DOI: https://doi.org/10.21323/2618-9771-2024-7-3-438-443

Received 14.05.2024
Accepted in revised 27.09.2024
Accepted for publication 30.09.2024
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Original scientific article
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UTILIZATION OF ARTICHOKE (*CYNARA SCOLYMUS* L.) BY-PRODUCTS FOR ENHANCING THE NUTRITIONAL VALUE AND PHYTOCHEMICAL CONTENT OF COOKIES

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KEY WORDS:
artichoke by-products, bakery products, antioxidant activity, functional foods

ABSTRACT

This study was conducted to make functional cookies using powdered artichoke stems and bracts, which are rich in phytochemicals. The chemical composition and phytochemicals in wheat flour, artichoke bract powder, artichoke stem powder and the produced cookies were determined. Physical properties, color and sensory characteristics were determined in wheat flour cookies, artichoke bract powder cookies and artichoke stem powder cookies. The results showed that artichoke bract powder cookies (15%) contained the highest levels of ash and protein being 2.07% and 9.65%, respectively. The cookies with powdered artichoke stems (15%) had the greatest overall lipid content (14.65%). Furthermore, the highest total phenolic content, total flavonoid content, and antioxidant activity were found in artichoke by-products (stems and bracts). The panelists approved of up to 15% artichoke by-product powder added to wheat flour. It can be seen from the results that the artichoke by-products are a good source of phytochemicals, minerals, total protein and total lipids, which improves the quality of cookies. Therefore, it can be concluded that using artichoke by-products up to 15% enhanced the antioxidant properties and nutritional value of the baked cookies.

Поступила 14.05.2024
Поступила после рецензирования 27.09.2024
Принята в печать 30.09.2024
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Научная статья
Open access

ИСПОЛЬЗОВАНИЕ ПОБОЧНЫХ ПРОДУКТОВ ПЕРЕРАБОТКИ АРТИШОКА (*CYNARA SCOLYMUS* L.) ДЛЯ ПОВЫШЕНИЯ ПИТАТЕЛЬНОЙ ЦЕННОСТИ И СОДЕРЖАНИЯ ФИТОХИМИЧЕСКИХ СОЕДИНЕНИЙ В ПЕЧЕНЬЕ

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КЛЮЧЕВЫЕ СЛОВА:
побочные продукты переработки артишока, мучные кондитерские изделия, антиоксидантная активность, функциональные продукты

АННОТАЦИЯ

Проведено исследование по изготовлению функционального печенья, используя порошкообразные стебли и прицветники артишока. Определяли химический состав и фитохимические соединения в пшеничной муке, порошке прицветников артишока, стеблях артишока и изготовленном печенье. В печенье из пшеничной муки, печенье с порошком прицветников артишока и печенье с порошком стеблей артишока определяли физические свойства, цвет и сенсорные характеристики. Результаты показали, что печенье с порошком прицветников артишока (15%) содержало более высокие уровни золы и белка (2,07% и 9,65%, соответственно). Печенье с порошком стеблей артишока (15%) имело наиболее высокое содержание общих липидов (14,65%). Кроме того, наивысшее общее содержание фенольных соединений, общее содержание флавоноидов и антиоксидантная активность были выявлены в побочных продуктах переработки артишока (стебли и прицветники). Члены дегустационной комиссии одобрили до 15% порошка побочных продуктов переработки артишока, добавленного к пшеничной муке. Как видно из результатов, побочные продукты переработки артишока являются хорошим источником фитохимических соединений, минеральных веществ, общего белка и общих липидов, которые улучшают качество печенья. Таким образом, можно сделать вывод, что использование побочных продуктов переработки артишока на уровне до 15% повышает антиоксидантные свойства и питательную ценность испеченного печенья.

1. Introduction

Food loss and waste are two of the biggest issues the global food supply chain is now dealing with. A 2011 survey by the Food and Agriculture Organization of the United Nations found that around one-third of the food produced for human use is lost or wasted annually [1]. Food waste is the reduction in food quantity or quality that results from consumer, food service, and retailer decisions and actions, whereas food loss is the reduction in food quantity or quality that happens as a result of decisions and actions made by food suppliers along the supply chain [1]. Food processing generates a lot of by-products that are rich in valuable ingredients that can be used as functional ingredients, such as antioxidants. It would be advantageous to use these ingredients in food to give customers healthier options [2]. There is a growing demand for functional foods enhanced with by-products as people become more conscious of the impact their current dietary choices have on their health [3].

