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Crackers Fortified with Various Ratios of *Cynara Scolymus* L. Leaf Extract Residue: Nutritional, Physical and Sensory Quality

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Artichoke leaf extract residue (ALER) is a by-product of the production of artichoke leaf extract. In the present research, ALER powder and wheat flour were utilized in the formulation to make crackers with high dietary fiber and antioxidant contents. The aim of the research was to investigate the impacts of ALER ratio on the nutritional, physical and overall sensory quality of crackers. ALER was rich in dietary fiber (72.9 ± 6.9 g/100 g dry basis) and phenolic compounds (12562 ± 800 mg GAE/kg dry basis). As the weight ratio of ALER was enhanced from 0 to 12 % of the blend flour, the crackers had increased dietary fiber and phenolic contents and improved antioxidative activities. Referring to physical properties, the diameter of the fortified crackers remained constant while their hardness was decreased and their color became darker. The addition of ALER to cracker recipe decreased overall acceptability of the product. Crackers with a 6 % ALER ratio had a total fiber amount of 6.4 g/100 g dry basis; they were a high dietary fiber food with acceptable overall sensory quality.

1. Introduction

Crackers are thin and crisp wafers or biscuits that are typically made from unsweetened dough (Han et al., 2010). They have a long shelf-life, can be eaten right out of the package, and come in a variety of shapes and sizes. Healthy crackers are fortified with various functional ingredients such as dietary fiber, antioxidants, calcium, iron, and vitamins (Davidson, 2018). Dietary fiber is referred to plant carbohydrates which are resistant to digestion and absorption in human small intestine; some dietary fibers can be partially or completely fermented in human large intestine (Trumbo et al., 2001). Dietary fiber intake can reduce risk of obesity, diabetes, hypertension, and some visceral illnesses (Anderson et al., 2009). Natural antioxidants in food can prevent cell damage by scavenging free radicals in human body. Among natural antioxidants, phenolic compounds are widely distributed in plant materials (Lobo et al., 2010).

Cynara scolymus L., also known as globe artichoke, is a Mediterranean native herbaceous. The industrial processing of artichoke results in different by-products (stems, leaves, and external bracts) which account for a significant amount of discarded material (45–50 %). These by-products are high in phenolic compounds, inulin, and other dietary fiber (Lattanzio et al., 2009). It is reported that artichoke by-products are added to bakery (Frutos et al., 2018) and meat (Ruiz Cano et al., 2015) products to improve the nutritional quality and healthy properties. In Vietnam, artichoke leaves are used in the production of concentrated extract as health support products, and the leaf residue is removed. This by-product has been used as animal feed and fertilizer; its utilization in food formulation has not been reported. In this research, artichoke leaf extract residue (ALER) was supplemented to cracker recipe to enhance its dietary fiber and antioxidant content. The aim of this research was to investigate the impacts of ALER ratio in cracker formulation on quality of the final product.

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2. Materials and methods

2.1 Materials

Artichoke (*Cynara scolymus* L.) leaf extract residue (ALER) was collected from Thanh Uyen Limited Liability Company (Lam Dong, Vietnam). The stalks were manually removed and the remaining residue was dried at 50 °C for 10 h until its moisture content was about 10−12 %. After grinding and passing through a 70-mesh screen, the obtained powder was kept at room temperature for experimentation.

Wheat flour (8 % protein) was purchased from DP Flour Milling Co, Ltd. (Vietnam). Cooking oil, refined saccharose, baking powder, table salt, calcium dihydrogen phosphate and lecithin were bought from a local super market.

Analytical chemicals were from Sigma-Aldrich (USA); protease and amylase preparations for analysis of dietary fiber were from Novozymes (Denmark).

2.2 Experimentation

The main ingredients for cracker making were 200 g wheat flour and ALER powder. The ratios of ALER to the blend weight were 0 (control), 3, 6, 9 and 12 %. The remaining ingredients included 28 g vegetable oil, 10 g ground saccharose, 0.52 g lecithin, 0.58 g monocalcium phosphate, 73.5 mL water, 4.08 g baking powder and 1.46 g table salt.

