

RESEARCH ON THE FORTIFICATION OF A PASTRY PRODUCT WITH CAULIFLOWER LEAVES POWDER TO INCREASE NUTRITIONAL QUALITY AND ANTIOXIDANT POTENTIAL

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Abstract

Considering the exponential population growth and climate change, it is necessary to develop strategies to produce more foods with high nutritional value and antioxidant capacity, with less waste, using sustainable food production systems. This paper presents the results of the research carried out for the fortification of cakes with cauliflower leaves powder (fortification levels in the range of 4-23%). The fortified cakes have superior sensory qualities and are notable for their protein content (15.16-16.06%), total fiber (6.04-6.92%), total ash (1.89-2.30%), total polyphenols (92.85-157.15 mg GAE/100 g), glucosinolates (117.21-647.87 mmol/100 g), α -Tocopherol (0.638-0.682 mg/100 g), β -Carotene (0.24-1.43 mg/100 g), chlorophyll a (1.09-5.75 mg/100 g), chlorophyll b (1.76-10.06 mg/100 g). At the same time, the cakes fortified with cauliflower leaves powder have antioxidant potential (215.34-364.23 mg Trolox Equivalents/100 g). Due to their high nutritional value and antioxidant potential, these pastries are beneficial in a healthy diet, but also in the prevention and diet therapy of nutritional deficiencies and diseases caused by oxidative stress.

Key words: cauliflower, leaves, cake, antioxidant potential.

INTRODUCTION

International studies highlighted the fact that plant by-products are important sources of nutrients and bioactive compounds, with a high potential for use in the development of fortified food products (Amoah et al., 2023; San José et al., 2018; Tamasi et al., 2019). Cauliflower by-products (leaves, stems, stalks) are the most important from this point of view, as they are important sources of proteins, mineral elements, dietary fibers and bioactive compounds (vitamin C, polyphenols, glucosinolates, carotenoids), chlorophyll a and b (Montone et al., 2018; Munir et al., 2018; Drabińska et al., 2021). Caliceti et al. (2019) mention that cauliflower leaves contain bioactive peptides exhibiting antioxidant properties, which may improve the viability of human vascular endothelial cells. At the same time, these authors highlight the fact that cauliflower by-products can be used as protein sources.

Due to the content in bioactive compounds and peptides, cauliflower by-products have

antioxidant, anti-inflammatory and anticarcinogenic effects (Montone et al., 2018; Munir et al., 2018; Stojceska et al., 2008). At the same time, Sanlier & Guler (2018) highlight the fact that cauliflower by-products contain very high concentrations of glucosinolates up to 75,000 μ g/g fresh weight.

Tukassar et al. (2023) made cauliflower by-products powder and characterized qualitatively this powder, which has a moisture content of 5.50% and stands out for its protein content (22.80%), crude fiber (15.32%), ash (5.81%), carbohydrates (47.62%), magnesium (36.3 mg/100 g), iron (20.03 mg/100 g), zinc (1.46 mg/100 g), total polyphenols (537.40 mg GAE/100 g), total flavonoid (252.20 mg CE/100 g). Catana et al. (2023) made a functional ingredient (powder) from cauliflower leaves that stands out for its content in protein (min. 28.5%), total fiber (min. 25%), ash (min. 10%), total sugars (min. 17.5%), mineral elements (potassium min. 3750 mg/100 g; magnesium: min. 110 mg/100 g; sodium: 475.58-525.73 mg/100 g; calcium:

min. 750 mg/100 g; iron: min. 40 mg/100 g; zinc: min. 5 mg/100 g), bioactive compounds (total polyphenols min. 5.5 mg GAE/g s.u.; vitamin C min. 70 mg/100 g; β -carotene min. 30 mg/100 g; glucosinolates min. 220 mmol/g.d.m.; lutein min. 10 mg/100 g).

Nartea et al. (2023) obtained flour from cauliflower leaves and stalks, using in their experiments two varieties: *Cheddar* (orange) and *Depurple* (purple). These flours rich in nutrients and bioactive compounds (glucobrassicin, carotenoids, phytosterols) were used for fortification (fortification levels 10% and 30%) of some pizza assortments. Pizza prepared with flour from violet stalks showed the highest glucobrassicin content (8.4 mg/200 g portion). Pizza prepared with orange stalks had the highest total content of phytosterols, a portion of 200 g providing 5.8% of the health claims imposed by EFSA (2009), for this class of bioactive compounds. Pizza prepared with cauliflower leaves flour had the highest content in β -carotene (4.09 mg/100 g d.w. of pizza) and lutein (3.04 mg/100 g d.w. of pizza).

