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Effect of artichoke (*Cynara scolymus L.*) by-product on the quality and total phenol content of bread

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Abstract: Legume flours, due to their phenol and fibre content, are ideal ingredients for improving the nutritional value of bakery products. In this study, artichoke stem powder (ASP) was used to substitute 0%, 2.5%, 5%, 7.5% and 10% of wheat flour for making breads. Proximate composition of wheat flour and ASP were determined. Bread qualities and total phenols content were analyzed and compared with those of wheat bread. Results show that ASP contained 10.37% moisture, 10.28% ash, 11.53% protein, 0.86% fat, 51.29% fibre and 1350 mg EAG/100g d.m. ASP addition considerably modified the bread quality: altered appearance and texture, darker crumb and more intense odour were observed. From the sensory evaluation, tastes of bread with higher content of ASP (7.5 and 10%) were the most acceptable for assessors. Total phenol contents of breads significantly increased with the addition of ASP. Therefore ASP may be considered as valuable ingredients for industrial manufacture of functional foods.

Keywords: artichoke, phenol, bread, texture, fibre.

Introduction

The interest in functional foods increased in the recent decades due mainly to increase in the number of health-conscious people all over the world. Functional foods are known to have positive effects on human health, such as prevention of cancer, reducing cholesterol risk and regulating the digestive system. Therefore, research on functional food and/or ingredients have been carried out to satisfy consumer demand. In human nutrition, cereal products, especially bread, maintain their importance because of their availability and nutritional value. In recent years, demand of functional bakery products has been increasing [1]. Vegetable such as potato, chestnut, Jerusalem artichoke, grape, date, pear, apple, carrot and orange [2–9] have been investigated to obtain functional bakery products. Vegetable by-products are an excellent source of dietary fibre and phenol compounds. They are inexpensive and available in large quantities. Therefore, by-products may be incorporated into food products for partial replacement of flour, fat or sugar, as enhancers of water and oil retention and to improve emulsion or oxidative stabilities [10]. Artichoke by-products (leaves, external bracts and stems) discarded at harvesting or after industrial processing, which represent a huge amount of discarded material [11], are increasingly being used to obtain functional ingredients (i.e., phenolic compounds, inulin) for use in the design of functional foods [12–14]. It is known that artichoke by product is a rich source of polyphenols, inulin and dietary fibre [15–17] possessing beneficial effects on human health. Few works are interested to study the supplementation of bread with artichoke powder [18,19]. So far, there are no reports on the use of artichoke stem by-products as the source of both DF and polyphenols. Therefore, the aim of this experimental work is not only waste valorization but also making bread a functional food. Thus, two sets of experiments were carried out, one to determine the composition of artichoke stem powder (ASP) and the other to evaluate the influence of ASP addition on bread quality (e.g. volume, colour, texture and sensory properties) and phenol content.

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Experimental Section

Materials

Artichoke stem by-product (Cyanara scolymus L.) was collected from technical centre for potato and artichoke of Tunisia (CTPTA). The samples were washed with tap water, cut into small pieces, dried using a laboratory tray dryer at 40 °C for 3 days, ground to a powder form using blender and passed through a 0.500 mm sieve. The wheat flour, salt and yeast used in the formulation of bread were purchased from a local market.

Proximate composition of ASP and flour

Proximate analysis including moisture, ash, fat and protein were determined in triplicate, according to AOAC methods [20]. The moisture content was determined by further heating of the dried sample at 105 °C overnight until constant weight; the ash content was determined by weighing the incinerated residue obtained at 550°C for 24 h; crude protein content was estimated by Kjeldahl technique, protein content was determined by multiplying the nitrogen content by a factor of 5.75 (wheat flour) and 6.25 (artichoke flour); the crude fat content was determined by Soxhlet extraction with petroleum ether as a solvent; total, soluble and insoluble dietary fibre contents were determined by enzymatic–gravimetric method [21]. The sum of insoluble dietary fibre and soluble dietary fibre contents were calculated as total dietary fibre. The total carbohydrates content were calculated by difference: Total carbohydrates (g) = 100 - (g protein + g fat + g ash + g fibre); Proximate analyses were expressed as grams per 100 g of dry matter.