Cracker making procedure: Mixture 1 (including vegetable oil, lecithin, and ground saccharose) was well stirred in a mixer (Model M8, UNIE, Vietnam) at 200 rpm for 1 min; monocalcium phosphate was first dissolved in 5.5 mL water, then added into mixture 1, and stirred at 200 rpm for 1 min to get mixture 2; table salt was dissolved in 68 mL water and added into mixture 2; after that, wheat flour, ALER powder and baking powder were put in the mixing bowl and kneaded at 400 rpm for 12 min; the obtained dough was removed and incubated in a thermostat at 45 °C; after 12 min, the dough was rolled into sheets with 2 mm thickness; a round mould with 42 mm diameter was used to cut the dough sheets into uniform pieces. The crackers were baked at 230 °C for 10 min in an oven (Sanaky, Vietnam). At the end of baking, the crackers were chilled to room temperature, preserved in polyethylene bags and used for further analyses.

2.3 Analytical methods

2.3.1 Nutritional composition

Moisture was determined by drying method, using a fully automatic moisture analyzer (A&D Co., Japan). Protein was quantified by Kjeldahl Nessler method (AOAC 984.13). Lipid was evaluated according to Soxhlet method (AOAC 960.39). Insoluble dietary fiber (IDF), soluble dietary fiber (SDF) and total dietary fiber (TDF) were analyzed by AOAC 991.43, 993.19 and 985.29 methods. Total ash was measured according to AOAC 930.30 method. Starch was determined by AOAC 996.11 method. Total carbohydrate expressed in g/ 100 g dry basis (DB) was estimated by deducting the ash, lipid and protein from 100.

2.3.2 Antioxidant contents and activities

Total phenolics (mg gallic acid equivalent per kg dry basis, GAE/kg DB) were quantified using spectrophotometric method and Folin-Ciocalteau reagent (Nielsen, 2017). Total flavonoids (mg quercetin equivalent per kg dry basis, QE/kg dry DB) were analyzed by colorimetric method (Orefice et al., 2022). Antioxidant activities (millimole Trolox equivalent per kg dry basis, mmol TE/kg DB) were measured according to ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) assays (Nielsen, 2017).

2.3.3 Physical characteristics

Oil and water holding capacities of ALER powder and wheat flour were measured by a method previously reported (Bassani at al., 2020). Size of cracker samples was measured by a method reported elsewhere (Igbabul et al., 2015). Hardness of crackers was evaluated by Texture profile analyzer using TA.XT Plus Connect Instrument (Stable Micro Systems, UK) by piercing measurement (Biel et al., 2020). Instrumental color was estimated by colorimetric method using a CR-300 chronometer (Konica Minolta, Japan) and CIE Lab system.

2.3.4 Overall acceptability of crackers

Sensory evaluation of crackers was evaluated by acceptance test which gives a score on a 9-point scale, corresponding to the range from “extremely dislike” (1 point) to “extremely like” (9 points) (Noor Aziah et al., 2009). The number of panelists was 60 people who were recruited from universities in Ho Chi Minh City.

2.4 Statistical analysis

All cracker samples were performed with three replicates. The experimental results were expressed in mean ± standard deviation. The analysis of variance was done using Statgraphics plus (version 3.2). Multiple range tests ($p < 0.05$) were used to compare significant difference between the obtained experimental results.

3. Results and Discussion

3.1 Nutritional composition, antioxidative activities and physical characteristics of powder of artichoke leaf extract residue and wheat flour

Table 1 shows nutritional composition and antioxidative activities of the ALER powder and wheat flour. In terms of protein and lipid contents, ALER powder and wheat flour were not significantly different. The ALER powder contained much more ash than the wheat flour. Starch was not identified in ALER powder but this component accounted for 76 % DB of the wheat flour. The ALER powder contained less carbohydrate than the wheat flour. The main carbohydrates of artichoke leaf extract are simple sugars, disaccharides, and some polysaccharides (Biel et al., 2020). The ALER powder contained much more dietary fiber than the wheat flour. Specifically, the SDF, IDF and TDF contents of ALER powder were 24.4, 39.1 and 35.6 times greater than those of wheat flour. Specifically, the TDF amount of ALER powder was also greater than that of other by-products such as potato peel powder (45.91 % DB) and pear peel powder (39.53 % DB) (Elhassaneen, 2016). Products with a dietary fiber level of more than 50 % can be considered a good source of dietary fiber (Larrauri, 1999). As a result, the residue from artichoke leaf extraction was a potential fiber material for cracker fortification.

