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ABSTRACT

This study aimed to assess the chemical composition of chicory leaves and their potential benefit as a food ingredient in bakery products such as pies and crackers, to enhance their nutritional value. The proximate chemical composition, total phenolic content, minerals, antioxidant activity, and essential/non-essential amino acids of both chicory leaves powder and bakery products fortified with chicory leaves powder were analyzed. The results demonstrated that chicory leaves are a rich source of protein (11.60%) and minerals, including Fe (41.12 mg/100g), K (77.04 mg/100g), Mg (31.25 mg/100g), Mn (18.46 mg/100g), Ca (14.27 mg/100g), and Zn (12.35 mg/100g) on a dry weight basis. Additionally, chicory leaves exhibited significant DPPH radical scavenging activity (42.25%) and contained a substantial amount of total phenolic compounds (857.38 mg/100g). Notably, essential amino acids, particularly leucine, and phenylalanine, were found in high levels (0.403 and 0.436 mg/100g, respectively) in chicory leaves powder, while non-essential amino acids, such as aspartic acid and glutamic acid, were present at levels of 1.355 and 0.799 mg/100g, respectively. Sensory evaluation indicated that bakery products fortified with 2.5% chicory leaf powder received favorable acceptance, whereas those fortified with 5% and 7.5% were less preferred. Depending on this evaluation and farinograph results, this study focused on using bakery products fortified with 2.5% chicory leaf powder. This study underscores the significance of further research and experimentation to develop high-nutritional-value products like pies and crackers fortified with chicory leaves. `

Keywords: Chicory leaves, bakery products, nutritional value, sensory evaluation, rheological properties, farinograph.

1. INTRODUCTION

Vegetables have long been considered a dietary staple for humans since ancient times, particularly Mediterranean plants known for their abundant nutrients and beneficial components. They are widely recognized for their highly effective promotion of health and well-being **(Guarrera & Savo, 2016)**. Leafy vegetables, in particular, are rich in essential minerals such as calcium and iron, and they contain numerous beneficial compounds associated with various health benefits. These compounds can aid in managing various health conditions **(Natesh et al., 2017).** In recent times, there has been a growing interest in wild edible plants and a better understanding of the beneficial properties of their phytochemical substances. Consequently, these plants are now regarded as "new functional foods" due to their ability to provide health benefits beyond basic nutrition, which contain bioactive compounds with physiological effects **(Khalifa et al., 2022).** Chicory (*Cichorium intybus L.*), a Mediterranean plant belonging to the Asteraceae family and part of the cichorieae tribe, which encompasses numerous species, is frequently utilized as a salad vegetable **(Carazzone et al., 2013).** Wild edible plants such as succory or Hendibeh are consumed in different regions worldwide, including Lebanon and Arab countries. They can naturally grow in diverse environments such as fields, roadsides, and home gardens. In addition to their culinary uses, these plants are recognized as functional ingredients in the food industry. They contribute to dietary fiber and other nutrients that promote a healthy and well-balanced diet **(Bais & Ravishankar, 2001).** Chicory is a resilient plant that thrives in harsh weather conditions, making it a favored winter vegetable in many countries **(Hammer et al., 2013).** It possesses numerous medicinal and nutritional properties, offering potential benefits in reducing the risk of chronic diseases such as arthritis and cancer **(Francis et al., 2014).** The plant's anti-inflammatory and antioxidant properties contribute to its protective effects against these conditions. Its bioactive compounds exhibit radical scavenging and antioxidant activities known to promote health **(Ferioli & D'Antuono, 2012).** The name "Chicory" originates from

the Egyptian term "Ctchorium," and all parts of the plant contain a diverse range of nutrients and compounds. These include inulin, flavonoids, terpenoids, vitamins, steroids, oils, volatile compounds, and lactones. Both the leaves and roots of chicory can be utilized as functional and medicinal ingredients **(Minaiyan et al., 2012).** Moreover, chicory boasts a rich nutritional profile, containing various essential nutrients such as magnesium, calcium, sodium, zinc, copper, selenium, manganese, nitrogen, phosphorus, potassium, iron, sulfur, boron, and tannins **(Janda et al., 2021).** Therefore, the objective of this study is to explore the incorporation of chicory leaves as a functional food ingredient to enhance the nutritional value of bakery products, including pies and crackers.

2. MATERIALS AND METHODS

2.1. Materials:

The materials utilized in this study consisted of fresh leaves obtained from the chicory (*Cichorium intybus* L) plant, as shown in photo (1). These leaves were collected from the Faculty of Agriculture at Ain-Shams University in Cairo. Other ingredients included wheat flour, baking powder, sugar, sunflower oil, butter, yeast, eggs, cheese, and sesame seeds. These ingredients were sourced from a local market in Alexandria, Egypt. All chemicals and reagents used in the present study were of analytical grade and purchased from El-Gomhouria Company.

Photo (1): Chicory plant (*Cichorium intybus L.)* (Aldahak et al., 2021)

2.2. Methods:

2.2.1 Preparation of samples:

After obtaining the chicory plant from the Faculty of Agriculture at Ain-Shams University, the fresh leaves were carefully separated using a sharp knife. Immediately following separation, the leaves were thoroughly washed with tap water to ensure cleanliness and remove any impurities. Subsequently, the fresh chicory leaves were dried in a hot air oven set at a temperature of 60°C for 48 h approximately. After the drying process, the leaves were ground into a fine powder. The powdered leaves were carefully packed and stored at ambient room temperature for further analysis.

2.2.2. Preparing of pies fortified with dried chicory leaves:

The pies were prepared using the method outlined in the **A.A.C.C. (2012)** guidelines. To make the pies, wheat flour was sifted and placed in a mixing bowl with different percentages of dried chicory leaves powder instead of wheat flour. Dry yeast, salt, one egg, and oil were added and mixed for one minute. The necessary amount of water was added to form the dough. The pie dough was then fermented at 37°C for 30 minutes. After fermentation, the dough was rolled out, and butter and cheese were placed on it. The dough was then rolled up, divided, and left to ferment again for approximately 30 minutes. Finally, the pies were shaped and baked at 200 °C for 25 minutes. The composition of pies is presented in Table 1.

