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Effect of Using Broccoli Florets on Chemical and Sensory Characteristics of Cup Cake and Green Burger (Falafel)

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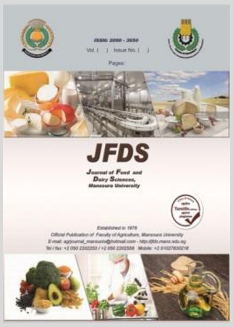

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ABSTRACT

This study aimed to determine the chemical composition and some of the bioactive ingredients and antioxidants present in two varieties of broccoli and knowing the possibility of making cupcakes and falafel supplemented with broccoli powder and also sensory evaluation of them and measuring nutritional content of these products. Broccoli contains large amounts of fiber, minerals and important bioactive components, but its use in food products is still limited despite its usefulness. Three samples of each product, whether cupcakes or falafel fortified with different percentages of broccoli powder (5%,10%,15%) were prepared by replacing an equivalent weight of white flour or falafel dough with those percentages of broccoli powder. And the sensory evolution and chemical composition of control cupcakes and falafel were evaluated. Cupcakes and Falafel supplemented with 5% broccoli powder was more acceptable to the consumer than other samples, where the average sensory scores of supplemented cupcakes were 5% of broccoli in terms of appearance (٨.١2±0.15), color (٨.٢١±0.12), flavor (8.٠3±0.17), taste (٧.٦٢±0.19), texture (8.06±0.16) and overall appearance (7.43± 0.13), while falafel supplemented with 5% of broccoli powder had high sensory evolution, where appearance, color, flavor, taste, texture, crunch and overall acceptance recorded that (9.10 ±0.15), (9.10±0.7), (8.70±0.19), (8.53±0.27), (8.83±0.24), (8.57±0.26) and (8.67 ± 0.14) respectively. The chemical composition of both cupcakes and falafel fortified with broccoli powder also showed a rise in protein and fiber in cupcakes supplemented by 15% of broccoli, and the fiber and fat contents increased in falafel as the percentage of fortification with broccoli powder increased.

Keywords: broccoli powder, cupcake, falafel, nutritional content, sensory evolution.

INTRODUCTION

A healthy diet is known to positively affect an individual's quality of life. The food sector faces the challenge of creating new food products with unique health-promoting qualities. Consumers' interest in nutrition, rising health care expenditures, an aging population, and advances in food technology have led to the development of such goods (Lebesi and Tzia, 2011). According to former studies, incorporating functional food ingredients into daily meals may have good health consequences (Xu *et al*., 2017). Research and trends in healthy eating have evolved around functional natural food additives such as those that have antioxidant activity without causing negative side effects unlike synthetic compounds (Abdel-Mawgoud and Stephanopoulos, 2018; Bandyopadhyay *et al*., 2014).

In recent years there has been great development in fried meals as they are very popular all over the world (Heredia *et al*., 2014). On the other hand, people of all ages can eat fried foods. Fried foods are renowned for being delicious and crunchy (AbdRahman *et al*., 2017; Yu *et al*., 2020). Many fried foods require vegetables as their main ingredient, and among those foods is falafel, which is considered one of the most important foods in the Middle East, especially in the State of Egypt, and it has a large nutritional value Ismail and (Kucukoner, 2017; Ayat, 2016). There are many names that are given to it because of the different location. "Ta'amiyya" is the name given to it in Egypt and Sudan, and it is small fried balls made of faba beans and / or chickpeas (Abdullah, 2015) and cooked in hot oil in the form of tablets after being soaked in water for some time, ground and kneaded with spices (Katz and Gonzalez, 2002). In low-income families, "Ta'amiyya" is considered a meal that is eaten for breakfast or dinner frequently due to its low cost, continuous availability and distinctive flavor (Abdulla and Amr, 2003).

"snackers", which are ready-to-eat meals that are frequently served in small modules due to behavioral changes in eating habits. Donuts, muffins, cupcakes, and cookies are a few examples of these goods (Zouari *et al*., 2016). The basic method of cake making is to combine flour, eggs, yeast and other ingredients and flavors can also be added. There is a type of cake called cupcake that is very popular in all age groups especially by children because of its attractive properties and recipes. One of the advantages of these products is the technological possibility to add additional components and also have a long shelf life. But these products contain a large amount of fat, sugars and calories, one useful strategy to change the nutritional profile of cupcakes is to add ingredients and by-products such as fruits and vegetables that contain high percentages of minerals, vitamins and fiber (Coutinho *et al*., 2021).

A large variety of vegetables including broccoli belong to genus Brassica (family brassicaceae or cruciferae). Broccoli (*Brassica oleracea L. var. Italica*) is believed to have originated in the Eastern Mediterranean region and was brought to Europe in mediaeval times (Latté *et al*., 2011; Gray and Econ, 1982). The name for broccoli comes from the Latin word "brachium" (brocco in modern Italian) meaning branch and indicates to the repeated sprouts that make up the head (Nooprom, Santipracha,

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2014). Among the important benefits of cruciferous vegetables are their positive effects on reducing diabetes, inflammation, cardiovascular health, eye disorders, cancer, and neurodegenerative disorders. For cancer cell lines it has been confirmed that cruciferous vegetables are able to inhibit activities them (Boivin *et al*., 2009; Tilg, 2015). This happens because of the presence of well-known antioxidants such as glucosinolates, tocopherols, ascorbic acid, glucosinolates and phenolics in these plants (De Pascale *et al*., 2007).

Through science and industry, new ready-to-eat improved products have been produced in response to the growing demand for nutritious snacks by consumers, so customer acceptance of the product is just as important as the health benefits and technological quality of the product. Consumers may not tolerate the unique taste, smell and color of these vegetables, so it is important to make assessments of the physical properties and sensory tests of the products that broccoli is incorporated into (Chevilly *et al*., 2023; Hong *et al*., 2022). Due to the important compounds present in broccoli, new functional foods depending on or enhanced with broccoli have been created (Dominguez-Perles et al., 2011; Zhang et al., 2020; Marchioni *et al*., 2021; Sánchez-Bravo *et al*., 2023).

So, the main goal of such research is to study the possibility to utilize two types of broccoli florets cultivated in Egypt and produce some high quality/nutritional and acceptable food products such as cupcakes and falafel.

MATERIALS AND METHODS

Materials

Raw materials:

Two types of fresh Broccoli (*Brassica oleracea* var. *italica* 'Naxos F1' and *Brassica oleracea* var. *italica* 'Parthenon F1') were collected from the farm of the Faculty of Agriculture, Mansoura University.

White Flour, Eggs, milk, Oil, Sugar, Salt, Baking powder, Baked soda, Dehulled faba beans, Onion, parsley, Coriandrum and Dill were obtained from local market in Mansoura city.

Chemicals and reagents

All chemicals were purchased from El-Gomhouria Company for Chemicals and Drugs, Mansoura, Egypt.

Methods

Preparation of dried broccoli powder:

Broccoli florets and stalks samples were cleaned under running water and sliced into small pieces. Samples are dried in the oven on a tray and temperature is controlled up to 50℃ for 2 days and then extinguished. Dried samples are cooled for an hour and were grinding and then sieving and bolted for analysis.

Chemical composition of broccoli and produced cupcakes and falafel samples:

Proximate analysis was carried out on raw material and produced cupcakes and falafel samples. Fat, ash and moisture contents were determined according to the method (AOAC, 2005). Protein and fiber content were measured according to the method described in (AOAC, 2019). Carbohydrates content was calculated on dry basis by difference.

Minerals (Fe, Mn, Zn and Cu) were determined out at atomic absorption lab, unit of genetic engineering and biotechnology, Mansoura University, Egypt. Minerals were analyzed using an Atomic Absorption Spectrophotometer on a Buck Scientific Accuses 211 series, USA by an air /acetylene flame system according to the method of (Allen *et al*., 1974). Meanwhile, P, K, Na and Ca were determined out at Central labs, faculty of Agriculture, Mansoura University, Egypt. Sodium and potassium was determined using flame photometer according to Hesse (1971). Calcium was determined using atomic absorption (Perkin-Elmer 2380) according to Cottenie *et al*. (1982). Phosphorous was determined calorimetrically as described by Keeney and Nelson (1982).

Fatty acids profile of extracted broccoli oil was analyzed out at National Research Centre, Cairo, Egypt. Preparation of fatty acid methyl ester (FAME) was carried out according to Murcia *et al*. (1992).

Amino acids pattern of dried as well as defatted broccoli samples was analyzed out at National Research Centre, Cairo, Egypt using the method described by AOAC (1990).