Cynara scolymus L., also known as the globe artichoke, is a crucial part of the Mediterranean diet. It is highly valued for its organoleptic qualities, whether it is used as a fresh vegetable or processed food. The globe artichoke is not only low in lipids but also a potential source of minerals, vitamins, and dietary ingredients. It also has a high concentration of inulin and a large number of naturally occurring antioxidants like flavonoids [4]. Approximately 80 to 85% of the entire plant biomass is lost during the industrial preparation of artichokes. The majority of this material is made up of stems and bracts, or exterior parts of flowers, as they are generally known. It is normally disposed of as solid trash because it is unfit for human consumption. However, an analysis of composition reveals that artichoke waste contains a significant amount of polyphenols [5].

Based on a 2018 FAO assessment, artichokes are widely cultivated in the Mediterranean region, including Egypt. The total area planted with artichokes in Egypt was 17287 hectares, with artichoke production around

FOR CITATION: **Ammar, A. S. M., Riyad, Y. M., Ebrahiem, A. A. A.** (2024). Utilization of artichoke (*Cynara scolymus* L.) by-products for enhancing nutritional value and phytochemical content of cookies. *Food Systems,* 7(3), 438–443. https://doi.org/10.21323/2618-9771-2024-7-3-438-443

ДЛЯ ЦИТИРОВАНИЯ: **Аммар, А. С. М., Рияд, Ю. М., Ибрахим, А. А. А.** (2024). Использование побочных продуктов переработки артишока (*Cynara scolymus* L.) для повышения питательной ценности и содержания фитохимических соединений в печенье. *Пищевые системы*, 7(3), 438–443. https://doi.org/10.21323/2618-9771-2024-7-3-438-443

323866 tons [6]. Globe artichokes provide various nutritional benefits, including high levels of water (91% of dietary portions) and minerals, as well as high levels of vitamins, carotenoids, and polyphenols [7]. According to Rangboo et al., [8] globe artichokes have the ability to decrease the production of reactive oxygen species, oxidation of low-density lipoproteins, lipid peroxidation, and increase the glutathione peroxidase activity. According to De Falco et al., [9] these effects are linked to artichoke phenolics, which can modify several important enzyme pathways as well as cell defensive antioxidants.

Eman et al. [10] studied the chemical composition of the globe artichoke by-products (bracts and floral stems) and found that raw bracts contained 84.51% moisture, 15.71% crude protein, 1.78% crude ether extract, 24.84% crude fiber, 7.33% ash and 50.34% nitrogen free extract, while raw stems had 89.57% moisture, 17.12% crude protein, 2.55% crude ether, 14.88% crude fiber, 10.45% ash and 55.00% nitrogen free extract (on dry weight basis). Lavecchia et al., [11] reported that the polyphenol content of stems was 51.10 ± 0.74 mg GAE/g and that of bracts was 24.58 ± 0.57 mg GAE/g. Using 50% aqueous ethanol provided the highest extraction yields, with over 80% of phenolic compounds recovered.

According to Cappa et al. [12], cookies are typically made using wheat flour, oil, and sugar, with a moisture content of no more than 20%. Cookies are the most popular snack because they are available in a wide range of flavors, kept well in storage for a long time, and can be eaten in between larger meals that do not provide enough nutrients [13]. Based on the above-mentioned considerations, therefore, the aim of this study was to assess and utilize the powdered artichoke by-products (either the stems or the bracts) as a rich source of bioactive components to improve the nutritional value and phytochemical content of cookies.

2. Materials and Methods

2.1. Materials

Artichoke bracts (outside portions of the flowers), artichoke stems (floral stems), weak wheat flour (72% extraction –flour containing much less bran and germ), sugar, salt, shortening and baking powder were purchased from a local market in Cairo, Egypt. Folin–Ciocalteu reagent and DPPH reagent were purchased from Sigma Company (USA) and other chemicals were purchased from EL-Gomhoria Company, Egypt.

2.2. Methods

2.2.1. Preparation of artichoke bract powder (ABP) and artichoke stem powder (ASP)

The samples were washed with tap water and the stems were cut into small pieces. Samples were dried using an oven (Astell Hearson, England) at 50 °C for 24 h. The dried pieces were ground, and powder was sieved using a sieve of 425 µm (USA Standard Testing Sieve) to obtain a fine powder and preserved in the freezer (Fresh, Egypt) at −18 °C until used.

2.2.2. Preparation of flour blends

Wheat flour (72%) was partially replaced by ABP (0, 10 and 15%) or by ASP (0, 5 and 15%) as presented in Table 1.