2.2.2. Preparing of crackers fortified with dried chicory leaves:

The method used was based on the technique described by **Isik and Topkaya (2016).** In a mixing bowl, wheat flour was sifted and placed in a mixing bowl with different percentages of dried chicory leaves powder instead of wheat flour. liquid ingredients (oil and water) and butter were combined and mixed for two minutes. The dry ingredients were then added and kneaded until dough was formed. The dough was allowed to rest for ten minutes before being rolled out to a thickness of no more than 1/4 inch. It was then cut into circles and triangles, and sesame seeds were sprinkled on top. The crackers

were baked in an oven at 180°C for 10 minutes. After baking, the crackers were cooled to room temperature before further analysis (refer to Table 2).

Table (1): Ingredients of pies fortified with dried chicory leaves

Ingredients	C.P	P.D.C.L (2.5%)	P.D.C.L (5%)	P.D.C.L (7.5%)
Wheat flour (72%) (g)	100	98.5	95	92.5
Sunflower oil (ml)	10	10	10	10
Butter (g)	3	3	3	3
Yeast (g)	2	2	2	2
Egg	1	1	1	1
Water (ml)	50	50	50	50
Salt (g)	2	2	2	2
Cheese (g)	15	15	15	15
Sesame (g)	1	1	1	1
Chicory leaves (g)		2.5	5	7.5

Where: C. P = Control pies, P.D.C. L= Pies with dried chicory leaves

Table (2): Ingredients of crackers fortified with dried chicory leaves

Ingredients	C.C	C.D.C.L (2.5%)	C.D.C.L (5%)	C.D.C.L (7.5%)
Wheat flour (72%) (g)	100	98.5	95	92.5
Butter (g)	3	3	3	3
Sugar (g)	1	1	1	1
Sunflower oil (ml)	20	20	20	20
Salt (g)	3	3	3	3
Baking powder (g)	1	1	1	1
Water (ml)	50	50	50	50
Sesame (g)	1	1	1	1
Chicory leaves (g)		2.5	5	7.5

Where: C.C= Control crackers, C.D.C. L= Crackers with dried chicory leaves.

2.2.4. Sensory evaluation of food products fortified with chicory leaves:

Two food products (pies and crackers) fortified with dried chicory leaves were prepared and assessed for overall acceptability. The sensory evaluation was conducted by 30 individuals, including staff and students from the Faculty of Specific Education at Alexandria University. Various parameters such as appearance, color,

taste, odor, texture, and overall acceptability were considered during the evaluation. A 9-point hedonic scale was used, with a range from 1 (indicating extreme dislike) to 9 (indicating extreme like), to rate the sensory attributes. The chemical analysis will focus on the attributes that received the highest scores in terms of overall acceptability **(watts et al., 1989).**

2.2.5. Farinograph test for rheological properties of flour and dough:

Farinograph tests were conducted using a Brabender R farinograph to measure various parameters to assess the dough properties such as water absorption, dough development time, dough stability, and dough weakening. The absorption values were adjusted and estimated on a 14% moisture basis using the specified equation from **A.A.C.C (2000)** guidelines. **% Absorption** = (x + y - 300)/ 3. Where X, ml of water is required to produce a curve with maximum consistency entered on 500 B.U. line y, grams of flour equivalent to 300 grams 14% moisture basis.

2.2.6. approximate analysis:

Chemical analysis was performed on all the materials used in this study, including dried chicory and the two final products such as pies, and crackers. The moisture content of the samples was determined using the **AOAC (2012)** method. This involved drying the samples in an oven at 60°C, transferring them to a desiccator for cooling, and then reweighing to calculate the moisture content. The crude protein content was determined using the micro-Kjeldahl method, while the total fat content was analyzed using the Soxhlet extraction method with petroleum ether as the solvent. The total ash content was determined by igniting the samples in a muffle furnace, and the carbohydrate content was calculated by the difference method. Finally, the crude fiber content was evaluated using a modified method according to **(Jangra & Madan., 2018).** involving acid and alkali treatments, filtration, drying, and ignition. The respective equations and procedures were followed as per the **AOAC (2012**) guidelines. These analyses provided valuable insights into the

chemical composition of the samples, enabling a comprehensive understanding of their nutritional characteristics.

2.2.7. Determination of minerals:

Mineral analysis of iron (Fe), zinc (Zn), calcium (Ca), magnesium (Mg), manganese (Mn), and potassium (K) was conducted using the Perkin Elmer Atomic Absorption Spectrophotometer (A.A.S) (Model 2380, Germany) and the flame photometer (model PE P7, England). The A.A.S system utilized a hollow mono-element cathode lamp (Hollow Cathode Lamp, England), and an air-acetylene flame with specific pressure ratios. The wavelengths used for each element were 248.3 nm (Fe), 213.9 nm (Zn), 422.7 nm (Ca), 285.2 nm (Mg), 279.5 nm (Mn), and 766.5 nm (K). These conditions, along with the detection limits, were employed to measure the mineral concentrations in the samples accurately **(Fernandez-Hernandez et al., 2010)**

2.2.8. Amino acid analysis:

The sample (1 gram) was mixed with 5 mL hexane and allowed to macerate for 24 hours. After filtration, the residue was incubated with 10 mL 6N HCl at 110°C for 24 hours. The resulting solution was filtered, evaporated, and dissolved in 100 mL dilution buffer. A 1 mL aliquot was further diluted in a 10 mL volumetric flask, filtered, and 100 µl was injected. Amino acid analysis was performed using the Sykam Amino Acid Analyzer equipped with various components including a solvent delivery system, autosampler, amino acid reaction module, and refrigerated reagent organizer. The analyzer allowed for accurate measurement of amino acid concentrations **(El-Naggar et al., 2017)**

2.2.9. Antioxidant activity:

Two methods for measuring the antioxidant activity including 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging described by **Brand-Williams et al., (1995).** And the Folin–Ciocalteu method to determine total phenolic content was according to **Arabshahi -Delouee and Urooj (2007**).