This paper presents the results of the research carried out for the fortification of cakes with cauliflower leaves powder (fortification levels in the range of 4-23%).

MATERIALS AND METHODS

Materials

Cauliflower leaves powder was made within the Vegetable-Fruit Processing Pilot Experiment Station, from IBA Bucharest. To obtain the product "Minicake fortified with cauliflower leaf powder" the following ingredients were used: cauliflower leaves powder, white wheat flour, apple waste powder, hemp seeds, eggs, brown sugar, dehydrated cranberries, sunflower oil, cinnamon sugar, vanilla essence, baking powder and sea salt. The ingredients have been carefully selected, so that both their sensory and nutritional qualities, as well as the synergism of the bioactive compounds, are exploited. In parallel with the fortified product, the product "Control Minicake" (non-fortified minicake with cauliflower leaves powder) was also produced.

Minicake-making

The technological flow to obtain the products "Control Minicake" and "Minicake fortified with cauliflower leaf powder" includes the following operations: preparation of raw materials and auxiliary materials, dough preparation, dosing, baking, cooling, packaging, labeling and storage. To obtain the fortified product, the following fortification levels with cauliflower leaves powder were used: 4% (V1), 9% (V2), 18% (V3) and 23% (V4). Figure 1 shows cauliflower leaves powder.

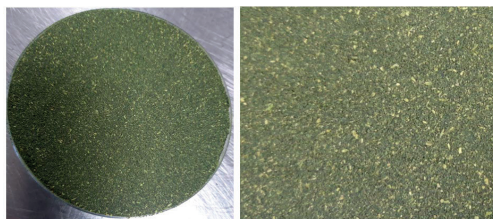


Figure 1. Cauliflower leaves powder



Figure 2. "Control Minicake" product



Figure 3. "Minicake fortified with cauliflower leaves powder" product

Methods

Statistical Analysis

"Control Minicake" and "Minicake fortified with cauliflower leaves powder" were analyzed

in triplicate, the results being presented as arithmetic mean and standard deviation.

Sensory analysis

Sensory analysis (appearance, taste, color, smell, consistency) was carried out using the descriptive method and "Method of comparison with unit score scales" (Burnete et al., 2020).

The determination of instrumental color parameters (L^* , a^* and b^*) was carried out using CM-5 colorimeter (Konica Minolta, Japan) with SpectraMagic NX software.

The determination of the texture parameters (firmness elasticity, cohesiveness and guminess) was carried out using the Instron Texture Analyzer (model 5944, Illinois Tool Works Inc., USA) and Bluehill 3.13 software.

Physico-chemical analysis

The physical-chemical analysis was carried out using SR 91:2007 "Bread and fresh pastry products. Methods of analysis". Total fiber content was determined according to AOAC method 985.29. Total carbohydrate content was analytically determined using the following formula: Total carbohydrate (%) = 100 – moisture (%) – ash (%) – protein (%) – fat (%). The determination of the energy value (expressed in kcal/100 g and kJ/100 g) was carried out according to the provisions of Commission Regulation no. 1169/2011 (European Commission, 2011).

The determination of the minerals was carried out by dry digestion of the samples and by high-performance analytical techniques: High-Resolution Continuum Source Atomic Absorption Spectrometry (in the case of magnesium, sodium, calcium and potassium) and Inductively Coupled Plasma Mass Spectrometry (in the case of manganese, zinc iron and copper).

Bioactive compounds content

Total polyphenol content was performed by extracting the sample in a methanol:water = 1:1 mixture, applying the Folin-Ciocalteu spectrophotometric method, using UV-VIS Jasco V 550 spectrophotometer (Horszwald and Andlauer, 2011). Determination of the absorbance of the extracts was performed at wavelength $\lambda = 755$ nm and a gallic acid calibration curve was used, in the concentration

range 0-0.20 mg/mL. The content of total carotenoids, chlorophyll a and chlorophyll b was determined using a spectrophotometric method (Chinnadurai et al., 2013). β -carotene content was determined using a chromatographic method (Catană et al., 2020). Vitamin E (α -tocopherol) content was determined using a chromatographic method (Popović et al., 2015). Determination of the total glucosinolates content was carried out using a spectrometric method (Mawlong et al., 2017).