Baking procedure

Five bread formulations were prepared by replacing the flour with 0%, 2.5%, 5%, 7.5% and 10% (w/w) of artichoke stem powder (ASP). The other ingredients were yeast (2 g/100 g), salt (1.8 g/100 g), and water (variable, depending on the farinograph absorption). The baking procedure was as follows: The flour, salt, ascorbic acid and water were mixed for 5 min. Then, yeast, previously diluted in water at 30°C, was added to the mixture. The dough obtained was optimally mixed for 5 min at low speed, fermented for 45 min. Then, it was hand rounded placed at 30°C for fermentation for 60 min up to optimum volume increase. The baking is done at 230 °C for 30 min in an electric oven. The oven was preheated to set temperatures before placing the dough samples into it. Afterwards the bread was taken out of the bread case, cooled to room temperature.

Crumb colour

Bread crumb colour was measured using a chroametre Minolta (CR-410). The parameters determined were L* (lightness, black=0, white=100), a* (redness>0, greenness<0) and b* (yellowness, b*>0, blue<0). Crumb colour was determined on three points on the three central slices of each sample for bread type.

Crumb texture

Texture of bread was measured with a 5 kg capacity Texture Analyzer TA.XT plus (Stable Micro Systems Ltd, Godalming, UK), using a 10 mm cylinder probe. On each test, four slices per formulation were selected at random, for the texture test at 3 h post-bake. A texture profile analysis (TPA) was carried out. All bread loaves were uniformly sliced to a thickness of 10 mm and the loaf crust was cut off allowing only crumb texture measurements. Each bread slice was precisely centred on the base and, positioned just above it, was slowly lowered 5mm to deform to a 50%, avoiding fracture. The cross-arm speed was 1.0 mm/s. The results presented are the average of four trials. The sample was compressed twice (curves 1 and 2) to give a two-bite TPA. Four primary TPA parameters (hardness, springiness, cohesiveness, and resilience), and two derived parameters (chewiness and consistency) were calculated. Attributes were calculated as follows: Hardness (N): the first peak in TPA analysis ; Springiness is the distance (mm) that the sample recovers after the first compression [22], Cohesiveness, the ability of a material to stick together, is the area of work during the second compression divided by the area of work during the first compression (dimensionless); resilience, defined as a dimensional ratio between the area under the curve during the withdrawal for the first compression and the area of first compression; Chewiness (N mm) is calculated by multiplying hardness, cohesiveness and springiness, and represents the amount of energy needed to disintegrate a food for swallowing. Consistency (N s) sums the combined area of the two resistance peaks.

Sensory Evaluation

Sensory analysis was carried out as follows: one slice of bread, served in white plates, identified by code numbers, was served to each panelist under normal (daylight) illumination. Breads were evaluated for odour (not intense till acute), taste (1 represented 'dislike extremely', 4–5 represented 'acceptable' and 8–9 represented 'like extremely'), hardness (tender to hard) and crumb colour (light to dark). Sensory analysis was carried out using a 10-point scale scoring 1 (lowest) - 10 (highest). Sensory evaluation was performed by 14 trained panellists from students of the National Institute of Agronomy of Tunisia (INAT). The samples were analyzed on 3 h after baking.

Extracts preparation and determination of total phenolic content (TPC)

Bread slices (1 cm thickness) were dried in an oven (40°C) for 24 h then grinded and sieved through a 100-mesh screen; 10 g of bread flour was weighed, and 100 mL of 80% ethanol was added.