Total Flavonoids and total phenolic content (TPC) were performed according to Singleton *et al*. (1965) at Food Safety & Quality Control Laboratory, Faculty of Agriculture, Cairo University, Cairo, Egypt.

The free radical scavenging capacity of Broccoli methanolic extracts was determined out at Food Safety & Quality Control Laboratory, Faculty of Agriculture, Cairo University, Cairo, Egypt. Using DPPH assay (Brand-williams *et al*., 1995).

Preparation of cupcakes fortified with broccoli powder:

Cupcakes were made using a slightly modified version of the (Coutinho *et al*., 2021) procedure. Using a home mixer, the cupcake was made by combining white flour, baking powder, oil, eggs, milk, and salt until everything was well combined. The following amounts of broccoli florets powder were added to cupcakes: 0%, 5%, 10%, and 15% (w/w) control. By substituting a quantity of white flour in the cupcake's original recipe with different proportions of broccoli. The batter was poured into circular metal molds greased with oil that measured 8.5 cm in diameter at the top, 5 cm at the bottom, and 2 cm in height. The compositions were baked for 30 minutes in an oven that had been preheated to 250°C. They were then allowed to rest until they reached room temperature, which is 22°C. Table (A) listed every ingredient that was used to make the cupcakes.

Table A. Percentage composition of control and fortified cupcakes with broccoli powder.

Constituents(g)	Control	5% broccoli	10%broccoli	15%broccoli
White Flour	30	28.5	27	25.5
Broccoli powder	-	1.5	3	4.5
Eggs	8	8	8	8
milk	15	15	15	15
Oil	8.5	8.5	8.5	8.5
Sugar	3	3	3	3
Baking powder	0.5	0.5	0.5	0.5

Broccoli incorporated into cupcakes by replacing an equivalent amount of white flour in the standard formulation (control–0%, 5%B, 10%B, 15%B (w/w).

Preparation of falafel fortified with broccoli powder:

Falafel was prepared according to the method described by Mahfouz *et al*. (2019) with some modifications. Broccoli was incorporated into a dough of falafel in the following percentages: 5% ,10%, 15 % (w/w). by replacing an equivalent amount of falafel dough in the standard formulation of falafel. After that, homogenous balls (55 g each) can be formed and cooked in a mixture of sunflower oil for 4 minutes at 170°C. Table (B) listed every ingredient that was used to make the falafel.

Table B. Percentage composition of control and fortified falafel with broccoli powder.

Constituents (g)	Control	5% broccoli	10% broccoli	15% broccoli
Falafel dough	40	38	36	34
Broccoli powder	-	2	4	6
Salt	0.3	0.3	0.3	0.3
baked soda	0.2	0.2	0.2	0.2
Oil	10	10	10	10

Broccoli incorporated into green burger by replacing an equivalent amount of falafel dough in the standard formulation (control–0%,5%B,10%B,15%B (w/w).

Sensory evaluation of cupcake samples:

A sensory evaluation of cupcakes was conducted as previously described in Krupa – Kozak *et al.* (2012) with some modifications. Briefly, 30 panelists (staff members and graduate students of Food Industry Department, Faculty of Agriculture, Mansoura University) evaluated cupcakes according to a hedonic scale. Each panelist was asked to rate the experimental cupcakes for overall quality on a 9 – point hedonic scale (0 – dislike, 9 – like) based on color, flavor, taste, appearance, texture and overall acceptability. The results are presented as mean values for each sample. The scores were grouped as follows: dislike (1-4), neutral (5), and like (6-9).

Sensory evaluation of falafel samples:

The sensory characteristics of the samples were evaluated according to Abd-Elhak and Hassan (2024) with some modifications by 30 panelists from staff, employees and students of Faculty of Agriculture, Mansoura University. Parameters were taste, color, appearance, flavor, crispy, texture and the overall acceptability which was determined as the total mean score of all the sensory parameters.

Statistical analysis:

Data analyzed by SPSS version 17 statistical packages (2008) (SPSS Inc, Chicago, IL). Data are expressed as mean ± Standard Deviation (mean ± SD). One way analysis of variance (F-test) used for comparison of the mean of more than two groups followed by Duncan's test at $p \leq 0.05$ level of significance.

RESULTS AND DISCUSSION

Chemical composition of studied broccoli samples:

Data in Table (1) showed chemical composition (ash, moisture, fibers, fat, protein and carbohydrates) of studied broccoli samples.

From obtained data, there are no significant differences in moisture and ash content between dried samples. Protein levels are significantly higher in dried sample 1 which recorded 28.77±0.58%, compared to dried sample 2. Significant increase was observed in fiber and fat contents in dried sample1 compared to dried sample2, the mean values of fiber were ranged from 42.94±0.58% to 39.54±0.58%, and the mean values of fat were ranged from 0.7±0.06% to 0.95±0.01%. Dried sample 2 showed the highest carbohydrate content compared to dried sample 1 reaching up to 26.59±0.58%.

Table 1. The chemical composition of studied broccoli samples:

Components% / Samples	Moisture	Protein	Fibers	Fat	Ash	Carbohydrate
Dried sample 1	15.34^{a}±0.58	28.77^{a}±0.58	42.94^{a}±0.58	0.95^{a}±0.01	7.67^{a}±0.58	19.67^{b}±0.01
Dried sample 2	13.83^{a}±0.58	25.46^{b}±0.58	39.54^{b}±0.58	0.7^{b}±.06	7.71^{a}±0.58	26.59^{a}±0.58
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

Values are expressed as means ± SE.
Means with the different letter superscripts in the same column denote significance at *P*< 0.05.
N.D means not detected.

The range of moisture in dried broccoli in our results was higher than those reported in Campas-Baypoli *et al.* (2009),while the range of protein in the dried samples close to the range of values in Quizhpe *et al.* (2024), where this research reported that the ranged values of protein were ranged (26.44–31.28 g/100gDW), and this research also indicated that broccoli is rich in protein in all their plant parts. According to Udousoro and Ekanem (2013), plant-based foods that contain more than 12% protein are considered to be a healthy source of protein. Brassica vegetables, such as broccoli, are abundant in protein; in fact, one-third of their dry mass is composed of protein components (Souci *et al*., 2000).

Fiber has been shown to help control blood sugar levels, clear the digestive tract, and eliminate possible carcinogens from the body. It is well known to give bulking, which help with bowel movements and reduce the consumption of excessive amounts of starchy foods (Ajayi *et al*., 2018). The amount of dietary fiber in dried samples was consistent with literature (Mansour *et al*., 2017; Kalala et al., 2018), where in those studies, it ranged from 36% to 37%. Factors that affect fiber include type of field or storage conditions (Berndtsson *et al*., 2020).

According to Malghani *et al.* (2022), green and leafy vegetables are low in fat. The amount of ash in dried samples in our results consistent with Kundu *et al.* (2022), where this study indicated that the percentage ranged from 6.5% to 7.9% across six varieties of broccoli florets.

The majority of carbohydrates consumed by vegetarians worldwide come from vegetables. The amount of carbohydrate in dried samples in our results was lower than those reported with Ashoush *et al.* (2017) and was higher than this study (Dos Reis et al.,2015). This variation may be due to differences in the cultivar, agricultural conditions and analytical techniques.

Minerals content of studied broccoli samples:

Data in Table (2) showed mineral content (P, K, Na, Ca, Zn, Mn, Cu and Fe) in studied broccoli samples.

The results in Table (2) indicate a significant increase in mineral content in dried broccoli samples (dried sample 1 and dried sample 2) compared to fresh broccoli florets (fresh sample 1 and fresh sample 2).On the other hand, dried Sample 1 showed a significant increase in some minerals such as P, K, Na, and Mn which recorded 47±0.1, 227±0.58, 30±0.06 and 63.53±0.65 mg/kg respectively, compared to dried Sample 2, which measured 37±0.1%, 204±0.58%, 1±0.1%, and 53.15±3.25 mg/kg respectively. Meanwhile, dried sample 2 exhibited a significant increase in some minerals (Cu and Fe) which registered 5.73±12 and 173.07±2.25 mg/kg respectively, compared to dried Sample 1 which recorded 4.71±1.29 and 136.93±8.16 mg/kg respectively. On the other hand, there was no significant difference between fresh sample 1 and fresh sample 2 in the content of all minerals except Cu, where fresh sample 2 showed the highest Cu content. The highest Content was observed in dried sample 1 and dried sample 2.