The total phenolic and flavonoid contents of ALER powder were 2.9 and 12.2 times greater than those of wheat flour. Notably, *Cynara scolymus* L. contained a high level of phenolic acids including caffeoylquinic acids and luteolin glucosides with high antioxidant capacity (Rouphael et al., 2012). The antioxidative activities measured by the FRAP and DPPH assays in wheat flour were much lower than those in ALER powder. The partial replacement of wheat flour by ALER powder in cracker formula would improve antioxidative activities of the final product.

Table 1: Nutritional composition and physical characteristics of powder of artichoke leaf extract residue and wheat flour

	ALER powder	Wheat flour
Protein (g/100 g DB)	11.1 ± 0.4^{a}	10.7 ± 0.6^{a}
Lipid (g/100 g DB)	2.4 ± 0.2^{a}	2.5 ± 0.1^{a}
Ash (g/100 g DB)	7.5 ± 0.4^{b}	0.6 ± 0.0^{a}
Starch (g/100 g DB)	ND	76.0 ± 5.7
Carbohydrates (g/100 g DB)	79.1 ± 0.1^{a}	86.2 ± 0.6^{b}
SDF (g/100 g DB)	12.2 ± 0.7^{b}	0.5 ± 0.0^{a}
IDF (g/100 g DB)	62.5 ± 5.7^{b}	1.6 ± 0.1^{a}
TDF (g/100 g DB)	74.7 ± 6.2^{b}	2.1 ± 0.2a
Total phenolics (mg GAE/kg DB)	12562 ± 800^{b}	4313 ± 153^{a}
Flavonoids (mg QE/kg dry DB)	3766 ± 279^{b}	308 ± 30a
Antioxidative activity by FRAP assay (mmol TE/kg DB)	48.45 ± 3.01^{b}	2.51 ± 0.23^{a}
Antioxidative activity by DPPH assay (mmol TE/kg DB)	97.40 ± 2.09^{b}	2.55 ± 0.16^{a}
L*	51.6 ± 0.1^{a}	93.6 ± 0.2^{b}
a*	1.4 ± 0.0^{b}	0.3 ± 0.0^{a}
b*	10.0 ± 0.1^{b}	8.7 ± 0.0^{a}
Water holding capacity (g water/g DB)	6.0 ± 0.5^{b}	1.4 ± 0.0^{a}
Oil holding capacity (g oil/g DB)	2.2 ± 0.2^{b}	1.4 ± 0.1^{a}

Each value is mean ± standard deviations (n = 3) and means with different letter superscripts in a same row are significantly different ($p < 0.05$); ND: Not detected.

Table 1 also reveals that the instrumental color of ALER was different from that of wheat flour. The ALER was darker than wheat flour since its L* value was lower. The a* and b* values of ALER were 4.6 and 1.1 times greater than the values of wheat flour probably because of the residual carotenoids and flavonoids in the ALER powder (Ben Salem et al., 2017). The ALER powder had high water holding ability. This property was due to the presence of pores generated by polysaccharide chains, which can retain water by forming hydrogen bonds with their -OH groups (Rouphael et al., 2012). Wheat flour had low fiber content and hence had a limited ability to absorb water. The ALER powder also had high oil holding capacity. The lipophilic groups of plant materials

enhance their oil holding capacity (Rafieian et al., 2015). The capillary structure of the insoluble dietary fiber may retain oil (Elleuch et al., 2011).

3.2 Effects of addition ratio of artichoke leaf extract residue on nutritional composition and antioxidative activities of crackers

The impacts of supplementation ratio of ALER on the cracker quality are visualized in Table 2. The addition of ALER slightly enhanced moisture and lipid contents of the product probably owning to the greater oil and water holding abilities of fiber-fortified crackers. Similar results were reported when apple pomace was used in the biscuit formulation (Usman et al., 2020). The protein content of all cracker samples remained statistically unchanged due to the similarity in protein levels between ALER and wheat flour. Noteworthy, when the ALER ratio increased from 3 % to 12 %, the ash content rose 1.8 times to 2.4 times in comparison to that of the crackers without ALER addition. This was associated with greater ash content in the ALER powder. Contrarily, the starch amount of fortified crackers was significantly declined when the ALER ratio was enhanced; this was due to the fact that the starch content in the ALER flour was not identified. Similarly, a reduction in the total carbohydrate content of the ALER added crackers was also observed.