Table 1. **Ingredients used in producing different cookie blends**

Таблица 1. **Ингредиенты, использованные при изготовлении различных смесей для печенья**

Ingredients (gram)	Control	Artichoke bract powder cookies (ABPC)		
		5%	**10%**	**15%**
WF	100	—	90	85
ABP	—	—	10	15
		Artichoke stem powder cookies (ASPC)		
WF		95	—	85
ASP	—	5	—	15
Powdered sugar	58			
Shortening	28			
Baking powder	1.1			
Salt	0.9			
Water	22			
Baking conditions				
Baking time (min)	25			
Temperature (°C)	180			

2.2.3. Preparation of cookies

In addition to the control sample, cookie samples with ABP or ASP were prepared using the flour combinations as follows. Control cookies were made with 100 g wheat flour (WF), 58 g sugar, 28 g shortening, 1.1 g baking powder, 0.9 g sodium chloride, and 22 ml water as the ingredients. ABPC and ASPC were prepared from wheat flour with addition of ABP or ASP at the ratios indicated in 2.2.2 and Table 1 with all other ingredients being the same. After the dough was ready, it was sheeted to a thickness of 1.1 cm and cut into a circle with a diameter of 4.1 cm. In a preheated oven, cookies were baked for 25 minutes at 180 °C as mentioned in Table 1. After cooling to room temperature, the baked cookies were sealed in polythene bags.

2.2.4. Proximate chemical composition

Chemical analyses were performed on both the raw materials and the final cookies. The A. O.A.C. [14] was followed in determining the contents of moisture, ash, total lipids, and total protein.

Moisture determination: In a weighed clean crucible, 5 g of sample were weighed. The crucible and the sample were put in an oven at 105 °C. Then crucible was weighed, this was repeated until a constant weight was reached.

$$\text{Moisture, \%} = \frac{(W_2 - W_1) - (W_3 - W_1)}{W_2 - W_1} \times 100, \quad (1)$$

where: W_1 = weight of empty crucible; W_2 = weight of crucible + sample; W_3 = weight of crucible +dried sample.

Ash determination: In a weighed clean crucible, 5 g of sample were weighed. Then the sample in the crucible was put in a muffle furnace at 550–650 °C for more than 3 hours until getting ash. After that, the crucible was cooled in a desiccator, and then weighed.

$$\text{Ash, \%} = W_2 - W_1 / W_3 \times 100, \quad (2)$$

where: W_1 = weight of empty crucible; W_2 = weight of crucible with ash; W_3 = weight of sample.

Lipid determination: Using a weighed clean thimble (W_1), a 10-g sample was placed and re-weighed (W_2). Soxhlet extractor was fixed and 200 ml of petroleum ether (40–60 °C) was used as a solvent. Then, lipids in the sample were extracted for 4 h. After that, the thimble was removed, dried, then cooled and weighed again (W_3):

$$\text{Lipids, \%} = (W_2 - W_3) / (W_2 - W_1) \times 100. \quad (3)$$

Protein determination: Protein was determined using the micro-Kjeldahl distillation procedure. The samples were digested by heating with concentrated H_2SO_4 in the presence of the digestion mixture (K_2SO_4 + $CuSO_4$). The mixture was then made alkaline with 40% NaOH. Ammonium sulphate thus formed, released ammonia, which was collected in 4% boric acid solution and titrated against standard HCl. The percent nitrogen content of the sample was calculated as follows:

$$\text{Nitrogen, \%} = 1.4\,(\text{ml HCl}_{sample} - \text{ml HCl}_{blank}) \times \text{conc. of HCl} \times \times\ 100 / \text{sample weight (g)}. \quad (4)$$

Total protein was calculated by multiplying nitrogen% with appropriate conversion factor (6.25).

$$\text{Protein, \%} = N\% \times 6.25. \quad (5)$$

Total carbohydrate determination: Total carbohydrates were calculated by difference as follows:

$$\text{Total carbohydrates, \%} = = 100 - (\text{Moisture\%} + \text{Lipids\%} + \text{Protein\%} + \text{ash\%}) \quad (6)$$

2.2.5. Physical characteristics of cookies

Weight (g), height (cm), volume (cm^3), specific volume (cm^3 /g), diameter (cm), and spread ratio (diameter/height) were measured according to Rabie et al. [15] and Ganorkar and Jain [16].

2.2.6. Color measurement of cookies

The L^*, a^* and b^* uniform color space was used to determine the color parameters of the cookies according to CIE [17] using a colorimeter (Model CR-410, Konica Minolta, Japan). The Hue angle (θ) is defined as a color wheel, with red-purple at angles of 0° and 360°, yellow at 90°, bluish-green at 180°, and blue at 270°. Chroma (C) represents color saturation or purity and is calculated from $C = (a^2 + b^2)^{1/2}$. The formula for calculating hue angles (θ) was $\theta = \tan^{-1} (b/a)$.

2.2.7. Samples Extraction

Samples were extracted in accordance with Khanavi et al. [18] with some modifications. A magnetic stirrer (IKA-Combimag RCT, Germany) was used to mix about 0.2 g of powdered artichoke by-products with 50 ml of methanol in a flask at 1100 rpm at room temperature for one hour. The mixture was then filtered using Whatman No. 5 filter paper. The total flavonoid and total phenolic contents, and antioxidant activity of each extract were measured.