Table 2. Minerals content of studied broccoli samples:

Minerals mg/kg Samples		P	K	Na	Ca	Zn	Mn	Cu	Fe
Sample1	Fresh	19^c±0.01	80^b±0.06	N.D	125^b±0.58	2.39^b±0.10	22.23^c±0.75	3.07^c±0.12	58.96^c±4.61
	Dried	47^a±0.01	227^a±0.58	30^a±0.06	420^a±0.58	2.87^a±0.05	63.53^a±0.65	4.71^b±0.29	136.93^b±8.16
Sample2	Fresh	18^c±0.01	70^b±0.06	N.D	80^b±0.06	2.40^b±0.12	23.42^c±0.97	5.44^a±0.12	53.81^c±5.68
	Dried	37^b±0.01	204^{ab}±0.58	1^b±0.01	422^a±0.57	2.94^a±0.11	53.15^b±3.25	5.73^a±0.12	173.07^a±2.25
Sig.		0.000	0.053	0.000	0.002	0.007	0.000	0.000	0.000

Values are expressed as means ± SE.
Means with the different letter superscripts in the same column denote significance at *P*< 0.05.
N.D means not detected.

Quizhpe *et al.* (2024) reported that the levels of (K), (Ca) and (Fe) are elevated in broccoli, this is in agreement with our study. In another study the values of Fe, Cu and Mn in fresh samples in our study were higher than what was reported in that study (Ağagündüz *et al.*, 2022),where values of these minerals were ranged from 0.059 to 6.9 mg/Kg but Na, K, Ca and P in our study were lower than what was reported in same study. This variation in the values may be attributed to differences in the cultivar, agricultural conditions and the sample analysis method.

Fatty acids content of studied broccoli samples:

Data in Table (3) showed the fatty acids content of studied broccoli samples.

Results in Table (3) indicate a significant increase in total saturated fatty acid content in fresh broccoli samples (fresh sample 1 and fresh sample 2) compared to dried broccoli samples (dried sample 1 and dried sample 2). The mean total values were78.3% in fresh sample 1 and 64.68% in fresh sample 2 compared to 32.85% in dried sample 1 and 34.5% in dried sample 2. Furthermore, the results indicate that $C_{16:0}$ and $C_{18:0}$ were the most abundant saturated fatty acids in fresh sample 1 and fresh sample 2, while $C_{16:0}$ was the most abundant in dried sample 1 and dried sample 2. On the other hand, there was a significant increase in total unsaturated fatty acid content in dried broccoli samples compared to fresh broccoli samples. The mean total values were 67.15% in dried sample 1 and 65.5% in dried sample 2. $C_{18:2;9,12}$ and $C_{18:3;\,9,12,15}$ were the most abundant unsaturated fatty acids in dried sample 1 and dried sample 2.

Table 3. Fatty acids content of studied broccoli samples:

Samples Fatty acids %	Fresh Sample1	Dried Sample1	Fresh Sample2	Dried Sample2	Sig.
		Saturated Fatty acids			
$C_{14:0}$	1.17^a±0.58	0.45^a±0.01	1.01^a±0.58	0.39^a±0.01	0.471
$C_{16:0}$	47.37^a±0.58	23.62^c±0.58	40.38^b±0.58	24.88^c±0.58	0.000
$C_{17:0}$	0.37^b±0.01	0.57^a±0.01	0.26^c±0.01	0.56^a±0.01	0.000
$C_{18:0}$	26.44^a±0.58	6.88^c±0.58	20.66^b±0.58	7.39^c±0.58	0.000
$C_{20:0}$	0.75^a±0.01	0.7^a±0.01	0.49^b±0.01	0.67^a±0.01	0.001
$C_{21:0}$	1.86^a±0.58	0.43^b±0.01	1.69^{ab}±0.58	0.44^b±0.01	0.065
$C_{22:0}$	0.34^a±.01	0.2^b±.58	0.19^b±0.01	0.17^b±.001	0.012
Total	78.3	32.85	64.68	34.5	
		Unsaturated Fatty acids			
$C_{16:1;\,7}$	0.19^d±0.01	0.56^b±0.01	0.33^c±0.01	0.64^a±0.01	0.000
$C_{18:1;\,9}$	1.47^b±0.58	7.5^a±0.58	1.79^b±0.58	7.47^a±0.58	0.000
$C_{18:2;9,12}$	4.12^c±0.58	17.2^a±0.58	9.32^b±0.58	17.64^a±0.58	0.000
$C_{18:3;9,12,15}$	6.98^d±0.58	39.79^a±0.58	15.06^c±0.58	37.59^b±0.58	0.000
$C_{20:2;\,11,14}$	0.6^a±0.58	0.27^{bc}±0.01	0.2^c±0.58	0.39^b±0.01	0.001
$C_{20:3;\,8,11,14}$	8.34^a±0.58	1.83^b±0.58	8.62^a±0.58	1.77^b±0.58	0.000
Total	21.7	67.15	35.32	65.5	

- **Values are expressed as means ± SE.**
- **Means with the different letter superscripts in the same column denote significance at *P*< 0.05.**

The findings of the analysis of the fatty acid contents are shown in Table 6. The broccoli varieties' florets contained just 13 of the 37 fatty acids that were examined. Two broccoli cultivars had more than 85% of their total fatty acid content in the form of four major fatty acids: palmitic, linoleic, linolenic, and stearic acids. These results were consistent with Bhandari *et al.* (2013). Linolenic acid was the major fatty acid in all dried cultivars, followed by palmitic and linoleic acids. This is consistent with Campas-Baypoli *et al.* (2009). However, the total saturated fatty acid content in dried broccolis analyzed in our study was higher than that reported in this study. Some fatty acid in dried broccoli ($C_{16:0}$), ($C_{18:2}$) and ($C_{20:0}$) in our study were similar to the ones reported by Campas-Baypoli *et al.* (2009), while ($C_{18:0}$) and ($C_{18:1}$) were lower than in our study , but ($C_{14:0}$) ,($C_{16:1}$) ,($C_{18:3}$) and ($C_{22:0}$) were slightly higher than in our study.

Some fatty acid ($C_{14:0}$, $C_{20:0}$, $C_{18:2}$ and $C_{18:3}$) values are consistent with the result of (Li *et al.*, 2022). The amount of $C_{14:0}$ in fresh broccoli samples agreed with literature (Murcia *et al.*, 1999), where its value was 1.1% in this study. The amount of $C_{16:0}$ in fresh broccoli from ranged 30.30% to 42.88% according to Bhandari *et al.* (2013), this agreed with our results. This previous result was agreed with the result obtained by West *et al*. (2002), who reported that the amounts of $C_{17:0}$, $C_{18:1}$, $C_{20:0}$ and $C_{22:0}$ were 0.18%, 0.92%, 0.40% and 0.36% respectively in fresh broccoli samples.

Amino acids content of studied broccoli samples:

Data in Table (4) showed the amino acids content (essential amino acids and non-essential amino acids) in studied broccoli samples.

Results in Table (4) indicate a significant increase in total essential amino acids content in fresh broccoli samples (fresh sample 1 and fresh sample 2) compared to dried broccoli samples (dried sample 1 and dried sample 2). The mean total values were ranged 478.71 mg / gram protein in fresh sample 1and 508.7 mg / gram in fresh sample 2 compared to 432.3 mg / gram in dried sample 1 and 446.8 mg / gram in dried sample 2. On the other hand, the results indicate that threonine and histidine were the most abundant essential amino acids of all groups of broccoli except for dried sample 1, where lysine acid was the most abundant in this group.

In contrast, results in Table (4) indicate a significant increase in total non- essential amino acids content in dried broccoli samples (dried sample 1 and dried sample 2) compared to fresh broccoli samples (fresh sample 1 and fresh sample 2). The mean total values were 517.44 mg / gram protein in dried sample 1 and 501.79 mg / gram in dried sample 2 compared to 469.51 mg / gram in fresh sample 1 and 439.46mg / gram in fresh sample 2. On the other hand, the results indicate that aspartic acid was the most abundant non -essential amino acids in all groups of broccoli except for fresh sample1, where glutamic acid was the most abundant in this group.