Table 2: Nutritional, physical and sensory quality of crackers supplemented with different ratios of artichoke leaf extract residue

Composition	Cracker with ALER powder added by mass ratio				
	T0	T3	T6	T9	T12
Moisture (%)	3.5 ± 0.3^{a}	3.7 ± 0.1^{ab}	3.8 ± 0.3^{ab}	4.0 ± 0.2^{b}	4.0 ± 0.2^{b}
Protein (g/100 g DB)	9.6 ± 0.4^{a}	9.5 ± 0.6^{a}	9.6 ± 0.2^{a}	9.7 ± 0.4^{a}	9.9 ± 0.3^{a}
Lipid (g/100 g DB)	15.0 ± 0.5^{a}	15.1 ± 0.7^{a}	16.2 ± 0.3^{b}	16.3 ± 0.5^{b}	16.4 ±0.4^{b}
Ash (g/100 g DB)	1.3 ± 0.0^{a}	2.3 ± 0.0^{b}	2.5 ± 0.0^{c}	2.8 ± 0.1^{d}	3.1 ± 0.1^{e}
Starch (g/100 g DB)	65.9 ± 0.9^{e}	64.1 ± 0.7^{d}	62.6 ± 0.7^{c}	60.5 ± 0.9^{b}	58.2 ± 0.7^{a}
Carbohydrates (g/100 g DB)	74.1 ± 0.4^{b}	73.1 ± 1.2^{b}	71.6 ± 0.1^{a}	71.2 ± 0.7^{a}	70.6 ± 0.3^{a}
TDF (g/100 g DB)	2.1 ± 0.1^{a}	4.3 ± 0.2^{b}	6.3 ± 0.2^{c}	8.5 ± 0.1^{d}	10.6 ± 0.2^{e}
SDF (g/100 g DB)	0.5 ± 0.0^{a}	0.9 ± 0.0^{b}	1.2 ± 0.0^{c}	1.6 ± 0.1^{d}	1.9 ± 0.0^{e}
IDF (g/100 g DB)	1.6 ± 0.1^{a}	3.4 ± 0.2^{b}	5.1 ± 0.2^{c}	6.9 ± 0.1^{d}	8.7 ± 0.2^{e}
IDF:SDF ratio	3.4 ± 0.4^{a}	3.8 ± 0.2^{b}	4.4 ± 0.1^{c}	4.3 ± 0.1^{c}	4.7 ± 0.0^{d}
Total phenolics (mg GAE/kg DB)	1202± 117^{a}	2351 ± 164^{b}	2766 ±177^{c}	3332 ± 122^{d}	3823 ± 175^{e}
Flavonoids (mg QE/kg dry DB)	121 ± 12^{a}	332 ± 15^{b}	399 ± 17^{c}	434 ± 21^{d}	499 ± 19^{e}
Antioxidative activity by FRAP assay (mmol TE/kg DB)	1.79 ± 0.17^{a}	4.00 ± 0.06^{b}	4.33 ± 0.41^{b}	4.91 ± 0.23^{c}	5.83 ± 0.34^{d}
Antioxidative activity by DPPH assay (mmol TE/kg DB)	1.65 ± 0.10^{a}	2.59 ± 0.24^{b}	3.01 ± 0.27^{b}	3.77 ± 0.33^{c}	4.26 ± 0.41^{c}
Diameter (mm)	42.5 ± 0.1^{a}	42.5 ± 0.2^{a}	42.1 ± 0.7^{a}	42.4 ± 0.6^{a}	42.5 ± 0.3^{a}
Thickness (mm)	3.7 ± 0.1^{c}	3.6 ± 0.0^{c}	3.3 ± 0.1^{b}	3.2 ± 0.2^{ab}	3.0 ± 0.1^{a}
Hardness (g)	2969 ± 95^{e}	2739 ± 70^{d}	2559 ± 96^{c}	2349 ± 79^{b}	2107 ± 81^{a}
SF index	11.6 ± 0.3^{a}	11.9 ± 0.1^{a}	12.9 ± 0.4^{b}	13.4 ± 0.8^{bc}	14.1 ± 0.5^{c}
L*	77.7 ± 0.0^{e}	65.2 ± 0.3^{d}	62.0 ± 0.2^{c}	57.8 ± 1.2^{b}	55.7 ± 0.5^{a}
a*	5.3 ± 0.0^{b}	3.2 ± 0.4^{a}	2.5 ± 0.5^{a}	2.5 ± 0.6^{a}	2.7 ± 0.2^{a}
b*	23.6 ± 0.0^{d}	19.3 ± 0.5^{c}	17.1 ± 1.3^{b}	14.7 ± 0.4^{a}	14.2 ± 0.3^{a}
Sensory score	6.7 ± 1.3c	5.9 ± 1.4^{b}	5.7 ± 1.6^{b}	4.9 ± 1.6^{a}	4.8 ± 1.6^{a}