2.2.8. Total phenolic content (TPC)

Total phenolic content was estimated by the Folin–Ciocalteu method [19]. Two hundred microliters of the diluted sample were added to 1 ml of 1:10 diluted Folin–Ciocalteu reagent. An amount of 800 µl of saturated sodium carbonate (75 g/l) was added after 4 min. After 2 h of incubation at room temperature, the absorbance at 765 nm was measured. Gallic acid (0–500 mg/l) was used for the standard calibration curve. The TPC was expressed as milligrams of gallic acid equivalents per gram of the sample (mg GAE/g).

2.2.9. Total flavonoid content

Total flavonoid content was determined according to the colorimetric aluminum chloride method described by Zhishen et al. [20]. An amount of 1.25 ml of water and 75 µl of a 5% $NaNO_2$ solution were added to an aliquot (250 µl) of each extract or standard solution. Then, 150 µl of 10% $AlCl_3$ solution were added after 6 minutes. Next, 0.5 ml of 1 M NaOH solution was added after 5 minutes, and the total volume was then brought to 2.5 ml with water. Absorbance was measured at 510 nm against a blank. Quercetin acid was used as a standard and the total flavonoid content of the samples was expressed as mg of quercetin equivalent per g dry sample.

2.2.10. Antioxidant activity

The DPPH• radical scavenging activity was measured by following the method as described by Platat et al. [21]. Briefly, 3.9 mL of DPPH• solution (0.25mM) was added to 100 µL of extract. Absorbance of the extract was read at 515 nm at 0 and 30 min using methanol as blank. Percent (%) DPPH• scavenging activity was calculated as follows:

$$\text{Inhibition (\%)} = (A_{control} - A_{sample} / A_{control}) \times 100, \quad (7)$$

where $A_{control}$: the absorbance of the control; A_{sample}: the absorbance of the sample.

2.2.11. Sensory evaluation of cookies

Ten semi-trained panelists, including employees and students from the Food Science Department of the Faculty of Agriculture, Cairo University, assessed cookie samples organoleptically. A ten-point hedonic scale was used to rate appearance, color, texture, flavor, taste, and overall acceptability of each sample. A score of 10 indicated the qualities that were most preferred, a score of 5 indicated the characteristics that were unacceptable, and a score of 1 indicated the characteristics that were most disliked [22].

2.2.12. Statistical analysis

Every measurement was carried out in triplicate, except for sensory evaluation (n=10). Analysis of variance (ANOVA) was performed on the data. The significance level was set at ≤ 0.05.

3. Results and discussion

3.1. Artichoke bracts

3.1.1. Proximate chemical composition, phytochemical compounds and antioxidant activity of wheat flour (WF) and artichoke bract powder (ABP)

The proximate chemical composition, total phenolic and total flavonoid contents, and antioxidant activity of *ABP* and *WF* are presented in Table 2. Data showed that significant differences ($p \leq 0.05$) were observed among *ABP* and *WF* in their composition. In contrast to commercial wheat flour, *ABP* contained significantly less moisture. *ABP* had higher protein and ash contents than *WF*. The protein content of *ABP* was 19.57%, whereas the ash content was 8.95%. These results are in agreement with Boubaker et al. [23] and Eman et al. [10]. The content of phenolic compounds in *WF* and ABP was 0.16 and 7.49 mg GAE/g, respectively. The content of flavonoid compounds in *WF* and ABP was 0 and 1.79 mg QE /g, respectively. The antioxidant activity as DPPH radical scavenging activity in *WF* and *ABP* was 4.79 and 74.67%, respectively. The results are in agreement with Sihem et al. [24] who noted that artichoke bracts and stems have the high content of polyphenols and antioxidant activity.

Table 2. **Proximate chemical composition (%), phytochemical compounds and the antioxidant activity of WF and ABP**

Таблица 2. **Химический состав (%), фитохимические соединения и антиоксидантная активность пшеничной муки (WF) и порошка прицветников артишока (ABP)**

Parameters \ Constituent	WF	ABP
Moisture (%)	$11.63^a \pm 0.38$	$4.42^b \pm 0.01$
Ash (%)	$0.57^b \pm 0.00$	$8.95^a \pm 0.02$
Total lipids (%)	$1.00^a \pm 0.00$	$0.45^b \pm 0.02$
Total protein (%)	$10.00^b \pm 0.00$	$19.57^a \pm 0.23$
Total carbohydrates* (%)	$76.80^a \pm 0.38$	$66.61^b \pm 0.20$
Total phenolic content (mg GAE/g)	$0.16^b \pm 0.01$	$7.49^a \pm 0.64$
Total flavonoid content (mg QE/g)	$0.00^b \pm 0.00$	$1.79^a \pm 0.12$
Antioxidant activity DPPH (%)	$4.79^b \pm 0.00$	$74.67^a \pm 0.45$

* Total carbohydrates were calculated by difference. Means ± (SD) followed by different superscripts within rows are significantly different ($p \leq 0.05$).