After that, solution was shaken at 200 rpm at 37°C for 24 h. Then the mixing was centrifuged at 2000g for 15 min. The supernatant was filtered by using Whatman no. 1 filter paper. The fresh extracts were used to determine total phenol content (TPC). The amount of TPC was determined with the Folin–Ciocalteu reagent using the method of Djeridane et al [23] . A standard curve was first plotted using Gallic acid as a standard. Different concentrations of Gallic acid were prepared in 80% of ethanol, and the absorbance was recorded at 765 nm after their reaction with the Folin-Ciocalteu reagent. 100 µL of sample was dissolved in 500 µL (1/10 dilution) of the Folin–Ciocalteu reagent and 1000 µL of distilled water. The solutions were mixed and incubated at room temperature for 1 min. After 1 min, 1500 µL of 20% sodium carbonate (Na_2CO_3) solution was added. The final mixture was shaken and then incubated for 2 h in the dark at room temperature. The absorbance of all samples was measured at 765 nm using a Milton Roy 601 UV–Vis spectrophotometer and the results are expressed in mg Equivalents Acid Gallic (EAG)/100 g d.m.

Statistical Analysis

The data in triplicate, unless stated otherwise, for different treatments were analyzed by one-way ANOVA and Duncan's new multiple range tests to determine the statistical significance of differences among the values by using of the SPSS software 20.0.0 (SPSS Chicago, IL). Confidence levels were set at 95% ($P < 0.05$). Results were presented as x±SD with x the mean of replications and SD the standard deviation

Results and discussion

Chemical analysis of flours

Proximate compositions of artichoke stem powder (ASP) and wheat flour (WF) are presented in Table 1. Data indicated that significant differences were observed among WF and ASP in their composition. It is noteworthy that ASP contained much less moisture than the commercial wheat flour .The protein and fat content of the wheat flour was higher than those of ASP .The protein content of ASP(11.53 g/100 g d.m) showed similar values to the protein content reported in different artichoke by products (10.35 to 17.9%) [13,18,24], whereas the ash content in ASP was higher than that of flour, suggesting an important mineral content. Artichoke stem powder, exhibited much ash content (10.26 g/100 g d.m) than other artichoke by products such as leaf and stem (8.42%) [18] and bract (5.12%) [24]. Total dietary fibre (TDF) content in ASP was high (51.29 g/100 g dry sample), a value that resembles to that found in artichoke leaf and stem (55 %) [18] but higher than in artichoke bract (44.23%) [24]. Larrauri et al [25] reported that products with fibre content above 50% can be regarded as a rich source of dietary fibre. The IDF fraction was higher than the SDF fraction. Table 1 showed also that the phenol content in artichoke stem powder (1350±0.07 mg EAG/100g d.m.) is much higher than that present in wheat flour (106±0.11 mg EAG/100g d.m.). The addition of ASP to wheat flour is expected to increase the fibre and phenol content of the blends leading to fibre enriched breads.

Table 1. Proximate Compositions of artichoke stem powder and wheat flour

Component	Wheat Flour (WF)	Artichoke Stem Powder (ASP)
Moisture (g/100 g d.m.)	13.94±0.12^b	10.37±0.5^a
Crude protein (g/100 g d.m.)	12.66±0.15^b	11.53±0.04^a
Crude ash (g/100 g d.m.)	0.47±0.05^a	10.26±0.34^b
Fat (g/100 g d.m.)	1.07±0.00^b	0.86±0.00^a
Carbohydrates** (g/100 g d.m.)	85.50±0.05^b	26.06±0.05^a
Total dietary fibre (g/100 g d.m.)	0.3±0.0^a	51.29±0.21^b
Insoluble dietary fibre (g/100 g d.m.)	-	47.14±0.13
Soluble dietary fibre (g/100 g d.m.)	-	4.15±0.08
Total phenol (mg EAG/100g d.m)	106±0.11^a	1350±0.07^b

*Each value is expressed as mean ± SD (n = 3) and means having different letter superscripts within a same row are significantly different ($P < 0.05$).**Carbohydrates were calculated by subtracting total percent values of protein, fat, ash and total dietary fibre from 100.

Effect of artichoke stem powder substitution on bread colour

The effects of Artichoke Stem Powder (ASP) addition on the bread colour are shown in Table 2. The crumb colour of samples was affected by the replacement of wheat flour with ASP. For crumb colour, the L* and b* value decreased significantly however the a* values showed significant increase with the addition of artichoke stem powder, indicating that a darker, blueness and redness crumb was obtained as a result of ASP substitution. This was quite likely due to the darker colour of ASP.