2.2.10. Determination of vitamins:

Vitamin B complex group was measured by HPLC Series (Agilent, USA), equipped with a Quaternary pump, C18 BDS (100 mm x 4.6 mm) (Phenomenex®, USA), operated at 350 C. Water-soluble vitamins are separated on a Lichrosorb RP-18 250x4.0 mm, The injected volume was 20µL **(Papadoyannis et al., 1997)**. Fat-soluble vitamins E and A were measured by column C18 hyper sail BDS with particle size 5 µm according to **(Afify et al., 2012)**. Vitamin D was determined on a (250 x 4.6mm) 5µm particle, ultra-base C18 analytical column (Scharlau Science, Spain). The injection volume was 100 µm **(Gámiz-Gracia et al., 2000)** for the extraction of vitamin K by hexane according to **(Gijsbers et al., 1996).**

2.2.11. Statistical Analysis:

The results were analyzed by the Statistical Package for the Social Sciences SPSS Software Version (26). Means ± standard deviation (S.D.) and using a one-way analysis of variance (ANOVA) followed by the Duncan test **(Kirkpatrick & Feeney, 2013).**

3. RESULTS AND DISCUSSION

3.1. Sensory Evaluation of Pies fortified with 2.5%, 5% and 7.5% of Dried Chicory Leaves:

Table (3) presents the results of a sensory evaluation conducted on pies fortified with different percentages of dried chicory leaves (2.5%, 5%, and 7.5%). The sensory evaluation assessed various attributes including appearance, color, taste, odor, texture, and overall acceptability. The control pies (C.P.) received consistent ratings in all sensory attributes, with scores ranging from 7.70 to 8.17. The pies fortified with 2.5% dried chicory leaves (P.D.C.L (2.5%)) showed similar ratings to the control pies, with scores ranging from 7.80 to 8.17. These scores indicate that the addition of 2.5% dried chicory leaves did not significantly affect the sensory attributes. Similarly, the pies fortified with 5% dried chicory leaves (P.D.C.L (5%)) and 7.5% dried chicory leaves (P.D.C.L (7.5%)) also received comparable

ratings to the control pies. The scores for appearance, color, taste, odor, texture, and overall acceptability remained relatively consistent across all samples. The statistical analysis indicates that there are no significant differences ($p \geq 0.05$) in sensory attributes among the different samples. This suggests that the addition of dried chicory leaves at 2.5%, 5%, and 7.5% did not have a significant impact on the sensory qualities of the pies. Overall, the results suggest that the fortification of pies with dried chicory leaves at different percentages did not result in noticeable changes in sensory attributes such as appearance, color, taste, odor, texture, and overall acceptability. The sensory quality of the pies remained consistent across all samples, indicating that dried chicory leaves can be incorporated into pies without negatively affecting their sensory appeal. **Sayed and Khali (2017)** conducted a study that revealed that there were no significant differences in sensory attributes (such as texture, color, appearance, and taste) between the control cookies and the samples where up to 40% of fat was replaced with inulin. The study also found that the sensory quality of these cookies was well accepted by the panel of evaluators.

Table (3): Sensory evaluation of pies fortified with 2.5%, 5%, and 7.5% of dried chicory leaves

Samples	The ratios	Sensory evaluation					
		Appearance	Color	Taste	Odor	Texture	Overall Acceptability
C.P	Control	$7.70^{a}\pm0.221$	$7.83^{a}\pm0.209$	$7.93^{a}\pm0.225$	$7.80^{a}\pm0.182$	$8.03^{a}\pm0.195$	$8.17^{a}\pm0.152$
P.D.C. L	(2.5%)	$7.93^{a}\pm0.197$	$7.90^{a}\pm0.200$	$8.07^{a}\pm0.166$	$7.80^{a}\pm0.188$	$8.13^{a}\pm0.142$	$8.17^{a}\pm0.145$
P.D.C. L	(5%)	$7.80^{a}\pm0.200$	$7.77^{a}\pm0.196$	$7.60^{a}\pm0.189$	$7.77^{a}\pm0.196$	$7.93^{a}\pm0.159$	$8.07^{a}\pm0.172$
P.D.C. L	(7.5%)	$7.83^{a}\pm0.173$	$7.93^{a}\pm0.203$	$7.77^{a}\pm0.196$	$7.37^{a}\pm0.260$	$7.77^{a}\pm0.202$	$7.90^{a}\pm0.175$
	F	0.235	0.134	1.079	1.026	0.790	0.606
	P	0.872	0.940	0.361	0.384	0.502	0.612

Data were expressed using Mean ±SE, F.F test (DUCAN), C. P = Control Pies, P.D.C.L= Pies fortified with Dried Chicory Leaves

Photo (2): **C.P**

Photo (3): **P.D.C.L (2.5%)**

Photo (4): **P.D.C.L (5%)**

Photo (5): **P.D.C.L (7.5%)**

Photos (2, 3, 4, and 5): Sensory evaluation of pies fortified with 2.5%, 5% and 7.5% of dried chicory leaves.