3.1.2. Proximate chemical composition (%), total phenolic content and antioxidant activity of wheat flour cookies (WFC) and artichoke bract powder cookies (ABPC)

The addition of powdered artichoke bracts to cookies had an impact on their chemical composition, as shown in Table 3. Compared to the control, the cookie samples with the added artichoke bract powder had higher contents of moisture, ash, and total protein. Cookies made with artichoke bracts also had lower contents of total lipids and total carbohydrates. These results imply that adding artichoke bracts to cookies improved their mineral and total protein contents. The results are in agreement with the results found by Eman et al., [10] who noted that artichoke bracts have high moisture, high total protein and high ash contents, but the low total lipid content. The *ABPC* (15%) showed significant difference ($p \leq 0.05$) and the highest phenolic content, flavonoid content and antioxidant activity followed by *ABPC* (10%). With an increase in the *ABP* concentrations in cookies, the phenolic content and antioxidant activity increased. An increase in the antioxidant activity in cookies may be due to the high levels of polyphenols that are present in *ABP*. These results are in agreement with those reported by Sihem et al. [24] who found that *ABP* contains high levels of polyphenolic compounds.

3.1.3. Physical characteristics and color measurement of WFC and ABPC

The physical properties and color parameters of the cookies prepared either from wheat flour (*WFC*) or from wheat flour with artichoke bract powder (*ABPC*) are shown in Table 4 and Figure 1. Data show that supplemented cookies with artichoke bracts exhibited significantly ($p \leq 0.05$) lower values of volume, specific volume and diameter than the control cookies. There were no significant ($p \leq 0.05$) differences between the values obtained for weight, height and spread ratio of the cookies enriched with 10 and 15% *ABPC* and the control (100% wheat flour) cookies. The

Figure 1. **Wheat flour cookies (control) and artichoke bract powder cookies.**

Рисунок 1. **Печенье из пшеничной муки (контроль) и печенье с порошком прицветников артишока**

Table 3. **Proximate chemical composition (%), total phenolic content and the antioxidant activity of WFC and ABPC**

Таблица 3. **Химический состав (%), фитохимические соединения и антиоксидантная активность печенья из пшеничной муки (WFC) и печенья с порошком прицветников артишока (ABPC)**

Parameters \ Samples	WFC	ABPC 10%	ABPC 15%
Moisture (%)	$5.40^b \pm 0.14$	$7.14^a \pm 0.01$	$7.16^a \pm 0.10$
Ash (%)	$1.07^c \pm 0.02$	$1.62^b \pm 0.14$	$2.07^a \pm 0.13$
Total lipids (%)	$13.70^a \pm 0.24$	$12.70^b \pm 0.01$	$10.9^c \pm 0.14$
Total protein (%)	$6.15^c \pm 0.07$	$8.15^b \pm 0.07$	$9.65^a \pm 0.01$
Total carbohydrates* (%)	$73.68^a \pm 0.14$	$70.39^b \pm 0.22$	$70.22^b \pm 0.37$
Total phenolic content (mg GAE/g)	$0.01^c \pm 0.00$	$0.86^b \pm 0.07$	$1.75^a \pm 0.11$
Antioxidant activity DPPH (%)	$6.55^c \pm 0.42$	$34.98^b \pm 0.67$	$58.46^a \pm 0.81$

WFC — wheat flour cookies, ABPC — artichoke bract powder cookies. Means ± (SD) followed by different superscripts within rows are significantly different ($p \leq 0.05$). *Total carbohydrates were calculated by difference.

Table 4. **Physical characteristics and color measurement of WFC and ABPC**

Таблица 4. **Физические характеристики и измерение цвета печенья из пшеничной муки (WFC) и печенья с порошком прицветников артишока (ABPC)**