Table 4. Amino acids content of studied broccoli samples:

Samples	fresh Sample1	Dried Sample1	Fresh Sample2	Dried Sample2	Sig.
		Essential amino acids (mg / gram Protein)			
Histidine	$73.94^{b}\pm0.58$	$67.57^{c}\pm0.58$	$51.45^{d}\pm0.58$	$79.52^{a}\pm0.58$	0.00
Threonine	$79.48^{c}\pm0.58$	$59.63^{d}\pm0.58$	$106.44^{b}\pm0.58$	$132.28^{a}\pm0.58$	0.00
Valine	$44.77^{a}\pm0.58$	$35.17^{c}\pm0.58$	$27.71^{d}\pm0.58$	$41.23^{b}\pm0.58$	0.00
Methionine	$57.49^{b}\pm0.58$	$28.59^{c}\pm0.58$	$79.15^{a}\pm0.58$	$29.72^{c}\pm0.58$	0.00
Isoleucine	$59.54^{a}\pm0.58$	$39.93^{c}\pm0.58$	$55.89^{b}\pm0.58$	$18.94^{d}\pm0.58$	0.00
Leucine	$32.99^{c}\pm0.58$	$40.72^{b}\pm0.58$	$55.17^{a}\pm0.58$	$34.14^{c}\pm0.58$	0.00
Phenylalanine	$59.71^{b}\pm0.58$	$65.58^{a}\pm0.58$	$60.91^{b}\pm0.58$	$48.09^{c}\pm0.58$	0.00
Lysine	$70.79^{b}\pm0.58$	$95.11^{a}\pm0.58$	$71.98^{b}\pm0.58$	$62.88^{c}\pm0.58$	0.00
Total	478.71	432.3	508.7	446.8	
		Non-essential amino acids (mg / gram Protein)			
Aspartic acid	$67.76^{d}\pm0.58$	$109.53^{a}\pm0.58$	$89.56^{b}\pm0.58$	$83.2^{c}\pm0.58$	0.00
Glutamic acid	$90.58^{b}\pm0.58$	$98.35^{a}\pm0.58$	$49.27^{d}\pm0.58$	$68.13^{c}\pm0.58$	0.00
Serine	$44.57^{c}\pm0.58$	$45.01^{c}\pm0.58$	$50.58^{b}\pm0.58$	$57.14^{a}\pm0.58$	0.00
Glycine	$15.45^{d}\pm0.58$	$17.75^{c}\pm0.58$	$20.05^{b}\pm0.58$	$38.03^{a}\pm0.58$	0.00
Arginine	$52.83^{d}\pm0.58$	$68.85^{b}\pm0.58$	$72.41^{a}\pm0.58$	$62.28^{c}\pm0.58$	0.00
Alanine	$34.84^{d}\pm0.58$	$43.5^{c}\pm0.58$	$49.78^{b}\pm0.58$	$72.29^{a}\pm0.58$	0.00
Proline	$81.75^{b}\pm0.58$	$87.24^{a}\pm0.58$	$63.28^{d}\pm0.58$	$66.3^{c}\pm0.58$	0.00
Tyrosine	$65.54^{a}\pm0.58$	$35.75^{c}\pm0.58$	$28.83^{d}\pm0.58$	$48.47^{b}\pm0.58$	0.00
Cysteine	$16.19^{a}\pm0.58$	$11.46^{c}\pm0.58$	$15.7^{b}\pm0.58$	$5.95^{d}\pm0.58$	0.00
Total	469.51	517.44	439.46	501.79	

- **Values are expressed as means ± SE.**
- **Means with the different letter superscripts in the same column denote significance at $P < 0.05$.**

According to this study, drying broccoli considerably raises its amount of total amino acids. Some amino acids in dried sample 1 (ASP, SER, ILE, TYR, ARG and CYS) and in dried sample 2 (GLY, ALA and PHE) in our study in our study were similar to those reported by Ashoush *et al*. (2017),where values were 110.5, 42.6, 38.4, 32.3, 68.6 and 10.8 mg / gram respectively in dried sample 1 and 42.1, 80.1 and 48.2 mg / gram respectively in dried sample 2, while amino acid (GLU, VAL and LEU) were higher than in our study , but (THE , PRO, MET, HIS, LYS) were lower.

According to Gomes and Rosa (2001), the amount of amino acids varied significantly based on the cultivar and growing season. Additionally, Lee *et al*. (2005) demonstrated that the type of fertilization used had a significant impact on the amount of methionine. This could explain the difference in amino acid ratios between the two types of broccoli in that study.

Total phenolic compounds and total flavonoids content of studied broccoli samples:

Data in Table (5) showed total phenolic and total flavonoids content in studied broccoli samples.

Table 5 indicate that the total phenols and total flavonoid levels in the broccoli dry powder floret samples (dried sample 1 and dried sample 2) increased significantly, where the total phenol content was 269.95±0.58, 427.91±0.58 mg gallic acid equivalent/100g respectively, and the total flavonoid content was 103.87±0.58, 171.78±0.58 mg Rut inequivalent/100g respectively compared with Fresh broccoli florets (fresh sample 1 and fresh sample 2). However, compared to fresh sample 1 and dried sample 1, fresh sample 2 and dried sample 2 demonstrated a considerable increase in total phenols and total flavonoids. The highest concentration of total phenol and total flavonoid was found in dried sample 2.

This study shows that drying broccoli greatly raises its overall phenolic and flavonoid content. This suggests that dried broccoli might offer more health advantages in terms of antioxidant activity. The variation between Sample 1 and Sample 2 may be due to differences in broccoli cultivars, growing conditions.

Total phenolics ranged from 25 to 153 mg gallic acid equivalent/100g in fresh broccoli. This is larger variationas compared to the combined range (80.76–109.9 mg/ 100 g) reported for other studies (Bahorun *et al*., 2004;

Gliszczyńska-Świgło *et al*., 2006). Hwang and Lim. (2015) said that total phenolic compounds in dried broccoli floret were in the range (164.4 – 528.9 mg GAE/100 g), this values consistent with our result. The total phenolic compounds in fresh sample 2 were in the range consistent with Koh *et al.* (2009), in their study carried out on 80 commercial broccoli samples, observed that total phenolic activity ranged from 48.15 to 157.77mg/100g fresh weight.

Cultivar selection, growth season, and storage conditions are some of the factors that affect the levels of total phenolics in fresh product. Broccoli varieties can differ in their levels of total phenolics by as much as 200% (Eberhardt *et al*., 2005; Singh *et al*., 2007). Barber *et al*. (2020) reported that broccoli has an excellent source of various flavonoids.

Table 5. Total phenolic compounds and total flavonoids content of studied broccoli samples:

Samples		Total phenols (mg gallic acid equivalent/100g)	Total flavonoids (mg Rutin equivalent/100g sample)
Sample 1	Fresh	$25.14^{d}\pm0.58$	$14.42^{d}\pm0.58$
	Dried	$269.95^{b}\pm0.58$	$103.87^{b}\pm0.58$
Sample 2	Fresh	$153.45^{c}\pm0.58$	$88^{c}\pm0.58$
	Dried	$427.91^{a}\pm0.58$	$171.78^{a}\pm0.58$
Sig.		0.00	0.00

•Values are expressed as means ± SE.

• Means with the different letter superscripts in the same column denote significance at *P* < 0.05.

Evaluation of the antioxidant activity of studied broccoli samples:

Data in Table (6) presented the evaluation of antioxidant activity in different broccoli samples based on their DPPH radical-scavenging activity at various concentrations (1%, 3% and 5% in dried samples).

At all tested concentrations, dried sample 2 has greater DPPH radical-scavenging activity than dried sample 1. At 5% concentration, dried sample 2 exhibits the maximum antioxidant activity compared to all concentrations in dried samples, reaching 85.02%.

Table 6. Evaluation of the antioxidant activity of studied broccoli samples:

	% DPPH Free Radical – Scavenging Activity		
Concentration	**1%**	**3%**	**5%**
Dried Sample1	$54.68^{c}\pm0.58$	$73.03^{c}\pm0.58$	$80.0^{b}\pm0.58$
Dried Sample2	$62.55^{d}\pm0.58$	$81.27^{d}\pm0.58$	$85.02^{c}\pm0.58$
Sig.	0.00	0.00	0.00

• Values are expressed as means ± SE.

• Means with the different letter superscripts in the same row denote significance at *P*< 0.05.

These findings demonstrate dried broccoli's potential as a powerful antioxidant material for nutraceutical formulations or functional food applications.

Activity of antioxidants assessed the 2,2-diphenyl-1-picrylhydracyl (DPPH) free radical-scavenging ability of various broccoli cultivars in order to quantify antioxidant activity. Broccoli cultivars' levels of antioxidant activity varied greatly. The highest antioxidant activity was observed in dried sample 2, this may be due to the fact that phenolics are a significant component to overall antioxidant activity (Zhou and Yu, 2006), so this increase might be attributed to the increased concentration of total phenols in dried sample 2 as shown in table (5). There are many studies that have shown that broccoli has high antioxidant activity (de la Fuente *et al*., 2019; Le *et al*., 2019; Di Bella *et al*., 2020). Broccoli contains a high content of antioxidant and bioactive compounds, such as sulforaphane, with health-promoting properties against diabetes (Raiola *et al*., 2017; Mangla *et al*., 2021).