Antioxidant capacity

The antioxidant capacity was determined by applying the DPPH spectrophotometric method Horszwald and Andlauer (2011). The method is based on measuring the ability of antioxidants to scavenge stable radicals. The free radical DPPH (1,1-diphenyl-2-picryl hydrazyl) is reduced to the corresponding hydrazine, when reacting with hydrogen donors, and this stability is visible by the discoloring test, which evaluates the decrease in absorbance at 517 nm produced by the addition of the antioxidant to the solution of DPPH in methanol. UV-VIS Jasco V 550 spectrophotometer and calibration curve of Trolox (0-0.4375 mmol/L) were used.

Microbiological analysis

The microbiological parameters were determined by using the following methods: SR ISO 21527-1:2009 (Yeasts and molds), SR EN ISO 21528-1:2017 (*Enterobacteriaceae*), SR ISO16649-2:2007 (*Escherichia coli*), SR EN ISO 6579-1:2017 (*Salmonella*), SR EN ISO 6888-1:2021/A1:2023 (*Staphylococcus coagulase* positive), ISO 21807:2004 (Water activity).

RESULTS AND DISCUSSIONS

Sensory analysis

Following the sensory analysis, it was found that the addition of cauliflower leaf powder (fortification levels of 4%, 9% and 18%) in the composition of the minicakes does not affect their taste and smell/aroma. Thus, minicakes fortified with cauliflower leaf powder, in the specified concentrations, have a pleasant taste and smell/aroma, characteristic of a well-baked pastry product, with the addition of cinnamon sugar, vanilla essence, dried cranberries and

cauliflower leaf powder. At the same time, the product "Minicake fortified with cauliflower leaf powder" has a dark-brown uniform crust, and an elastic, dense core, with uniform pores, characteristic of a well-baked flour product and characteristic green color (in the core you can distinguish fragments of dehydrated cranberries burgundy color). Following the sensory analysis, it was found that the addition of cauliflower leaf powder in the composition of the minicakes, corresponding to 23% fortification level, affects their taste and smell/aroma. Following the sensory evaluation, using the "Method of comparison with unit scoring scales", the products "Control Minicake" and "Minicake fortified with cauliflower leaf powder" (V1, V2, V3) obtained the qualification "very good", recording the following scores (Figure 4):

- ✓ "Control Minicake": 19.68 points
- ✓ "Minicake fortified with cauliflower leaf powder" (V1): 19.60 points
- ✓ "Minicake fortified with cauliflower leaf powder" (V2): 19.52 points
- ✓ "Minicake fortified with cauliflower leaf powder" (V3): 19.60 points.

The experimental variant V4 (fortification level 23%) of the product "Minicake fortified with cauliflower leaf powder" obtained the qualification "satisfactory", registering 14.4 points.

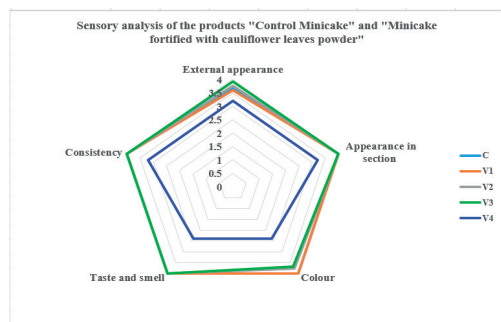


Figure 4. Sensory analysis of the products "Control Minicake" and "Minicake fortified with cauliflower leaves powder"

Following the instrumental analysis of the color, it was found that the addition of cauliflower leaf powder, in the composition of the minicakes, cause the green color of their core, which is reflected in the decrease of about 31.63% of the luminance value (L^*) and the decrease with about 47.22% of the color

parameter a^* (a^* - red-green color coordinate), compared to the Control minicake sample (Figure 5).

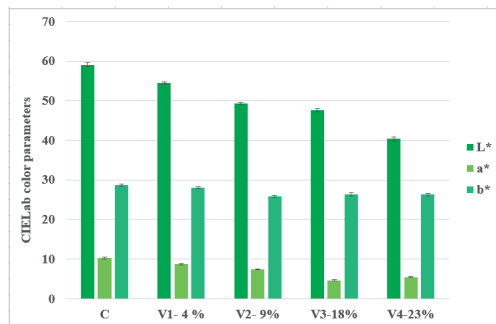


Figure 5. Colour parameters of the products "Control Minicake" and "Minicake fortified with cauliflower leaves powder"

The textural properties of the products "Control Minicake" and "Minicake fortified with cauliflower leaves powder" packed in a polypropylene bag, for 24 days from the date of manufacture, are presented in Table 1.