Samples / Parameters		WFC	ABPC 10%	ABPC 15%
Weight (g)		16.28ᵃ±0.54	16.44ᵃ±0.60	16.43ᵃ±0.44
Height (cm)		1.30ᵃ±0.00	1.15ᵃ±0.07	1.15ᵃ±0.07
Volume (cm^3)		29.50ᵃ±0.70	20.5ᵇ±0.70	20.5ᵇ±0.70
Specific volume (cm^3/g)		1.81ᵃ±0.10	1.24ᵇ±0.00	1.24ᵇ±0.07
Diameter (cm)		4.60ᵃ±0.14	4.30ᵇ±0.00	4.30ᵇ±0.00
Spread ratio (diameter/height)		3.53ᵃ±0.10	3.74ᵃ±0.22	3.74ᵃ±0.22
Color	***L****	70.45ᵃ±0.53	53.59ᵇ±0.30	53.85ᵇ±0.43
	a*	1.55ᵇ±0.06	3.31ᵃ±0.10	3.16ᵃ±0.15
	b*	18.67ᵃ±0.02	10.97ᵇ±0.36	10.40ᵇ±0.37
	C	18.73ᵃ±0.08	11.45ᵇ±0.44	10.87ᵇ±0.51
	H	85.25ᵃ±0.33	73.20ᵇ±0.77	73.09ᵇ±0.32

WFC — wheat flour cookies, ABPC — artichoke bract powder cookies. Means±(SD) followed by different superscripts within rows are significantly different (p ⩽ 0.05).

results are in agreement with Canale et al. [25] and Eman et al. [10]. The color was changed to green by the addition of artichoke ABP. The *a** value significantly increased, but *b*, L**, C and H decreased, with a greater decrease at the 15% substitution level. According to the findings of Frutos et al. [26], there was a tendency for the cookies to get noticeably darker as more artichoke bract flour was added. According to Manonmani et al. [27], the Maillard reaction is primarily responsible for the cookie color.

3.1.4. Sensory evaluation of WFC and ABPC

Sensory evaluation values of *WFC* and *ABPC* are presented in Table 5. Data showed that the panelists approved of all properties of all samples. Also, data showed that the sample that contained 10% artichoke bracts was described as most liked. Statistical analysis revealed that there were no significant differences between the cookies containing 0, 10, 15% *ABP* in all properties except taste and overall acceptability in 15% *ABP* that had lower scores. Overall acceptability refers to how customers or panelists accept the product in general. The results of taste and overall acceptability are in agreement with Natale et al. [28] who reported that artichoke bracts may be a cause of bitter taste due to the presence of flavanols.

3.2. Artichoke stems

3.2.1. Proximate chemical composition, phytochemical compounds and antioxidant activity of wheat flour and artichoke stem powder (ASP)

The proximate chemical composition, total phenolic and total flavonoid contents, and the antioxidant activity of artichoke stem powder (*ASP*) and wheat flour (*WF*) are presented in Table 6. Data showed that significant differences (p⩽0.05) were observed between *ASP* and *WF* in their composition. In contrast to commercial wheat flour, *ASP* contained significantly less moisture. *WF* had more protein than *ASP*, whereas the ash content was higher in *ASP* than in *WF*. These results are in agreement with the results reported by Boubaker et al. [23] and Eman et al. [10]. The content of phenolic compounds in *WF* and *ASP* was 0.16 and 27.25 mg GAE/g, respectively. The content of flavonoid compounds in *WF* and *ASP* was 0 and 1.77 mg QE/g, respectively. Moreover, the antioxidant activity as the DPPH radical scavenging activity in *WF* and *ASP* was 4.79 and 77.96%, respectively. The results are in agreement with Sihem et al. [24] who noted that artichoke bracts and stems have the high content of polyphenols and antioxidant activity.

3.2.2. Proximate chemical composition, total phenolic content and the antioxidant activity of wheat flour cookies (WFC) and artichoke stem powder cookies (ASPC)

The addition of powdered artichoke stems to cookies had an impact on their chemical composition, as shown in Table 7. Compared to the control, the cookie samples with the added artichoke stem powder had higher contents of moisture, ash, and total lipids. Cookies made with artichoke stems also had lower contents of total protein. These results imply that adding artichoke stems to cookies improved their mineral and total lipid contents. The results of ash and total protein contents are in agreement with Boubaker et al. [23]. The highest antioxidant activity, total phenolic and total flavonoid contents were found in the *ASPC* (15%), followed by *ASPC* (5%). This difference was significant (p⩽0.05). The total phenolic and antioxidant activity of cookies were all increased by raising *ASP* concentrations. The high quantities of polyphenols found in *ASP* may be the cause of the increased antioxidant activity in cookies. These findings were supported by the findings of Sihem et al. [24] who mentioned that ASP contains a significant amount of polyphenolic compounds.