Sensory evaluation of studied cupcake samples using broccoli.

Consumer acceptability based on appearance, color, flavor, texture, taste, and overall acceptability of the samples, are shown in Table (7).

Data in Table 7 showed there was significant difference between all samples in which broccoli was added compared to the control sample in sensory evaluation, except texture in 5% broccoli. The higher the concentration of broccoli, the greater the decrease in sensory evaluation. There was no significant difference in appearance, color, smell and texture between the sample 10% broccoli and 15% broccoli while there was a significant difference in taste between the sample 15% broccoli and the sample 10% broccoli. These results are consistent with the study (Afriani *et al*., 2015) that showed that the panelists had a lower preference for pempek if more green broccoli was added, as it was average A0 organoleptic test score was 6.42 (without broccoli) and an A4 score of 5.38 (20% addition of green broccoli). The highest degree of consumer acceptance among all samples was 5% broccoli while the lowest was at 15% broccoli, which indicates that the higher the percentage of broccoli in the cupcakes, the more negatively it affects consumer acceptance. Finally, in the overall acceptability, the highest score of overall acceptability was the sample with which broccoli was fortified with a percentage of 5% (7.43± 0.13), followed by 10% (6.76± 0.11) and then 15% (5.30± 0.14). Despite the decrease in the sensory evaluation, the samples remained within acceptable range.

Table 7. Sensory evaluation of studied cupcake samples using broccoli.

Samples	Appearance(٩)	Color(٩)	Flavor(٩)	Taste(٩)	Texture(٩)	Overall acceptability(9)
Control	٨.5٧^{a}±0.14	٨.6٩^{a}±0.11	٨.5٥^{a}±0.12	٨.5٧^{a}±0.16	$8.51^{a}\pm0.13$	$8.60^{a}\pm 0.09$
5%broccoli	٨.١2^{b}±0.15	٨.٢١^{b}±0.12	8.٠3^{b}±0.17	٧.٦٢^{b}±0.19	$8.06^{a}\pm0.16$	$7.43^{b}\pm 0.13$
10%broccoli	٧.6١^{c}±0.18	٧.٤٩^{c}±0.19	٦.٧5^{c}±0.26	٧.٣٢^{b}±0.23	$7.41^{b}\pm0.21$	$6.76^{c}\pm 0.11$
15%broccoli	٧.٤٧^{c}±0.21	٧.٥٦^{c}±0.21	٦.٥٤^{c}±0.22	$6.69^{c}\pm0.26$	$7.52^{b}\pm0.26$	$5.30^{d}\pm 0.14$
Sig.	0.00	0.00	0.00	0.00	0.00	0.00

• Values are expressed as means ± SE.

• Means with the different letter superscripts in the same column denote significance at *P* < 0.05.

Sensory evaluation of studied falafel samples using broccoli.

Table 8 showed the values of the sensory evaluation recorded by tasters for falafel.

The results in Table (8) showed significant differences between the sensory properties (color, appearance, taste, crispy, texture and overall acceptability) of the falafel in which broccoli was added in the proportions of 5%, 10% and 15% and the control sample. There was significant difference in all sensory evaluation in all samples containing broccoli compared with control samples. There was no significant difference in appearance between all samples with added broccoli, and there was no difference in appearance color, texture and crispy between the sample with 10% broccoli added and the sample with 15% broccoli added. The lowest broccoli addition by 5% recorded the best score in all sensory properties. And in terms of overall acceptance, the addition of broccoli to falafel by 5% (8.67 ± 0.14) was the highest value of sensory acceptance, while the addition of 15% broccoli (5.57± 0.13) was the lowest value. But all concentrations of broccoli powder led to an acceptable sensory evaluation.

Table 8. Sensory evaluation of studied falafel samples using broccoli.

Samples	Appearance(10)	Color(10)	Flavor(10)	Taste(10)	Texture(10)	Crispy(10)	Overall acceptability(10)
Control	9.77^{a} ±0.09	9.63^{a}±0.13	9.37^{a}±0.16	9.66^{a}± 0.12	9.53^{a}±0.13	9.17^{a}±0.26	9.67^{a}± 0.09
5%broccoli	9.10^{b}±0.15	9.10^{ab}±0.7	8.70^{b}±0.19	8.53^{b}±0.27	8.83^{b}±0.24	8.57^{ab}±0.26	8.67^{b} ± 0.14
10%broccoli	9.00^{b}± 0.21	8.86^{b}±0.23	8.43^{ab}±0.23	8.30^{ab}±0.24	8.40^{b}±0.27	8.30^{b} ± 0.3	7.43^{c} ± 0.13
15%broccoli	8.80^{b}±0.21	8.56^{b}±0.28	8.00^{c}± 0.27	7.70^{c} ±0.28	8.20^{b}±0.25	8.10^{b}±0.26	5.57^{d}± 0.13
Sig.	0.001	0.005	0.000	0.000	0.000	0.038	0.000

- **Values are expressed as means ± SE.**
- **Means with the different letter superscripts in the same column denote significance at *P* < 0.05.**

We can conclude from evaluation of cupcake and falafel that supplemented with different levels of dried broccoli powder .Through supplantation with broccoli results given in Tables (7 and 8) showed that products that supplemented with 5 % dried broccoli powder had the highest sensory products and accepted for human consumption whether falafel or cupcake, which significantly had the highest scores for all evaluated attributes, followed by products that supplemented with (10% dried broccoli powder) then products supplemented with (15% dried broccoli powder). So, it strongly recommended to produce such products are a functional food because of the advantages of these products since they are accepted and provide humans with the necessary requirements of nutritive compounds such as proteins, fiber, carbohydrates, minerals, phenolic compounds, antioxidants, antimicrobial, anticancer compounds, anti-inflammatory and antihypertensive activities.

Effect of incorporation broccoli powder on the nutritional composition of cupcakes.

Data from Table 9 showed the moisture content showed an upward trend, from (26.39 ± 0.58) in control sample to (35.46 ± 0.58) in the 15 % broccoli sample. 15 % broccoli sample (9.73 ± 0.58 %) was highest in protein and control sample (7.08 ± 0.58 %) had lowest protein compared to all other treatments. In terms of fiber content, it was observed to be significantly increasing with substitution starting at 15 % (3.50±0.58 %) compared to than the control sample (1.19 ± 0.58 %). For fat and ash content, there is no significant difference between all samples with broccoli and the control sample, whereas ash contents ranged from 1.80 ± 0.58 to 2.44 ± 0.58 %, and fat contents ranged from 17.12 ± 0.58 to 19.00 ± 0.58 %. The carbohydrate content, the highest percentage was recorded in control sample (46.42 ± 0.58), followed by 5 % broccoli (42.31 ± 0.58) then 10 % broccoli (38.09±0.58) and 15% broccoli (29.87 ± 0.58).

Table 9. Effect of incorporation broccoli powder on the nutritional composition of cupcakes

Components% Samples	moisture	Protein	Fiber	Fat	Ash	Total Carbohydrate
Control	26.39^{c}±0.58	7.08^{b}±0.58	1.19^{b}±0.58	17.12^{a}±0.58	1.80^{a}±0.58	46.42^{a}±0.58
5 % broccoli	28.12^{bc}±0.58	7.99^{ab}±0.58	1.46^{b}±0.58	18.15^{a}±0.58	1.97^{a}±0.58	42.31^{b}±0.58
10% broccoli	29.64^{b}±0.58	8.78^{ab}±0.58	2.65^{ab}±0.58	18.60^{a}±0.58	2.24^{a}±0.58	38.09^{c}±0.58
15% broccoli	35.46^{a}±0.58	9.73^{a}±0.58	3.50^{a}±0.58	19.00^{a}±0.58	2.44^{a}±0.58	29.87d±0.58
Sig.	0.000	0.057	0.071	0.197	0.865	0.000

- **Values are expressed as means ± SE.**
- **Means with the different letter superscripts in the same column denote significance at *P* < 0.05.**

We conclude from these results that protein and fiber contents increased when the percentage of broccoli increased to 15% compared to control sample, the increase was 37% in protein and it roughly tripled fiber. And the higher percentage of broccoli in the cupcakes, the higher moisture content, the increase reached 34.4%. While total carbohydrate decreased as the proportion of broccoli substitution increased, reaching a reduction of 35.7% at the highest level of substitution. Khalaf *et al.* (2018) demonstrated that the carbohydrate content declined as the replacement level increased in cake made from gamma-irradiated florets and had a noticeable improvement (%) in its chemical composition (protein and fiber content). And Anwar *et al.* (2017) assessed the physicochemical, rheological, and sensory characteristics of bread by Using a range of floret flour proportions, the result was an increase in fiber and protein levels. These studies were consistent with our results.