3.2. Sensory evaluation of crackers fortified with 2.5%, 5%, and 7.5% of dried chicory leaves:

Table (4) presents the results of a sensory evaluation conducted on crackers fortified with different percentages of dried chicory leaves (2.5%, 5%, and 7.5%). The sensory evaluation assessed various attributes including appearance, color, taste, odor, texture, and overall acceptability. The control crackers (C.C.) received high ratings in all sensory attributes, with scores ranging from 8.03 to 8.43. The crackers fortified with 2.5% dried chicory leaves (C.D.C. L (2.5%)) showed similar ratings to the control crackers, with scores ranging from 8.23 to 8.47. These scores indicate that the addition of 2.5% dried chicory leaves did not significantly impact the sensory attributes. However, as the percentage of dried chicory leaves increased to 5% and 7.5%, there were noticeable decreases in sensory scores. The crackers fortified with 5% dried chicory leaves (C.D.C. L (5%)) received lower scores in appearance, color, taste, odor, texture, and overall acceptability compared to the control crackers. The

lowest scores were observed in the crackers fortified with 7.5% dried chicory leaves (C.D.C. L (7.5%)), indicating a further decline in sensory quality. The statistical analysis indicates that there are significant differences ($p \leq 0.001$) in sensory attributes among the different samples, except for odor and texture, where the differences were not statistically significant. Overall, the results suggest that the addition of up to 2.5% dried chicory leaves to the crackers did not significantly affect their sensory attributes. However, higher percentages (5% and 7.5%) negatively impacted the sensory quality, particularly in terms of appearance, color, texture, and overall acceptability. **Ivanišová et al., (2020)** found that there were no differences in taste, flavor, and overall acceptability in biscuits fortified with 1% and 3% of chicory fiber. However, the taste varied significantly in biscuits fortified with 5% chicory fiber, with some evaluators perceiving a bitter taste. Also, **Abo Taleb et al., (2017)** reported that there were no significant differences in taste and odor between natural crispy snacks fortified with chicory leaves powder at levels of 1%, 3%, and 5%. However, there was a significant difference in overall palatability and color between the natural crispy snacks fortified with 5% chicory leaves powder and those fortified with 1% and 3%, as well as the control sample.

Table (4): Sensory evaluation of crackers fortified with 2.5%, 5% and 7.5% of dried chicory leaves

Samples	The Ratios	Sensory evaluation					
		Appearance	Color	Taste	Odor	Texture	Overall Acceptability
C.C	Control	8.33^{a}±0.154	7.93^{b}±0.179	8.03^{ab}±0.182	8.10^{a}±0.147	8.27^{a}±0.151	8.43^{a}±0.141
C.D.C. L	(2.5%)	8.23^{a}±0.157	8.47^{a}±0.104	8.37^{a}±0.148	7.93^{a}±0.172	8.30^{a}±0.153	8.40^{a}±0.123
C.D.C. L	(5%)	8.00^{a}±0.209	7.77^{b}±0.190	7.60^{bc}±0.223	7.63^{ab}±0.222	7.80^{ab}±0.222	7.93^{ab}±0.197
C.D.C. L	(7.5%)	7.33^{b}±0.221	7.23^{c}±0.233	7.23^{c}±0.252	7.30^{b}±0.226	7.67^{b}±0.205	7.50^{b}±0.243
	F	5.743	7.740	5.831	3.273	3.025	5.848
	P	≤0.001	≤0.001	≤0.001	0.024	0.032	≤0.001

Data were expressed using Mean ±SE, F.F test (DUCAN), C.C= Control crackers, C.D.C. L= Crackers fortified with dried chicory leaves

Photo (6): C.B

Photo (7): C.D.C.L (2.5%)

Photo (8): C.D.C.L (5%)

Photo (9): C.D.C.L (7. 5%)

Photos (6, 7, 8 and 9): Sensory evaluation of crackers fortified with 2.5%, 5% and 7.5% of dried chicory leaves.

3.3. Farinograph Values of Wheat Flour (WF) fortified with Dried Chicory Leaves at (2.5%), (5%) and (7.5%).

Table (5) presents the farinograph values of wheat flour (WF) fortified with dried chicory leaves at different concentrations: 2.5%, 5%, and 7.5%. The farinograph values provide information about the rheological properties of the dough during mixing and processing. They are important indicators of the dough's behavior, stability, and tolerance to mixing. From Table (5), it can be observed that the water absorption increased as the concentration of dried chicory leaves in the flour increased from 61.5% to 71%. This suggests that the dough required more water to reach the desired consistency and hydration level. The arrival time, which represents the time taken for the dough to reach a certain consistency, remained constant across most samples. The dough stability, which measures the dough's ability to resist changes in its properties over time, decreased with the addition of dried chicory leaves from 13 to 4.5 min. This indicates that the dough became less stable and more prone to changes during mixing and processing. The mixing tolerance, which indicates the dough's resistance to mechanical stress during mixing, increased with the addition of dried chicory leaves. This implies that the dough became more tolerant and could withstand longer mixing times without detrimental effects. The degree of softening, which represents the weakening of the dough structure during mixing, showed variations with the addition of dried chicory leaves. The lowest degree of softening was observed in the control sample 40, while the fortified samples exhibited higher values 120 **(B.U**), it can be concluded that the control sample had the highest degree of dough structure stability, while the samples fortified with dried chicory leaves exhibited higher degrees of softening. Overall, the fortification of wheat flour with dried chicory leaves influenced the Farinograph values, suggesting changes in the dough's water absorption, stability, tolerance, and softening. These changes can impact the processing characteristics and final quality of the dough and the products made from it. **Ivanišová et al., (2021)** found that the water absorption of bread dough increased with the addition of inulin. The water absorption increased from 58.6% in the control sample to 61.8% when 25% of inulin was added to the

flour. However, the other farinographic values such as dough development time, stability, degree of softening, and farinograph quality number were only informative in the control sample. The farinograph with inulin addition showed nonstandard and distorted values, indicating that the presence of inulin affected the farinographic characteristics in a specific and unique way. Also, **Reza et al., (2014)** reported that water absorption was increased by adding inulin at 1%, 2.5% and 5% in pasta dough when compared with control pasta. On the other hand, the dough stability was decreased in pasta dough at 2.5% and 5% and increased in pasta dough at 1%.