However, the crumb bread colour is usually similar to the colour of the ingredients because the crumb does not reach as high temperatures as the crust.

Table 2. Colour values (CIE L*a*b*) and of the breads crumb with different percentages of artichoke stem powder.

ASP%	L*	a*	b*
0%	84,51±0.7^{a}	-0.07±0.14^{a}	20,70±0.70^{a}
2.5%	79,54±3.39^{b}	-0.01±0.47^{a}	19,60±1.61^{ab}
5%	70,03±1.73^{c}	0.34±0.13^{a}	17,09±0.74^{b}
7.5%	70,90±3.90^{c}	1.19±0.34^{b}	11,08±3.24^{c}
10%	66,08±1.54^{d}	1.19±0.10^{b}	13,08±1.64^{c}

*Data are mean of 5 determinations ± SD. Means within columns followed by the same letter were not significantly different ($p<0.05$).

Effect of artichoke stem powder substitution on bread Texture

The effect of addition of artichoke stem powder on bread texture was studied for five different formulations (Table 3). Of these formulations, a gradual hardening of crumb texture was observed as the addition of artichoke powder increased. The increase was significant respect to the control when a 7.5% of ASP was added. The results are coincident with those reported in bread formulated with the addition of inulin [26]. There is a relationship between hardness and gluten content [27]. Gluten is responsible of the gas retention capacity during fermentation. Lower gluten content is related to a higher hardness of the crumb. The substitution of different amounts of wheat flour by artichoke powder had a dilution effect, decreasing the gluten content and modifying the viscoelastic properties of gluten. Springiness gives information about the after stress recovery capacity and refers to retarded recovery (after the delay between compressions). Cohesiveness is the extent to which a material can be deformed before it ruptures. Springiness and cohesiveness were not significantly different among the samples studied. The chewiness increases as ASP is added. The influence of ASP is significant respect to control for amounts of 7.5% of ASP and higher. The impacts of higher ASP contents on chewiness have been also reported by sudha et *al* [28]. Changes in resilience were not significant. Similar results were found in breads supplemented with different fibre sources [26], although the differences in resilience respect to control were much greater for the breads with AF.

Table 3. Effect of ASP on textural properties of breads

ASP%	Hardness (N)	Springiness (mm)	Cohesiveness	Chewiness (Nmm)	Resilience	Consistency
0%	1.41^{a}±0.07	0.87^{a}±0.12	0.82^{a}±0.31	1.01^{a}±0.19	0.30^{a}±0.00	80.54^{a}±6.25
2.5%	1.45^{a}±0.07	0.94^{a}±0.01	0.78^{a}±0.33	1.07^{a}±0.11	0.30^{a}±0.02	87.03^{a}±22.35
5%	1.60^{a}±0.05	0.92^{a}±0.02	0.78^{a}±0.02	1.15^{a}±0.05	0.29^{a}±0.02	91.19^{a}±7.91
7.5%	1.97^{b}±0.03	0.92^{a}±0.01	0.78^{a}±0.04	1.42^{b}±0.06	0.29^{a}±0.01	108.98^{a}±24.04
10%	2.30^{c}±0.25	0.92^{a}±0.01	0.79^{a}±0.03	1.66^{c}±0.17	0.29^{a}±0.01	113.03^{a}±24.45

Means within columns followed by the same letter were not significantly different ($p<0.05$).

Sensory evaluations of breads supplemented with artichoke stem powder

Sensory characteristics of wheat bread substituted with artichoke stem powder at different levels 0%, 2.5%, 5%, 7.5% and 10% are presented in Table 4. Colour, odour and hardness score of bread with ASP was significantly higher than control bread. The colour of crumb of the enriched bread was much darker (brown) than that of the control bread. The change in bread crumb colour is quite evident and with the increase of artichoke powder in bread, crumb colour became darker. Bread with 5%, 7.5% and 10% of ASP were significantly harder than wheat bread prepared only from wheat flour. The hardening effect observed after addition of ASP results from the dilution of gluten content. Evaluation of the taste of bread showed that acceptance of products with higher content of ASP (7.5 and 10%) was markedly increased despite the negatively effect on odour, colour and hardness of final products.

