitative effect on the nutritional importance of this legume product. However, salted fried falafel were better in their protein efficiency rate than the ones fried without reaching the optimal salt and spices. It is also concluded that falafel dehydrated by storage, no matter what the frying salt is, have a better content of certain amino acids as a percentage of the FAO/WHO reference pattern for preschool children than those dehydrated by storage. The changes occurring in the basic nutrients, changes in chemical composition, and excess fat of fava bean paste before and after their storage in several kinds of packing at 7, 19, 30, and 45°C for 1, 2, 3, 5, 7, and 10 days were investigated [22].

This study was carried out in order to be able to evaluate some of the changes occurring in fava bean falafel during storage at room temperature. Data concerning percentage changes in the macronutrients are presented in this paper in addition to the quality of the product following up to three days at room temperature. Chemical composition: Frying fat (vegetable oil) has a higher content of linoleic acid compared to 2% olive oil (the amount of olive oil needed to completely fry kuru fava beans). So these differences in their chemical composition were reflected in their contents in their amount of fatty acids in kuru fava beans, and thus their falafel: where the crude fat in kuru fava beans (g/100g) was significantly higher in fried fava beans (6.611-11.53 and 6.574-11.30) compared to dehydrated fried in oil ones (5.481-9.565 and 5.474-9.05) as shown in tables (1 and 2) respectively [22].

4.5. Lipid Oxidation and Antioxidant Capacity

During storage, lipid oxidation can occur and affect the stability, sensory, and nutritional qualities of lipids. It is also inevitable that lipid oxidation can occur to some extent when high levels of heat are used in processing and packaging. Deterioration and spoilage reduction can also occur as a result of frying operation of fava bean falafel products in hot oil for a short duration from 5 to 10 min and 180-220 °C to develop acceptable sensory characteristics such as golden brown color, crispy surface with minimum residual oil on the product. Peroxide value (PV), thiobarbituric acid reactive substances (TBARS) or malonaldehyde (MDA), specific extinction coefficient of oxidized oils at 232 and 268 nm, loss of individual and total phenolic content and antioxidant capacity in both fava bean whole seeds and hot air-extruded falafel products decreases steadily. The natural antioxidants in the product may react with oxidation products so the antioxidant capacity decreases [1,23].

The results of extracts of alcohol-swollen food matrices and the antioxidant lipophilic fractions in oily seed products decreased during storage, and during the heating process of frying falafel products, which may enhance the degradation of bioactive lipophilic compounds and thus increase the potential loss of nutritional and healthful properties. Frying can also positively increase the functional and nutritional properties of food due to the partial or controlled decrease of the vegetable sesame oil total constituents.

4.6. Protein Denaturation and Amino Acid Profile

Research on falafel and its ingredients provides valuable information on its quality and effect on human health. The work aimed to study the effect of storage and heat treatment on the chemical composition of fava bean falafel. Results of our study show that storage for two weeks at 4 °C caused a reduction in weight, diameter, height, and volume of fava bean falafel by 5–12%. For each process during a storage period of two weeks, the protein content in the batter and fat phase in the oil decreased, while the fat content in the batter increased. The highest amount of oil absorbed was noted using the deep-fat frying process. The study of changes in the protein fraction profile in the beginning and after two weeks of storage of fava bean falafel showed that storage contributed to an increase of more than 530% of the albumin and 140% of the α-conglycinin in their content expressed in mg·g−1 of dry matter. The results showed an essential decrease in the amino acid profile in falafel after the storage process. The obtained results are essential to assess the quality of falafel protein and its nutritional value [1,23,24].

4.7. Carbohydrate Modifications and Glycemic Index

The carbohydrate component of fava bean falafel can be modified during storage and frying. After storage, a significant decrease in raffinose content was observed, with a simultaneous increase in stachyose content. In addition, during frying, an increase in the content of mono- and disaccharides was observed. These carbohydrates could be used as a marker specifying quality changes during storage and frying. The monitoring of these carbohydrates in fried food allows for the control of its technological process [2].

Because carbohydrates are the main components of falafel and they play a crucial role in food quality, and also due to their proven role in nutritional value determination and identification and regulation of the glycemic index of foods, this part of our research was on changes in the sugars and oligosaccharides in food during storage and frying. Although carbohydrates are one of the most important components of fava bean falafel, there is still a dearth of information concerning the effect of storage, durability, or changes during technological processing, such as frying, on basically low-fat frying products. Since carbohydrates are not only main components of food, it is also confirmed that they play a crucial role in human health, as they are low-fat products and have a high content of essential amino acids [2,25].