Table (5): Farinograph values of wheat flour (WF) fortified with dried chicory leaves at (2.5%), (5%), and (7.5%)

Samples	Water Absorption (%)	Arrival time (min)	Dough Stability (min)	Mixing tolerance	Degree Softening (B.U)
C.W.F	61.5	2.0	13.0	30	40
W.F.D.C.L (2.5%)	64.5	2.0	7.0	70	90
W.F.D.C.L (5%)	67.5	2.0	6.0	120	110
W.F.D.C.L (7.5%)	71	2.5	4.5	120	120

Where: C.W.F= Control wheat flour, W.F.D.C.L = wheat flour fortified with dried chicory leaves,

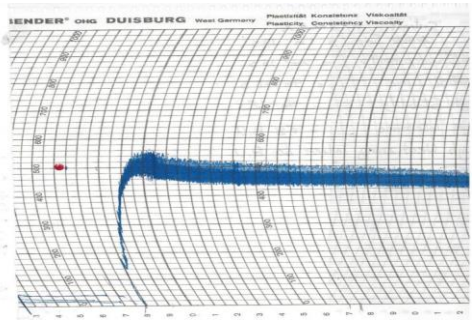

Figure (1): Farinograph of wheat flour.

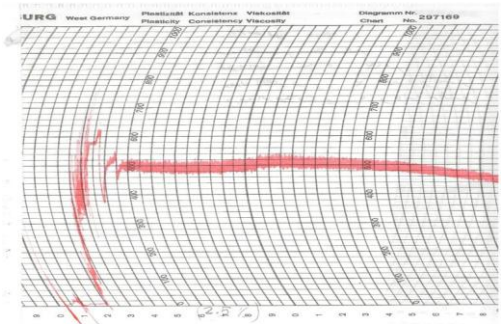

Figure (2): Farinograph of wheat flour fortified with dried chicory leaves at (2.5%).

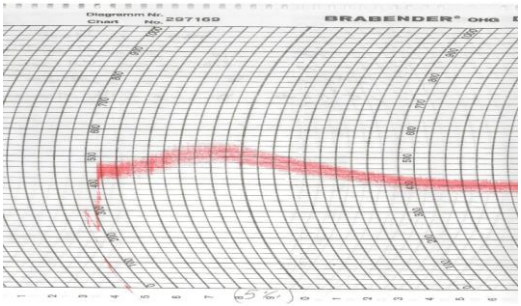

Figure (3): Farinograph of wheat flour fortified with dried chicory leaves at (5%).

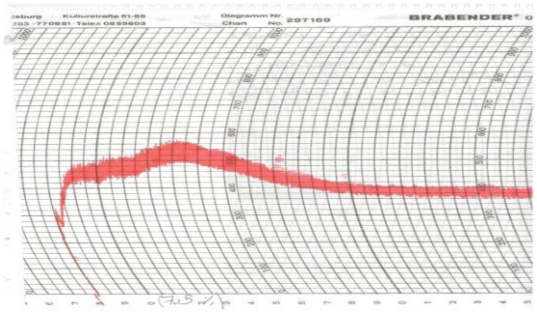

Figure (4): Farinograph of wheat flour fortified with dried chicory leaves at (7.5%).

3.4. Chemical composition of chicory leaves, Pies, and Crackers fortified with Dried Chicory Leaves 2.5%

The chemical composition of dried chicory leaves was determined, and the results are presented in Table 6. The moisture, crude protein, total fat, ash, carbohydrate, and crude fiber contents were found to be

11.13%, 11.60%, 11.40%, 14.32%, 51.55%, and 14.05% respectively. These findings are consistent with previous studies conducted by **Ziena et al., (2021), Nwafor et al., (2017),** and **Mahmoud (2018).** It should be noted that the chemical composition of chicory leaves can vary due to various environmental factors such as pH, soil characteristics, irrigation, fertilization, and climate, as discussed by **Tuncturk et al. (2018).** The pies made with 2.5% dried chicory leaves had slightly lower moisture content compared to the control sample, with values of 25.87% and 27.94% respectively. This decrease in moisture can be attributed to the baking temperature. On the other hand, the pies made with 2.5% dried chicory leaves had higher levels of crude protein, total fat, ash, carbohydrate, and crude fiber compared to the control sample. The values for these components in the pies with dried chicory leaves were 4.45%, 9.23%, 1.69%, 58.76%, and 0.42% respectively, while the control sample had values of 4.20%, 8.97%, 1.37%, 57.51%, and 0.29% respectively. The crackers made with 2.5% dried chicory leaves had a lower moisture content (5.05%) compared to the control sample (5.82%), which can be attributed to the baking temperature. Additionally, the protein content increased from 3.49% in the control sample to 3.78% in the crackers with dried chicory leaves. The total fat content increased slightly from 18.51% to 18.55%, while the ash content increased from 2.91% to 2.99%. The carbohydrate content increased from 69.26% to 69.63%, and the crude fiber content increased from 0.58% to 0.84%.

Table (6): Chemical composition of chicory leaves powder, Pies and Crackers fortified with dried chicory leaves 2.5%

	Chicory leaves	Pies fortified with 2.5% of dried chicory leaves				Crackers fortified with 2.5% of Dried Chicory Leaves			
		C.P	P.D.C.L (2.5%)	T	P	C.P	P.D.C.L (2.5%)	T	P
Moisture	1.13± 0.13	27.94± 0.07	25.87± 0.12	24.92	0.67	5.82± 0.04	5.05± 0.13	9.68	0.301
Crude protein	11.60± 0.14	4.20 ± 0.06	4.45± 0.14	2.83	0.394	3.49± 0.07	3.78± 0.10	4.12	0.649
Total fat	11.40± 0.09	8.97± 0.17	9.23± 0.11	2.22	0.585	18.51± 0.07	18.55± 0.03	0.91	0.353
Ash	14.32± 0.08	1.37± 0.09	1.69± 0.09	4.36	1	2.91± 0.04	2.99± 0.03	2.77	0.71
Carbohydrate	51.55± 0.07	57.51± 0.23	58.76± 0.10	8.63	0.358	69.26± 0.14	69.63± 0.05	4.31	0.293
Crude fiber	14.05± 0.12	0.29± 0.05	0.42± 0.03	3.86	0.53	0.58± 0.09	0.84± 0.05	4.37	0.481

Data were expressed using Mean ±SE, T: Student t-test. C.P = Control pies, P.D.C.L = pies fortified with dried chicory leaves, (g/ 100 dry weight basis).