Table 4. Sensory evaluation of breads prepared by the substitution of wheat flour with artichoke stem powder (ASP)

ASP%	Odour	Taste	Hardness	Crumb colour
0%	3,74±2,85^{a}	1,86±1,81^{a}	3,67±3,17^{a}	1,10±0,66^{a}
2.5%	4,70±2,35^{a}	3,73±2,05^{b}	3,46±2,17^{a}	2,94±0,85^{b}
5%	4,64±2,13^{a}	4,43±1,51^{b}	5,16±2,48^{b}	5,00±1,27^{c}
7.5%	4,90±2,39^{a}	6,16±1,93^{c}	5,77±2,00^{b}	6,65±1,10^{d}
10%	6,39±2,52^{b}	6,88±1,97^{c}	5,67±2,25^{b}	7,77±1,47^{e}

Effect of artichoke stem powder substitution on the total phenol content

The total phenol content for different samples, expressed as mg equivalent acid gallic per 100 gram of dry weight, is illustrated in figure 1.The phenol content in bread samples was gradually increased with increasing the ASP levels, the lowest phenol contents were presented in control bread and the maximum phenols content (16.99 mg EAG/100g d.m) was found in bread supplemented with 10 % ASP. This increase in phenolic compounds could be associated with the flavour changes in bread with 10% ASP as observed from organoleptic evaluation. The contents of phenols in breads were lower than in flour. Bioactive compounds existing in flour might be destroyed or lost during baking as a consequence of the heat/thermal process during baking. Sudha et al [29] reported that baking or drying at temperature above 60°C is regarded as unfavourable due to the possibility of inducing oxidative condensation or decomposition of thermo-liable compounds like phenolics

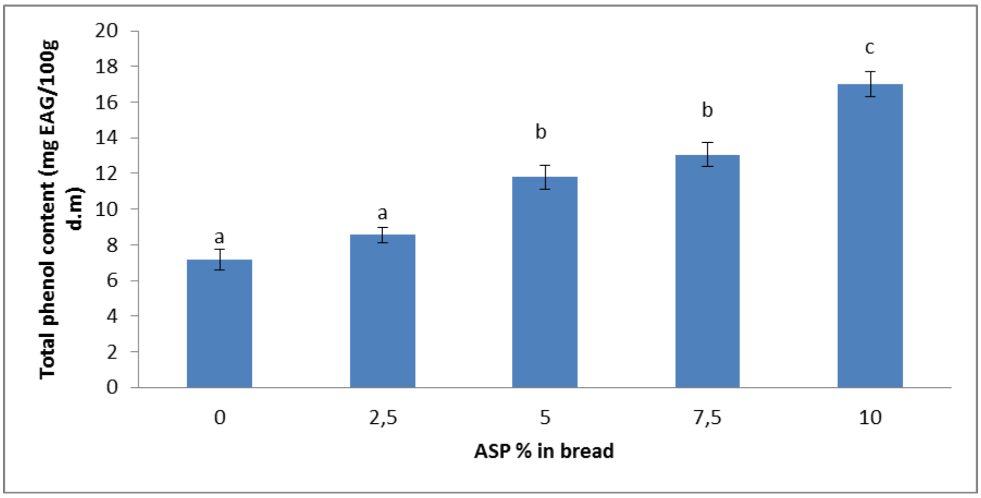

Figure 1.Total phenol contents of breads prepared with artichoke stem powder replacement for wheat flour. Bars represent standard error of means (n = 3) and means with different letters are significantly different ($P < 0.05$).

Conclusion

It has been observed that it is possible to use artichoke stem powder, as an alternative source of DF and polyphenols, to partially substitute wheat flour in the elaboration of bread. The chemical composition of ASP indicated high levels of fibre, ash and phenolic compounds. Based on sensory and physical characteristics, it may be concluded that higher amounts of ASP in the formulation would result in important changes in colour, odour, and texture but in term of taste it would make the bread more acceptable for the consumer.

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