Effect of incorporation broccoli powder on the nutritional composition of falafel.

The amount of moisture in falafel without broccoli was 45.15±0.58%. After adding broccoli with falafel moisture decreased as the proportion of added broccoli increased until it reached 30.52±0.58 in 15% broccoli sample. For protein and ash contents, there are no significant difference between all samples with broccoli and the control sample, where ash content was observed to range from 4.22± 0.58 to 4.91±0.58, whereas protein content ranges from 12.82±0.58 to 14.10±0.58. The higher the percentage of broccoli added in falafel, the higher the fiber and fat contents compared to the control sample. where the highest content of fat was 20.99±0.58 in 15% broccoli sample and the highest content of fiber was 13.51±0.58 in 15% broccoli sample. In contrast as the proportion of broccoli increased, the carbohydrate content decreased until it reached 12.97±0.58 in 15% broccoli.

The findings indicate that the moisture content decreased as broccoli substitution level increased, rate decreased reach 32.4% at 15%broccoli. fat and fiber contents increased gradually with the higher levels of broccoli addition, reaching their maximum at 15% broccoli substitution, where broccoli is a good source of dietary fiber, primarily insoluble fiber (García-Lorca *et al*., 2025). Incorporating cabbage varietals into flatbread compositions considerably raised the overall dietary fiber content when compared to the control, according to Santamaria *et al.* (2024), underscoring the Brassica genus's potential as a fiber source. And total carbohydrates decreased until the rate of decreased reached 36.9% in 15%broccoli sample.

Table 10. Effect of incorporation broccoli powder on the nutritional composition of falafel

Components% Samples	Moisture	Protein	Fiber	Fat	Ash	Total Carbohydrate
Control	45.15^{a}±0.58	12.82^{a}±0.58	2.92^{d}±0.58	9.53^{d}±0.58	4.22^{a}±0.58	25.33^{a}±0.58
5 % broccoli	34.33^{b}±0.58	13.44^{a}±0.58	7.00^{c}±0.58	13.27^{c}±0.58	4.50^{a}±0.58	25.06^{a}±0.58
10% broccoli	32.65^{b}±0.58	13.79^{a}±0.58	8.92^{b}±0.58	16.80^{b}±0.58	4.78^{a}±0.58	23.06^{b}±0.58
15% broccoli	30.52^{c}±0.58	14.10^{a}±0.58	13.51^{a}±0.58	20.99^{a}±0.58	4.91^{a}±0.58	12.97^{c}±0.58
Sig.	0.000	0.280	0.000	0.000	0.836	0.000

- **Values are expressed as means ± SE.**
- **Means with the different letter superscripts in the same column denote significance at $P < 0.05$.**

CONCLUSION

From previous results, that study showed that broccoli is rich in fiber, protein, mineral content, fatty acid, amino acid, antioxidants, phenolic compounds and flavonoids. Thus, it can be relied on to support many food products, especially since it has achieved high results in sensory evaluation. And also, when incorporated into cupcakes or falafel by replacing a percentage of the traditional white flour with broccoli powder this led to raising their nutritional value especially protein and fiber and decreasing carbohydrates. Therefore, we recommend using broccoli powder and fortifying food products with it to obtain nutritional benefits, enhance health levels, and prevent diseases.

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REFERENCES

Abd Rahman, N. A., Abdul Razak, S. Z., Lokmanalhakim, L. A., Taip, F. S., & Mustapa Kamal, S. M. (2017). Response surface optimization for hot air-frying technique and its effects on the quality of sweet potato snack. *Journal of Food Process Engineering*, *40*(4), e12507.

Abd-Elhak, N. A., & Hassan, N. S. Y. (2024). Preparation and evaluation of falafel powder free of legumes. *Food Technology Research Journal*, *5*(2), 160-173.

Abdel-Mawgoud, A. M., & Stephanopoulos, G. (2018). Simple glycolipids of microbes: Chemistry, biological activity and metabolic engineering. *Synthetic and Systems Biotechnology*, *3*(1), 3-19.

Abdullah, M. A., & Amr, S. Q. (2003). Chemical and physical changes in palm olein and soybean oil during falafel frying. In *Proceedings of the international palm oil congress (PIPOC 2003): Palm oil, the power-house for the global oils and fats economy* (pp. 53–68). Putrajaya, Malaysia.

Abdullah, T. (2015). Reduction of oil uptake in deep-fat fried falafel. *Journal of Nutritional Health & Food Engineering*, *2(4)*, 114-117.

Afriani, Y., Lestari, S., & Herpandi, H. (2015). Karakteristik fisiko-kimia dan sensori pempek ikan gabus (*Channa Striata*) dengan penambahan brokoli (*Brassica Oleracea*) sebagai pangan fungsiona. *Fishtech*, *4*(2), 95-103.

Ağagündüz, D., Şahin, T. Ö., Yılmaz, B., Ekenci, K. D., Duyar Özer, Ş., & Capasso, R. (2022). Cruciferous vegetables and their bioactive metabolites: From prevention to novel therapies of colorectal cancer. *Evidence-Based Complementary and Alternative Medicine*, *2022*(1), 1534083.

Ajayi, O. B., Bamidele, T. J., Malachi, O. I., & Oladejo, A. A. (2018). Comparative proximate, minerals and antinutrient analysis of selected Nigerian leafy vegetables. *Journal of Applied Life Sciences International*, *16*(1), 1-8.

Allen, S. E., Grimshaw, H. M., Parkinson, J. A., & Quarmby, C. (1974). *Chemical analysis of ecological materials* (pp. xii+-565). Chapman and Hall.

Anwar, B. R., Allah Rakha, A. R., Mahmood, M. A., Batool, I., Sohail, M., & Rashid, S. (2017). Enrichment of wheat flour bread to enhance physicochemical and sensory attributes using broccoli powder. *Pakistan Journal of Food Science, 27*(1),39-45.

AOAC (Association of Official Analytical Chemists). (1990). *Official methods of analysis* (*62nd ed.*, pp. 2742-2744). AOAC international.

AOAC (Association of Official Analytical Chemists). (2005). Determination of Moisture, Ash, Protein and Fat. *Official methods of analysis* (18th ed.). AOAC international, Washington, DC, USA.

AOAC (Association of Official Analytical Chemists). (2019). Determined of moisture, ash, crude fiber, crude protein and crude lipid. *Official methods of analysis*. (21st ed). AOAC international, Washington, DC, USA.

Ashoush, Y. A. M., Ali, A. M. F., Abozid, M. M., & Salama, M. S. M. (2017). Comparative study between celery leaves and broccoli flowers for their chemical composition and amino acids as well as phenolic and flavonoid compounds. *Menoufia Journal of Agricultural Biotechnology*, *2*(1), 1-13.

Ayat, T. (2016). Benefits and harms of falafel. *Almrsa l.com.* http://www. almrsal. com/post/300940.

Bahorun, T., Luximon-Ramma, A., Crozier, A., & Aruoma, O. I. (2004). Total phenol, flavonoid, proanthocyanidin and vitamin C levels and antioxidant activities of Mauritian vegetables. *Journal of the Science of Food and Agriculture*, *84*(12), 1553-1561.

Bandyopadhyay, K., Chakraborty, C., & Bhattacharyya, S. (2014). Fortification of mango peel and kernel powder in cookies formulation. *Journal of Academia and Industrial Research*, *2*(12), 661-664.

Barber, T. M., Kabisch, S., Pfeiffer, A. F., & Weickert, M. O. (2020). The health benefits of dietary fibre. *Nutrients*, *12*(10), 3209.

Berndtsson, E., Andersson, R., Johansson, E., & Olsson, M. E. (2020). Side streams of broccoli leaves: A climate smart and healthy food ingredient. *International journal of environmental research and public Health*, *17*(7), 2406.

Bhandari, S. R., Park, M. Y., Chae, W. B., Kim, D. Y., & Kwak, J. H. (2013). Seasonal variation in fatty acid composition in various parts of broccoli cultivars. *Korean Journal of Agricultural Science*, *40*(4), 289-296.