3.5.Minerals content of chicory leaves, Pies and Crackers fortified with Dried Chicory Leaves 2.5%

The results presented in Table (7) indicate that the chicory leaves contain a range of various elements including iron (Fe), zinc (Zn), manganese (Mn), magnesium (Mg), calcium (Ca), and potassium (K). The highest values belonged to potassium (K) and iron (Fe) elements were 77.04 ± 0.08 and 41.12 ± 0.12 mg/100g respectively, while the lowest values belonged to zinc (Zn), and calcium (Ca) were 12.35 ± 0.09 and 14.27 ± 0.13 respectively. These findings are in agreement with the results reported by **Abbas et al., (2015)** and **Perović et al., (2021).** These consistent results contribute to the growing body of knowledge regarding the mineral content of chicory leaves and provide valuable information for understanding their potential nutritional benefits. The same minerals measured in pies prepared with dried chicory leaves 2.5%. The fortification of pies with 2.5% dried chicory leaves resulted in an increase in the mineral element content compared to the control sample. The iron (Fe) level increased from 11.84 mg/100g

to 12.83 mg/100g. Also, the zinc (Zn) content increased from 7.09 mg/100g to 7.37 mg/100g. The manganese (Mn) level showed a significant increase from 2.37 mg/100g to 3.92 mg/100g, and the magnesium (Mg) content increased from 9.20 mg/100g to 9.95 mg/100g. The potassium (K) content also experienced an increase from 5.94 mg/100g to 7.84 mg/100g. The calcium (Ca) level remained relatively stable, with values of 14.22 mg/100g for the control sample and 14.25 mg/100g for the pies prepared with dried chicory leaves. A similar trend was observed in the crackers prepared with dried chicory leaves at 2.5%, where all mineral elements content increased. This increase in mineral content contributes to the enhancement of bakery products fortified with 2.5% dried chicory leaves.

Table (7): Mineral content of chicory leaves powder, Pies and crackers fortified with 2.5% of dried chicory leaves

		Chicory leaves	pies fortified with 2.5% of dried chicory					crackers fortified with 2.5% of dried chicory				
			C.P	P.D.C.L (2.5%)	% Change	T	P	C.P	P.D.C.L (2.5%)	% Change	T	P
Microminerals (mg/100g)	Fe	41.12± 0.12	11.84± 0.07	12.83± 0.05	8.36	19.93	0.666	23.41± 0.07	24.40± 0.08	4.23	16.13	0.860
	Zn	12.35± 0.09	7.09± 0.09	7.37± 0.11	3.95	3.41	0.792	7.76± 0.09	8.04± 0.15	3.61	2.77	0.530
	Mn	18.46± 0.05	2.37± 0.17	3.92± 0.15	65.40	11.84	0.869	4.37± 0.11	4.54± 0.14	3.89	1.65	0.753
Macrominerals (mg/100g)	Mg	31.25± 0.10	9.20± 0.04	9.95± 0.13	8.15	9.55	0.256	18.13± 0.13	18.89± 0.10	4.19	8.03	0.733
	Ca	14.27± 0.13	14.22± 0.06	14.25± 0.09	0.21	0.480	0.609	14.1± 0.06	14.2± 0.05	0.71	2.21	0.811
	K	77.04± 0.08	5.94± 0.03	7.84± 0.08	31.99	38.51	0.307	12.84± 0.04	14.74± 0.12	14.80	26.02	0.275

Data were expressed using Mean ±SE, T: Student t-test. C.P = Control pies, P.D.C.L = pies fortified with dried chicory leaves, (g/ 100 dry weight basis). (Fe) Iron, (Zn) Zinc, (Ca) Calcium, (Mg) Magnesium, (Mn) Manganese, (K) potassium. (mg / 100g dry weight)

3.6.Identification of amino acids in chicory leaves powder, Pies and Crackers fortified with Dried Chicory Leaves 2.5%:

Table (8) presents the amino acid composition of chicory leaves powder. The analysis revealed the presence of fourteen amino acid compounds in the leaves. Among the essential amino acids, phenylalanine exhibited the highest level, measuring 0.436 mg/100g, while lysine had the lowest content at 0.187 mg/100g. As for non-essential amino acids, aspartic acid showed the highest level, measuring 1.355 mg/100g, while tyrosine had the lowest content at 0.197 mg/100g. These findings closely align with the data reported by **Ziena et al. (2021).** The addition of dried chicory leaves resulted in an enhancement of both essential and non-essential amino acid levels in the fortified pies. In pies prepared with 2.5% dried chicory leaves, the content of methionine, an essential amino acid, increased from 0.546 to 0.550 mg/100g. Additionally, the content of glutamic acid, a non-essential amino acid, was the highest in pies fortified with dried chicory leaves at 2.5%, with an increase from 2.703 to 2.719 mg/100g. The levels of both essential and non-essential amino acids showed a significant increase in crackers fortified with dried chicory leaves at a concentration of 2.5%. Among the essential amino acids, methionine exhibited the highest value in the crackers fortified with dried chicory leaves at 2.5%, with an increase from 0.470 to 0.545 mg/100g. As for the non-essential amino acids, glutamic acid displayed the highest value in the crackers fortified with dried chicory leaves at 2.5%, with an increase from 2.025 to 2.040 mg/100g.