3.2.3. Physical characteristics and color measurement of WFC and ASPC

The physical characteristics of the cookies made with either wheat flour (*WFC*) or wheat flour with artichoke stem powder (*ASPC*) are displayed in Table 8 and Figure 2. The data demonstrate that cookies containing artichoke stems had significantly (p⩽0.05) lower values for height, volume, specific volume, and diameter than control cookies. In

Table 5. **Sensory evaluation of WFC and ABPC**

Таблица 5. **Сенсорная оценка печенья из пшеничной муки (WFC) и печенья с порошком прицветников артишока (ABPC)**

Samples / Parameters	Appearance (10)	Color (10)	Texture (10)	Flavor (10)	Taste (10)	Overall acceptability (10)
WFC	9.80ᵃ±0.44	9.60ᵃ±0.89	9.20ᵃ±0.83	9.80ᵃ±0.44	9.60ᵃ±0.54	9.80ᵃ±0.44
ABPC 10%	9.60ᵃ±0.54	9.37ᵃ ±0.57	9.20ᵃ±0.83	9.20ᵃ±0.83	9.40ᵃ±0.89	9.20ᵃ±0.83
ABPC 15%	9.60ᵃ±0.54	9.31ᵃ±0.65	9.20ᵃ±0.83	9.20ᵃ±0.83	8.10ᵇ±0.89	8.20ᵇ±0.44

WFC — wheat flour cookies, ABPC — artichoke bract powder cookies. Means±(SD) followed by different superscripts within columns are significantly different (p ⩽ 0.05).

Table 6. **Proximate chemical composition (%), phytochemical compounds and the antioxidant activity of WF and ASP**

Таблица 6. **Химический состав (%), фитохимические соединения и антиоксидантная активность пшеничной муки (WF) и порошка стеблей артишока (ABP)**

Parameter / Constituent	WF	ASP
Moisture	11.63ᵃ±0.38	5.22ᵇ±0.02
Ash	0.57ᵇ±0.00	10.57ᵃ±0.07
Total lipids	1.00ᵃ±0.00	1.42ᵃ±0.39
Total protein	10.00ᵃ±0.00	8.93ᵇ±0.01
Total carbohydrates*	76.80ᵃ±0.38	73.86ᵇ±0.33
Total phenolic content (mg GAE/g)	0.16ᵇ±0.01	27.25ᵃ±0.35
Total flavonoid content (mg QE/g)	0.00ᵇ±0.00	1.77ᵃ±0.26
Antioxidant activity DPPH (%)	4.79ᵇ±0.00	77.96ᵃ±0.09

* Total carbohydrates were calculated by difference. Means±(SD) followed by different superscripts within rows are significantly different (p ⩽ 0.05).

Table 7. **Proximate chemical composition (%), total phenolic content and the antioxidant activity of WFC and ASPC**

Таблица 7. **Химический состав (%), фитохимические соединения и антиоксидантная активность печенья из пшеничной муки (WFC) и печенья с порошком стеблей артишока (ASPC)**

Parameters / Samples	WFC	ASPC 5%	ASPC 15%
Moisture (%)	5.40ᵇ±0.14	6.22ᵃ±0.04	6.18ᵃ±0.04
Ash (%)	1.07ᵇ±0.02	1.25ᵃᵇ±0.31	1.69ᵃ±0.05
Total lipids (%)	13.70ᵇ±0.24	14.22ᵃᵇ±0.25	14.65ᵃ±0.21
Total protein (%)	6.15ᵃ±0.07	5.55ᵇ±0.07	4.90ᶜ±0.00
Total carbohydrates* (%)	73.68ᵃ±0.14	72.76ᵃ±0.61	72.58ᵃ±0.22
Total phenolic content (mg GAE/g)	0.01ᶜ±0.00	0.58ᵇ±0.08	1.7ᵃ±0.00
Antioxidant activity DPPH (%)	6.55ᶜ±0.42	18.52ᵇ±0.54	35.46ᵃ±0.79

WFC — wheat flour cookies, ASPC — artichoke stem powder cookies. Means±(SD) followed by different superscripts within rows are significantly different (p ⩽ 0.05). * Total carbohydrates were calculated by difference.

Table 8. Physical characteristics and color measurement of WFC and ASPC

Таблица 8. **Физические характеристики и измерение цвета печенья из пшеничной муки (WFC) и печенья с порошком стеблей артишока (ASPC)**

Parameters / Samples		WFC	ASPC5%	ASPC15%
Weight (g)		$16.28^{a}\pm0.54$	$16.16^{a}\pm0.10$	$14.06^{b}\pm0.10$
Height (cm)		$1.30^{a}\pm0.00$	$1.20^{ab}\pm0.00$	$1.15^{b}\pm0.07$
Volume (cm³)		$29.50^{a}\pm0.70$	$25.25^{b}\pm0.35$	$21.50^{c}\pm0.70$
Specific volume (cm³ /g)		$1.81^{a}\pm0.10$	$1.56^{b}\pm0.03$	$1.52^{b}\pm0.03$
Diameter (cm)		$4.60^{a}\pm0.14$	$4.30^{b}\pm0.00$	$4.30^{b}\pm0.00$
Spread ratio (diameter/height)		$3.53^{a}\pm0.10$	$3.58^{a}\pm0.00$	$3.74^{a}\pm0.22$
Color	***L****	$70.45^{a}\pm0.53$	$61.33^{b}\pm0.65$	$58.42^{c}\pm0.85$
	a*	$1.55^{c}\pm0.06$	$2.70^{b}\pm0.09$	$3.17^{a}\pm0.24$
	b*	$18.67^{a}\pm0.02$	$15.10^{b}\pm0.50$	$13.37^{c}\pm0.67$
	C	$18.73^{a}\pm0.08$	$15.33^{b}\pm0.14$	$13.74^{c}\pm0.34$
	H	$85.25^{a}\pm0.33$	$79.86^{b}\pm0.48$	$76.66^{c}\pm0.22$