Boivin, D., Lamy, S., Lord-Dufour, S., Jackson, J., Beaulieu, E., Côté, M., ... & Béliveau, R. (2009). Antiproliferative and antioxidant activities of common vegetables: A comparative study. *Food Chemistry*, *112*(2), 374-380.

Brand-Williams, W., Cuvelier, M. E., & Berset, C. L. W. T. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT-Food science and Technology*, *28*(1), 25-30.

Campas-Baypoli, O. N., Sánchez-Machado, D. I., Bueno-Solano, C., Núñez-Gastélum, J. A., Reyes-Moreno, C., & López-Cervantes, J. (2009). Biochemical composition and physicochemical properties of broccoli flours. *International Journal of Food Sciences and Nutrition*, *60*(sup4), 163-173.

Chevilly, S., Dolz-Edo, L., Blanca, J., Yenush, L., & Mulet, J. M. (2023). Identification of distinctive primary metabolites influencing broccoli (*Brassica oleracea,* var. *Italica*) taste. *Foods*, *12*(2), 339.

Cottenie, A., Verloo, M., Kiekens, L., Velghe, G., & Camerlynck, R. (1982). *Chemical analysis of plants and soils*. Lab. Agroch. State Univ. Gent, Belgium, 63, 44-45.

Coutinho, A. J. M., Santos, M. M. R., dos Santos, E. F., & Novello, D. (2021). Cupcake adicionado de farinha de resíduos de brócolis: Análise físico-química e sensorial entre crianças. *Multitemas*, 5-20.

de la Fuente, B., López-García, G., Máñez, V., Alegría, A., Barberá, R., & Cilla, A. (2019). Evaluation of the bioaccessibility of antioxidant bioactive compounds and minerals of four genotypes of *Brassicaceae microgreens*. *Foods*, *8*(7), 250.

De Pascale, S., Maggio, A., Pernice, R., Fogliano, V., & Barbieri, G. (2007). Sulphur fertilization may improve the nutritional value of *Brassica rapa* L. subsp. *sylvestris*. *European Journal of Agronomy*, *26*(4), 418-424.

Di Bella, M. C., Niklas, A., Toscano, S., Picchi, V., Romano, D., Lo Scalzo, R., & Branca, F. (2020). Morphometric characteristics, polyphenols and ascorbic acid variation in *Brassica oleracea* L. novel foods: Sprouts, microgreens and baby leaves. *Agronomy*, *10*(6), 782.

Dominguez-Perles, R., Moreno, D. A., Carvajal, M., & Garcia-Viguera, C. (2011). Composition and antioxidant capacity of a novel beverage produced with green tea and minimally-processed byproducts of broccoli. *Innovative Food Science & Emerging Technologies*, *12*(3), 361-368.

Dos Reis, L. C. R., De Oliveira, V. R., Hagen, M. E. K., Jablonski, A., Flôres, S. H., & de Oliveira Rios, A. (2015). Effect of cooking on the concentration of bioactive compounds in broccoli (*Brassica oleracea* var. *Avenger*) and cauliflower (*Brassica oleracea* var. *Alphina* F1) grown in an organic system. *Food Chemistry*, *172*, 770-777.

Eberhardt, M. V., Kobira, K., Keck, A. S., Juvik, J. A., & Jeffery, E. H. (2005). Correlation analyses of phytochemical composition, chemical, and cellular measures of antioxidant activity of broccoli (*Brassica oleracea* L. var. *italica*). *Journal of agricultural and food chemistry*, *53*(19), 7421-7431.

García-Lorca, N., Libero, C., Livigni, C., Frouzaki, N. E., & Aguayo, E. (2025). Sustainable fortification of corn tortillas with broccoli by-products. *Foods*, *14*(5), 799.

Gliszczyńska-Swigło, A., Ciska, E., Pawlak-Lemańska, K., Chmielewski, J., Borkowski, T., & Tyrakowska, B. (2006). Changes in the content of health-promoting compounds and antioxidant activity of broccoli after domestic processing. *Food additives and contaminants*, *23*(11), 1088-1098.

Gomes, M. H., & Rosa, E. (2001). Free amino acid composition in primary and secondary inflorescences of 11 broccoli (*Brassica oleracea* var *italica*) cultivars and its variation between growing seasons. *Journal of the Science of Food and Agriculture*, *81*(3), 295-299.

Gray, A. R. (1982). Taxonomy and evolution of broccoli (*Brassica oleracea* var. *italica*). *Economic Botany*, *36*(4), 397-410.

Heredia, A., Castelló, M. L., Argüelles, A., & Andrés, A. (2014). Evolution of mechanical and optical properties of French fries obtained by hot air-frying. *LWT-Food Science and Technology*, *57*(2), 755-760.

Hesse, P. R. (1971). *A textbook of soil chemical analysis*. J. Murray (Publishers) Ltd.

Hong, S. J., Jeong, H., Yoon, S., Jo, S. M., Lee, Y., Park, S. S., & Shin, E. C. (2022). A comprehensive study for taste and odor compounds using electronic tongue and nose in broccoli stem with different thermal processing. *Food Science and Biotechnology*, *31*(2), 191-201.

Hwang, J. H., & Lim, S. B. (2015). Antioxidant and anticancer activities of broccoli by-products from different cultivars and maturity stages at harvest. *Preventive Nutrition and Food Science*, *20*(1), 8-14.

Ismail, M., & Kucukoner, E. (2017). Falafel: A meal with full nutrition. *Food and Nutrition Sciences*, *8*(11), 1022-1032.

Kalala, G., Kambashi, B., Everaert, N., Beckers, Y., Richel, A., Pachikian, B., ... & Bindelle, J. (2018). Characterization of fructans and dietary fibre profiles in raw and steamed vegetables. *International Journal of Food Sciences and Nutrition*, *69*(6), 682-689.

Katz, D. L., & Gonzalez, M. H. (2002). *Way to eat: A six-step path to lifelong weight control*. Sourcebooks, Inc.

Keeney, D. R., & Nelson, D. W. (1982). Nitrogen—inorganic forms. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of soil analysis. Part 2. Chemical and microbiological properties* (2nd ed., Agronomy Monograph 9, pp. 643–698). American Society of Agronomy; Soil Science Society of America.

Khalaf, H. H. A., El Saadani, R. M. A., Anwar, M. M., & Aly, H. (2018). Physico-chemical and organolyptical characteristics of cake fortified by irradiated broccoli (*Brassica oleracea* L. Var *Italica*) Powder. *Middle East Journal of Applied Sciences, 6*(1), 13-29.

Koh, E., Wimalasiri, K. M. S., Chassy, A. W., & Mitchell, A. E. (2009). Content of ascorbic acid, quercetin, kaempferol and total phenolics in commercial broccoli. *Journal of Food Composition and Analysis*, *22*(7-8), 637-643.

Krupa-Kozak, U., Altamirano-Fortoul, R., Wronkowska, M., & Rosell, C. M. (2012). Breadmaking performance and technological characteristic of gluten-free bread with inulin supplemented with calcium salts. *European Food Research and Technology*, *235*, 545-554.

Kundu, P., Mukherjee, A., Adhikary, N., Ghosal, A., & Sahu, N. (2022). Morpho-chemical characterization of broccoli (*Brassica oleracea* var. *italica*). *Annals of Plant and Soil Research*, *24*(1), 110–115.

Latté, K. P., Appel, K. E., & Lampen, A. (2011). Health benefits and possible risks of broccoli–an overview. *Food and Chemical Toxicology*, *49*(12), 3287-3309.

Le, T. N., Luong, H. Q., Li, H. P., Chiu, C. H., & Hsieh, P. C. (2019). Broccoli (*Brassica oleracea* L. var. *italica*) sprouts as the potential food source for bioactive properties: A comprehensive study on in vitro disease models. *Foods*, *8*(11), 532.

Lebesi, D. M., & Tzia, C. (2011). Effect of the addition of different dietary fiber and edible cereal bran sources on the baking and sensory characteristics of cupcakes. *Food and Bioprocess Technology*, *4*(5), 710-722.

Lee, K. W., Hur, H. J., Lee, H. J., & Lee, C. Y. (2005). Antiproliferative effects of dietary phenolic substances and hydrogen peroxide. *Journal of Agricultural and Food Chemistry*, *53*(6), 1990-1995.