Table 8. Amino acids profile in chicory leaves powder, pies and crackers fortified with dried chicory Leaves 2.5%

Amino acid	Chicory leaves	Pies fortified with 2.5% of dried chicory leaves.					Crackers fortified with 2.5% of dried chicory leaves				
		C.P	P.D.C.L (2.5%)	Change (%)	T	P	C.P	P.D.C.L (2.5%)	Change (%)	T	P
Aspartic Acid	1.355± 0.024	0.455± 0.015	0.486± 0.004	6.81	3.46	0.229	0.401± 0.010	0.432± 0.012	7.73	3.44	0.811
Threonine	0.238± 0.010	0.248± 0.006	0.251± 0.008	1.21	0.520	0.710	0.208± 0.008	0.346± 0.011	66.35	17.57	0.682
Serine	0.281± 0.012	0.715± 0.005	0.720± 0.009	0.70	0.841	0.481	0.627± 0.020	0.631± 0.003	0.64	0.343	0.168
Glutamic	0.799± 0.021	2.703± 0.018	2.719± 0.006	0.59	1.46	0.275	2.025± 0.013	2.040± 0.008	0.74	1.70	0.548
Proline	0.733± 0.015	ND	ND	-	-	-	0.350± 0.010	0.366± 0.006	4.57	2.38	0.530
Glycine	0.476± 0.016	1.079± 0.008	1.088± 0.011	0.83	1.15	0.682	1.011± 0.008	1.020± 0.007	0.89	1.47	0.860
Alanine	0.482± 0.015	0.348± 0.015	0.358± 0.009	2.87	0.990	0.530	0.259± 0.014	0.269± 0.009	3.86	1.041	0.580
Methionine	0.215± 0.019	0.546± 0.010	0.550± 0.004	0.73	0.643	0.328	0.470± 0.008	0.545± 0.006	15.96	12.99	0.710
Valine	0.323± 0.023	0.082± 0.011	0.106± 0.007	29.27	3.19	0.573	0.068± 0.009	0.075± 0.011	10.29	0.853	0.792
Isoleucine	0.196± 0.016	0.250± 0.008	0.253± 0.006	1.20	0.520	0.710	0.105± 0.016	0.107± 0.007	1.90	0.198	0.361
Leucine	0.403± 0.017	0.041± 0.007	0.050± 0.012	21.95	1.12	0.511	0.058± 0.007	0.065± 0.020	12.07	0.572	0.287
Tyrosine	0.197± 0.020	ND	ND	-	-	-	0.178± 0.005	0.182± 0.007	2.25	0.805	0.666
Phenylalanine	0.436± 0.016	0.093± 0.012	0.117± 0.011	25.81	2.55	0.908	0.089± 0.009	0.097± 0.004	8.99	1.41	0.367
Histidine	0.204± 0.013	0.215± 0.020	0.219± 0.007	1.86	0.327	0.287	0.176± 0.007	0.179± 0.010	1.70	0.426	0.649
Lysine	0.187± 0.018	0.149± 0.021	0.152± 0.005	2.01	0.241	0.212	0.110± 0.006	0.113± 0.005	2.73	0.665	0.811
Arginine	0.216± 0.015	0.128± 0.017	0.132± 0.012	3.13	0.333	0.656	0.072± 0.004	0.076± 0.003	5.56	1.39	0.710

Data were expressed using Mean ±SE, T: Student t-test. C.C = Control crackers, C.D.C.L = crackers fortified with dried chicory leaves, (mg/ 100 dry weight basis).

3.7. Antioxidant activity and total phenolic content of chicory leaves, pies and crackers fortified with dried chicory leaves 2.5%:

The DPPH radical scavenging activities of chicory leaves were measured, and the results were shown as a percentage in Table (9). The leaves exhibited a DPPH radical scavenging activity of 42.25±0.07%. This finding is consistent with a previous study by **Ziena et al., (2021),** who reported a DPPH scavenging activity of 45.5%. Regarding the total phenolic content of chicory leaf powder, the results presented in Table (9) showed that the leaves were rich in total phenolic content, with a value of 857.38±0.09 mg/100g. These results agree with the findings of **Heimler et al., (2007)** and **Khalaf et al., (2018).** However, these results contradict the results reported by **Massoud et al., (2009).** Data in Table (10) presents the antioxidant activity and total phenolic content of pies and crackers fortified with 2.5% of dried chicory leaves. The pies fortified with 2.5% dried chicory leaves exhibited a favorable content of antioxidant and total phenolic content. The highest DPPH radical scavenging activity was observed in these pies, reaching a value of 26.40%, while the control pies showed the lowest DPPH radical scavenging activity at 25.26%. Additionally, the percentage of total phenolic content was significantly higher in the pies fortified with 2.5% dried chicory leaves compared to the control pies, with an increase from 167.21 to 188.62 mg/100g. Similarly, the crackers fortified with 2.5% dried chicory leaves displayed elevated DPPH radical scavenging activities compared to the control crackers, ranging from 30.70% to 31.74%. The total phenolic content in the crackers fortified with 2.5% dried chicory leaves also showed a significant increase compared to the control crackers, rising from 121.72 to 134.84 mg/100g.

Table (9): Antioxidant activity and total phenolic content of chicory leaves powder

Samples	DPPH scavenging activity (%)	Total phenolic (mg/ 100g)
Chicory leaves	42.25±0.07	857.38± 0.09

Table (10): Antioxidant activity and total phenolic content of pies and crackers fortified with 2.5% dried Chicory leaves

Parameters	DPPH scavenging activity (%)		Total phenolic (mg/ 100g)	
	Pies fortified with 2.5%	Crackers fortified with 2.5%	Pies fortified with 2.5%	Crackers fortified with 2.5%
C.P	25.26±0.08	30.70±0.09	167.21±0.11	121.72±0.07
P.D.C.L (2.5%)	26.40±0.09	31.74±0.05	188.62±0.13	134.84±0.04
Change%	4.51	3.39	12.80	10.78
T	16.40	17.50	217.76	281.86
P	0.876	0.481	0.826	0.498

Data were expressed using Mean ±SE, T: Student t-test. C.P = Control pies, P.D.C.L = pies fortified with dried chicory leaves, (mg/ 100 dry weight basis).