Each value is mean ± standard deviations (n = 3) and means with different letter superscripts in a same row are significantly different ($p < 0.05$); T0: Control crackers with 100 % wheat flour; T3, T6, T9, T12: Crackers supplemented with 3 %, 6 %, 9 %, 12 % ALER powder.

The TDF, SDF, and IDF contents of cracker samples were proportional to the increase in ALER ratio in the cracker recipe. At 12 % level of supplementation, the TDF, SDF and IDF contents of the cracker samples were increased by 5.0, 3.8, and 5.4 times, as compared to those of the control cracker. The crackers fortified with 6 % ALER exhibited a total dietary fiber level greater than 6 g/100 g DB, satisfying the criteria for a high fiber food (Le et al., 2020). The ratio of IDF:SDF of cracker samples was slightly enhanced with the increased ALER ratio. According to American dietetic association, the recommend IDF/SDF of food products should be about 3:1 to improve positive impacts of both insoluble and soluble fibers on human health.

Table 2 also presents the antioxidant contents and activities of all cracker samples. The increased ratio of ALER in the cracker recipe greatly enhanced antioxidant contents and activities of the product. At 12 % ALER ratio, the phenolic and flavonoid contents of the cracker were 3.2 and 4.1 times, greater than those of the control

crackers. The antioxidant capacities measured by FRAP and DPPH assays were enhanced by 3.3 and 2.6 times, as compared to those of the control crackers. The improvement in antioxidant contents and activities was recently reported when Jerusalem artichoke powder was added to the cracker formulation (Ozgoren et al., 2019).

3.3 Effects of addition ratio of artichoke leaf extract residue on physical properties of crackers

Table 2 presents that the increased ratio of ALER from 0 % to 12 % did not affect diameter of the product. The thickness of crackers supplemented with ALER powder was decreased. Consequently, the SF index of the ALER fortified crackers was slightly increased. That might be explained by the reduction in gluten content of the crackers (Ben Salem et al., 2017). As the ALER incorporation ratio increased from 0 % to 12 %, the hardness of the crackers decreased by 1.4 times. The reduction of hardness could be attributed to a less compact gluten network (Howard et al., 2009) in the product fortified with ALER.
The addition of ALER to cracker formulation reduced all instrumental color values of the product. The fortified crackers were darker than the control cracker since the wheat flour was less darker than the ALER powder.

3.4 Sensory evalutaion of crackers

Table 2 also demonstrates that the increased addition ratio of ALER reduced the overall acceptability of the product. That was due to the reduced hardness and the increased darkness of the ALER fortified crackers. Reduction in sensory quality is previously reported when different by-products are added to cracker recipe (Faccioli et al., 2021). It can be noted that at 6 % ALER level, the crackers were a food with high dietary fiber content and acceptable sensory quality.

4. Conclusion

Artichoke leaf extract residue (ALER) was rich in dietary fiber and natural antioxidants. As increasing the ALER addition ratio from 0 % to 12 % in cracker formulation, the lipid, and protein contents of the product remained unchanged; while their ash content increased by nearly a half and the starch content decreased by 8 %; the fiber and phenolic content of crackers increased by 5.0 times and 3.2 times. The use of ALER decreased the product thickness and hardness, increased its darkness while did not affect its diameter. Crackers supplemented with ALER powder had the decreased overall acceptability. Crackers fortified with 6 % ALER exhibited a total dietary fiber level greater than 6 g/100 g DB, satisfying the criteria for a high fiber food. ALER powder was therefore a good source of dietary fiber and natural antioxidants in the making of healthy crackers.

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