Mahfouz, M., Abd-Elnoor, A. V., & Abd El-Razek, R. I. (2019). The influence of adding turnip roots (*Brassica rapa* var. *rapa* L.) powder on the antioxidant activity and acrylamide content in some fried foods. *Alexandria Science Exchange Journal*, *40*(October-December), 717-730.

Malghani, N., Mahesar, S., Baig, J., Talpur, F., Sherazi, S. T. H., & Junaid, M. (2022). Nutritional assessment and proximate analysis of selected vegetables grown in Larkana, Sindh, Pakistan. *Journal of the Turkish Chemical Society Section A: Chemistry*, *9*(4), 985-998.

Mangla, B., Javed, S., Sultan, M. H., Kumar, P., Kohli, K., Najmi, A., ... & Ahsan, W. (2021). Sulforaphane: A review of its therapeutic potentials, advances in its nanodelivery, recent patents, and clinical trials. *Phytotherapy Research*, *35*(10), 5440-5458.

Mansour, A. A., Shekib, L. A., Elshimy, N. M., & Sharara, M. S. (2017). Biological evaluation of raw and steamed broccoli and cauliflower as sources of dietary fibers. *Journal of Food and Dairy Sciences*, *8*(4), 185-190.

Marchioni, I., Martinelli, M., Ascrizzi, R., Gabbrielli, C., Flamini, G., Pistelli, L., & Pistelli, L. (2021). Small functional foods: Comparative phytochemical and nutritional analyses of five microgreens of the Brassicaceae family. *Foods*, *10*(2), 427.

Murcia, M. A., López-Ayerra, B., & García-Carmona, F. (1999). Effect of processing methods and different blanching times on broccoli: Proximate composition and fatty acids. *LWT-Food Science and Technology*, *32*(4), 238-243.

Murcia, M. A., Vera, A., & Garcia-Carmona, F. (1992). Effect of processing methods on spinach: Proximate composition in fatty acids and soluble protein. *Journal of the Science of Food and Agriculture*, *59*(4), 473-476.

Nooprom, K., & Santipracha, Q. (2014). Growth and yield of broccoli planted year round in Songkhla province, Thailand. *Research Journal of Applied Sciences, Engineering and Technology*, *7*(19), 4157-4161.

Quizhpe, J., Ayuso, P., Rosell, M. D. L. Á., Peñalver, R., & Nieto, G. (2024). *Brassica oleracea* var. *italica* and their by-products as source of bioactive compounds and food applications in bakery products. *Foods*, *13*(21), 3513.

Raiola, A., Errico, A., Petruk, G., Monti, D. M., Barone, A., & Rigano, M. (2017). Bioactive compounds in Brassicaceae vegetables with a role in the prevention of chronic diseases. *Molecules*, *23*(1), 15.

Sánchez-Bravo, P., Abellan, A., Zapata, P. J., Garcia-Viguera, C., Dominguez-Perles, R., & Giménez, M. J. (2023). Broccoli products supplemented beers provide a sustainable source of dietary sulforaphane. *Food Bioscience*, *51*, 102259.

Santamaria, M., Ruiz, M., Garzon, R., & Rosell, C. M. (2024). Comparison of vegetable powders as ingredients of flatbreads: Technological and nutritional properties. *International Journal of Food Science and Technology*, *59*(10), 7203-7212.

Singh, J., Upadhyay, A. K., Prasad, K., Bahadur, A., & Rai, M. (2007). Variability of carotenes, vitamin C, E and phenolics in Brassica vegetables. *Journal of Food Composition and Analysis*, *20*(2), 106-112.

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American journal of Enology and Viticulture*, *16*(3), 144-158.

Souci, S. W., Fachmann, W., & Kraut, H. (2000). *Food composition and nutrition tables* (6th ed., pp. xxx+-1182).

Tilg, H. (2015). Cruciferous vegetables: Prototypic anti-inflammatory food components. *Clinical Phytoscience*, *1*(1), 1-6.

Udousoro, I., & Ekanem, P. (2013). Assessment of proximate compositions of twelve edible vegetables in Nigeria. *International Journal of Modern Chemistry*, *4*(2), 79-89.

West, L., Tsui, I., Balch, B., Meyer, K., & Huth, P. J. (2002). Determination and health implication of the erucic acid content of broccoli florets, sprouts, and seeds. *Journal of Food Science*, *67*(7), 2641-2643.

Xu, J., Rong, S., Gao, H., Chen, C., Yang, W., Deng, Q., ... & Huang, F. (2017). A combination of flaxseed oil and astaxanthin improves hepatic lipid accumulation and reduces oxidative stress in high fat-diet fed rats. *Nutrients*, *9*(3), 271.

Yu, X., Li, L., Xue, J., Wang, J., Song, G., Zhang, Y., & Shen, Q. (2020). Effect of air-frying conditions on the quality attributes and lipidomic characteristics of surimi during processing. *Innovative Food Science & Emerging Technologies*, *60*, 102305.

Zhang, S., Ying, D. Y., Cheng, L. J., Bayrak, M., Jegasothy, H., Sanguansri, L., & Augustin, M. A. (2020). Sulforaphane in broccoli-based matrices: Effects of heat treatment and addition of oil. *LWT*, *128*, 109443.

Zhou, K., & Yu, L. (2006). Total phenolic contents and antioxidant properties of commonly consumed vegetables grown in Colorado. *LWT-Food Science and Technology*, *39*(10), 1155-1162.

Zouari, R., Besbes, S., Ellouze-Chaabouni, S., & Ghribi-Aydi, D. (2016). Cookies from composite wheat–sesame peels flours: Dough quality and effect of *Bacillus subtilis* SPB1 biosurfactant addition. *Food Chemistry*, *194*, 758-769.

تأثير إستخدام زهيرات البروكلي على الخصائص الكيميائية والحسية للكب كيك و الفلافل

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الملخص

تهدف هذه الدراسة الي تحديد التركيب الكيميائي وبعض المكونات الفعالة ومضادات الاكسدة الموجودة في نوعين من البروكلي , ومعرفة امكانية صنع الكب كيك والفلافل المكملة بمسحوق البروكلي وكذلك التقييم الحسي لها وقياس التركيب الكيميائي لهذه المنتجات. يحتوي البروكلي علي كميات كبيرة من الالياف والمعادن والمكونات الفعالة المهمة ,لكن استخدامة في المنتجات الغذائية لا يزال محدودا علي الرغم من فائدتة. . تم تحضير ثلاثة عينات من كل منتج سواء كان كب كيك او فلافل مدعمة بنسب مختلفة من مسحوق البروكلي (٥٪, ١٠٪, ١٥٪) عن طريق استبدال وزن مكافئ من الدقيق الابيض في الكب كيك او عجينة الطعمية في الفلافل بهذه النسب المئوية من مسحوق البروكلي . وتم قياس التقييم الحسي والتركيب الكيميائي للكب كيك والفلافل. كان الكب كيك والفلافل المكملة بمسحوق البروكلي ٥٪ اكثر قبولا لدي المستهلك من العينات الاخرى , حيث بلغ متوسط القيم الحسية للكب كيك المكمل بنسبة ٥٪ من البروكلي من حيث المظهر (٨,١٢±٠,١٥), اللون (٨,٢١±٠,١٢),النكهه (٨,٠٣±٠,١٧) ,الطعم (٧,٦٢±٠,١٩) ,الملمس (٨,٠٦±٠,١٦) والمظهر العام (٧,٤٣±٠,١٣) , بينما الفلافل المكملة بنسبة ٥٪ من مسحوق البروكلي كان لديها تطورا حسيا عاليا حيث سجل المظهر واللون والنكهة والطعم والملمس والقرمشة والقبول العام (٩,١٠±٠,١٥), (٩,١٠±٠,٧), (٨,٧٠±٠,١٩), (٨,٥٣±٠,٢٧) , (٨,٨٣±٠,٢٤), (٨,٥٧±٠,٢٦) (٨,٦٧±٠,١٤) علي التوالي . كما اوضح التركيب الكيميائي لكل من الكب كيك والفلافل المدعمة بمسحوق البروكلي ارتفاع في البروتين والالياف في الكب كيك المكملة بنسبة ١٥٪ من البروكلي وارتفاع في الالياف والدهن في الفلافل كلما ذادت نسبة التدعيم بمسحوق البوكلي. لذلك توصي هذه الدراسة بالستخدام البروكلي كمصدر جيد للعناصر الغذائية ومضادات الاكسدة الطبيعية لأنتاج بعض الأغذية مثل الفلافل والكب كيك.

الكلمات الدالة : مسحوق البروكلي , الكب كيك, الفلافل , المحتوي الغذائي , التقييم الحسي