3.8. Determination of the fat-soluble vitamins A, D, E, K and water-soluble vitamins B complex in chicory leaves powder:

Table (11) presents vitamins content of chicory leaves, including water-soluble and fat-soluble vitamins. High content of the water-soluble vitamins in chicory leaves includes Vitamin B1 (Thiamine), Vitamin B_2 (Riboflavin), Vitamin B_3 (Niacin), and Vitamin B_{12} (Cobalamin) at a concentration of 2.14±0.08, 1.88±0.005, 5.30±0.07, and 20.40±0.03 mg/100g respectively, as the highest one. The highest of the fat-soluble vitamins found in chicory leaves is Vitamin K at 2.029±0.009 mg/100g. While low content of Vitamin A, Vitamin D, and Vitamin E were 0.042±0.008, 0.026±0.007, and 0.017±0.004 mg/100g respectively. Similar results of various studies reported on the vitamin content of chicory leaves. **Abo Taleb et al., (2017)** found that the dry leaves of chicory contained high amounts of vitamins B1, B2, B3, B12, and K, while the levels of vitamins A, D, and E were relatively low. Similarly, **Perovic et al., (2021)** observed the presence of vitamins B1, B2, B3, and vitamin A in fresh chicory leaves, with specific values reported. **Khalifa et al., (2022)** reported different vitamin concentrations in chicory leaves, with higher values for vitamins A, D, E, and K compared to vitamins B1, B2, and B12**. Saeed et al., (2017)** also studied the vitamin composition of chicory leaves and reported the presence of vitamins B1, B2, B3, B5, B6, and B9 in specific quantities.

Table (11): Determination of vitamins A, D, E, K and B complex in chicory leaves

Water-Soluble vitamins	Chicory leaves
Vit.B_1	2.14±0.08
Vit.B_2	1.88±0.005
Vit.B_3	5.30±0.07
Vit.B_{12}	20.40±0.03
Fat-Soluble vitamins	**Chicory leaves**
Vit. A	0.042±0.008
Vit. D	0.026±0.007
Vit. E	0.017±0.004
Vit. K	2.029±0.009

Data were expressed using Mean ±SE, (mg/100g on a dry weight basis)
Thiamine (B_1), Riboflavin (B_2), Niacin (B_3), Cobalamin (B_{12}), Vit =Vitamin

CONCLUSION

This study highlighted the characteristics of novel bakery products that incorporate chicory leaves powder, which possesses high-quality nutritional properties as a plant-based ingredient. The findings revealed that chicory leaves are rich in various components, including chemical composition, protein, antioxidant activity, minerals, total phenolic content, and essential and non-essential amino acids. Consequently, the addition of chicory leaves to food products proved beneficial in enhancing their nutritional value. Therefore, further research on this plant is recommended to enhance the sensory attributes of food products and promote their acceptance by consumers.

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تقييم الخصائص التغذوية والحسية لبعض المخبوزات المدعمة بمسحوق أوراق نبات الشيكوريا

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الملخص العربى

هدفت هذه الدراسة إلى تقييم التركيب الكيميائي لأوراق نبات الشيكوريا (السريس او السريسا) واستخدامها كمكون غذائي في بعض المخبوزات مثل الفطائر والمقرمشات، بهدف تعزيز قيمتها الغذائية. تم تحليل التركيب الكيميائي التقريبي والمكونات الفينولية الكلية والمعادن والنشاط المضاد للأكسدة والأحماض الأمينية الأساسية/غير الأساسية لمسحوق أوراق الشيكوريا والمخبوزات المحتوية على الشيكوريا. أظهرت النتائج أن أوراق الشيكوريا هي مصدر غني بالبروتين (11.60٪) والمعادن مثل الحديد (41.12 ملجم/100جم) والبوتاسيوم (77.04 ملجم/100جم) والمغنيسيوم (31.25 ملجم/100جم) والمنغنيز (18.46 ملجم/100جم) والكالسيوم (14.27 ملجم/100جم) والزنك (12.35 ملجم/100جم) بناءً على الوزن الجاف. بالإضافة إلى ذلك، أظهرت أوراق الشيكوريا نشاطًا مضادًا للأكسدة عاليًا (42.25٪) واحتوت على كمية كبيرة من المركبات الفينولية الكلية (857.38 ملجم/100جم). يجدر الذكر أن الأحماض الأمينية الأساسية، بخاصة اللوسين والفينيل لانين، توجد بكميات مرتفعة (0.403، 0.436 ملجم/100جم على التوالي) في مسحوق أوراق الشيكوريا، بينما تتواجد الأحماض الأمينية غير الأساسية مثل حمض الأسبارتيك وحمض الجلوتاميك بمستويات 1.355، 0.799 ملجم/100جم على التوالي. أشار التقييم الحسي إلى أن المخبوزات المحتوية على 2.5٪ من مسحوق أوراق الشيكوريا حازت على تقبل إيجابي، في حين أن تلك المحتوية على 5٪، 7.5٪ لم يتم تفضيلها بنفس القدر. تؤكد هذه الدراسة أهمية إجراء المزيد من البحوث والتجارب لتطوير منتجات عالية القيمة الغذائية مثل الفطائر والمقرمشات المحتوية على أوراق الشيكوريا.

الكلمات المفتاحية: أوراق الشيكوريا – المخبورات – القيمة الغذائية – التقييم الحسي – الخصائص الريولوجية – الفيرنوجراف.