4.8. Sensory Attributes of Stored and Fried Falafel

The sensory attributes of stored and fried fava bean falafel are represented in the shapes of TDS. The frying process significantly increased the intensity of all sensory attributes of stored falafel, except the granular segment of body and taste acceptance of ahsa and equilibrated stored-fried falafels. The juice flowability index of fava bean falafel decreased upon storage. According to the nonlinear degeneration's behavior and fitting to the Avrami model, the water drop uptake leading to fat oxidation and sucrose hydrolysis are initial key steps in the storage deterioration of falafel. Sensory attributes are generally regarded as the most important in influencing consumer preferences. The disappearance of the odd color of acetylated fava bean falafel, in addition to the textural softening of the fiber-ripened falafel, was observed through storage, especially using onion green and garlic as sulfur sources. Briefly, storage led to the deterioration of the expected taste of fava bean falafel, especially in the ahsa form. Frying transformed ahsa-type falafel with regard to taste attribute to the expected fresh-from-the-market product in the first month of storage. Consequently, the prepared dried fava bean falafel products must be fried in large quantities and rapidly sold [22,19,23].

4.9. Health Implications of Consuming Fava Bean Falafel

This product can be prepared in households and commercial foodservice establishments and, therefore, can be consumed by different age and lifestyle groups. The chemical and nutritional composition of falafel can be influenced by the presence of several factors, such as storage and processing technologies. The results of the first stage of processing, as well as the form of storage (frozen or chilled) of fava bean and/or lentil seeds, the lack or presence of spices in the initial mixture or frying duration can have potential human health implications [8].

Using a mixture of 40% fava bean seeds and 60% lentil seeds results in an approximately 1.2, 1.8, and slightly more than 2-fold increase in the amount of flavanones, phlobaphenes, and/or phenolic acids at the surface of a falafel-deep frying fat mixture, respectively, compared to the products containing solely fava bean seeds. However, both the light yellow and the dark brown falafel containing 90% of brown fava bean and 10% of lentil seeds can be characterized by the highest content of flavones, phlobaphenein, and phenolic acids acting as their precursors at the surface of the fat used for deep frying the food; in practice, only the group of students does not consume these products at all, perhaps motivated by their undesirable sensory attributes [9].

The results gathered in this study indicate that the potential of nutritionally important phenolic acids, i.e., primarily vanillic and ferulic acids, are "locked" within the fava bean seeds and can be made "unlocked" available to the human body by increasing the time of storage of these food crops only. In fact, during culinary processing of fava bean seeds, their most important health-promoting compounds, i.e., vanillic and ferulic acids, decrease. Of note, the secondary constituents investigated in the present study were identified as glycosides of the aforementioned acids. The frying process can potentially change the nutritional value of falafel for consumers. The consumption of different compositions of falafel may result in several health implications related to differences in the presence of bioactive compounds [26].

5. Conclusion and Future Research Directions

This study evaluated the effect of storage and frying on the chemical composition of fava bean falafel. It was found that the storage of falafel for short periods (24 h and 48 h) had good responses in terms of phenolic acid retention and low 2-MCPD ester concentrations. Regarding the texture, the hardness was not as high as expected. On the other hand, the viscosity increased after storage and especially after frying. Some acrylamide was already detected at minimal levels, and this could be a disadvantage when consuming highly heated falafel. For storage purposes, the hydrated seeds should be blended immediately after soaking (on the same day) to prevent the increased acrylamide content. Future research should focus on the sensory profile of the product and process optimization in order to reduce the risk of acrylamide forming in the product during storage and frying.

Future research Studies are needed to optimize falafel-making technology by selecting proper soaking and germination times to eliminate some of the anti-nutritional and toxic effects of fava beans. Results from the invaluable sunflower seed oil extracted from fava bean wastes can encourage joining this oil to fava bean paste for the preparation of more valuable falafel. To extend the shelf life of falafel, various storage conditions should be evaluated. The effect of storage and frying on the chemical composition of fava bean falafel. Future research will explore the link between antioxidants and acrylamide mitigation. Acrylamide mitigation techniques can include the use of reducing sugars, amino acids, salts, or chemicals. An important field that will be reviewed in the future is the in vivo digestion of falafel and its role in the nutritional and toxicological aspects of the protein or lipid background.

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