WFC — wheat flour cookies, ASPC — artichoke stem powder cookies. Means ± (SD) followed by different superscripts within rows are significantly different ($p \leqslant 0.05$).

Figure 2. **Wheat flour cookies (control) and artichoke stem powder cookies**

Рисунок 2. **Печенье из пшеничной муки (контроль) и печенье с порошком стеблей артишока**

terms of weight there were no significant differences between the control samples of cookies made with 100% wheat flour and the enriched cookies with 5% *ASPC* ($P \leqslant 0.05$). Also, there were no significant differences in spread ratio between the control samples of cookies made with 100% wheat flour and the enriched cookies with 5% and 15% *ASP* ($P \leqslant 0.05$). The results of height, volume and specific volume are consistent with Canale et al. [25] and Eman et al. [10]. The color was changed to green by the addition of artichoke stem flour. The *a** value significantly increased, but *b**, *L**, C and H decreased, with a greater decrease at 15% substitution level. According to the findings of Frutos et al. [26], there was a tendency for the cookies to get noticeably darker as more artichoke stem flour was added. According to Manonmani et al. [27], the Maillard reaction is primarily responsible for the cookie color.

3.2.4. Sensory evaluation of WFC and ASPC

Sensory evaluation values of *WFC* and *ASPC* are presented in Table 9. Data showed that the panelists approved of all properties of all samples. Also, data showed that there were no significant differences between *ASPC* (5 and 15%) and *WFC* in appearance, texture and flavor. Cookies made with artichoke stem powder had lower scores for color, taste and overall acceptability. Overall acceptability refers to how customers or panelists accept the product in general. According to Elhassaneen et al. [29], color which can be a sign of baking completeness, has a significant impact also on the initial acceptability of baked goods.

4. Conclusion

The current study showed that artichoke by-products were rich in phenolic compounds, flavonoids, and minerals. Furthermore, artichoke by-products demonstrated high levels of the inherent antioxidant activity. Artichoke by-product flour has a high mineral, total protein and total lipid contents, which makes it a useful ingredient in many local foods, including cookies and other bakery products. Artichoke by-products were found to significantly affect the phytochemical properties of cookies when added in small amounts (15%). Specifically, they increased the amount of polyphenolic compounds compared to the control cookies. The spread ratio of the cookies enhanced with 15% artichoke by-products and was comparable to that of the control cookies. Additionally, a color difference between the cookies with artichoke by-products and the control cookies was seen.

Table 9. **Sensory evaluation of WFC and ASPC**

Таблица 9. **Сенсорная оценка печенья из пшеничной муки (WFC) и печенья с порошком стеблей артишока (ASPC)**

Parameters / Samples	Appearance (10)	Color (10)	Texture (10)	Flavor (10)	Taste (10)	Overall acceptability (10)
WFC	$9.80^{a}\pm0.44$	$9.60^{a}\pm0.89$	$9.20^{a}\pm0.83$	$9.80^{a}\pm0.44$	$9.60^{a}\pm0.54$	$9.80^{a}\pm0.44$
ASPC 5%	$9.80^{a}\pm0.44$	$8.77^{ab}\pm0.83$	$9.40^{a}\pm0.89$	$9.60^{a}\pm0.54$	$9.00^{ab}\pm0.70$	$9.45^{ab}\pm0.50$
ASPC 15%	$9.60^{a}\pm0.54$	$8.04^{b}\pm0.71$	$9.40^{a}\pm0.83$	$9.60^{a}\pm0.89$	$8.80^{b}\pm0.44$	$8.90^{b}\pm0.12$

WFC — wheat flour cookies, ASPC — artichoke stem powder cookies. Means ± (SD) followed by different superscripts within columns are significantly different ($p \leqslant 0.05$).

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Contribution	**Критерии авторства**
Authors equally relevant to the writing of the manuscript, and equally responsible for plagiarism.	Авторы в равных долях имеют отношение к написанию рукописи и одинаково несут ответственность за плагиат.
Conflict of interest	**Конфликт интересов**
The authors declare no conflict of interest.	Авторы заявляют об отсутствии конфликта интересов.