Table 1. The textural properties of the products "Minicake fortified with cauliflower leaves powder", compared to the control sample C

Minicake	Period (days)	Firmness (N)	Elasticity	Cohesiveness	Gumminess (N)
C	0	2.21±0.20	0.99±0.01	0.67±0.01	1.86±0.31
	3	3.43±0.33	0.99±0.01	0.62±0.01	2.09±0.21
	6	4.08±0.50	0.98±0.01	0.54±0.02	2.18±0.14
	9	4.38±0.43	0.98±0.01	0.50±0.02	2.22±0.16
	13	4.71±0.01	0.98±0.01	0.38±0.06	2.34±0.18
V1	24	6.04±0.61	0.98±0.01	0.33±0.04	2.58±0.15
	0	1.53±0.11	0.96±0.01	0.69±0.01	1.02±0.07
	3	2.45±0.08	0.98±0.01	0.60±0.05	1.45±0.07
	6	2.88±0.16	0.98±0.01	0.57±0.03	1.61±0.02
	9	3.59±0.69	0.98±0.01	0.53±0.03	1.85±0.26
V2	13	4.21±0.59	0.99±0.01	0.33±0.06	1.73±0.16
	24	5.87±0.26	0.99±0.01	0.35±0.07	2.00±0.48
	0	1.71±0.35	0.98±0.01	0.69±0.01	1.16±0.23
	3	2.74±0.04	0.98±0.01	0.59±0.01	1.59±0.02
	6	3.21±0.13	0.98±0.01	0.50±0.01	1.58±0.05
V3	9	3.48±0.38	0.98±0.01	0.52±0.08	1.78±0.08
	13	4.07±0.59	0.98±0.01	0.34±0.09	1.87±0.08
	24	5.68±0.41	0.99±0.01	0.37±0.06	2.07±0.66
	0	1.79±0.12	0.98±0.01	0.64±0.06	1.13±0.03
	3	2.73±0.26	0.98±0.01	0.58±0.01	1.55±0.17
V4	6	3.31±0.19	0.98±0.01	0.55±0.01	1.79±0.09
	9	3.38±0.02	0.98±0.01	0.46±0.05	1.52±0.17
	13	3.98±0.59	0.99±0.01	0.45±0.05	1.68±0.23
	24	5.61±0.32	0.99±0.01	0.34±0.01	2.21±0.38
	0	1.85±0.39	0.98±0.01	0.63±0.04	1.15±0.29
V4	3	2.47±0.36	0.98±0.01	0.56±0.04	1.45±0.16
	6	2.64±0.09	0.98±0.01	0.53±0.01	1.54±0.08
	9	2.93±0.10	0.98±0.01	0.42±0.05	1.68±0.14
	13	3.71±0.14	0.98±0.01	0.35±0.03	2.04±0.17
	24	4.73±0.16	0.98±0.01	0.33±0.03	2.15±0.12

According to the results, addition of the cauliflower leaves powder, lead to a decrease in firmness of minicakes. Thus, after 24 days from the date of manufacture, the "Control Minicake" sample had a firmness about 1.27 times higher, compared to the "Minicake

fortified with cauliflower leaves powder" sample (V4, fortification level 23%). Firmness correlates sensorially with core softness: a high firmness represents a denser, harder core. Cohesiveness and elasticity were not influenced by the fortification of minicakes with cauliflower leaves powder. Also, according to the experimental results, the fortification of minicakes with cauliflower leaves powder lead to a reduction in their gumminess. The sample "Minicake fortified with cauliflower leaves powder" (V4, fortification level 23%), 24 days after the date of manufacture, had a 20% lower gumminess, compared to the sample "Control Minicake".

Physico-chemical analysis

The physico-chemical composition of the products "Control Minicake" and "Minicake fortified with cauliflower leaves powder" is presented in Table 2. The minicakes fortified with cauliflower leaves powder stand out for their protein content (15.16-16.06%), ash (1.89-2.30%) and total fiber (6.04-6.92%). The highest values of these chemical indicators were recorded in the case of the V4 variant of the "Minicake fortified with cauliflower leaves powder" product. At the same time, this product has the lowest content in carbohydrates, respectively, available carbohydrates.

Table 2. The physico-chemical indicators of the products "Minicake fortified with cauliflower leaves powder", compared to the control sample C

Physico-chemical indicators	Control	V1	V2	V3	V4
Moisture (%)	19.44±0.49	19.65±0.49	20.00±0.50	20.12±0.50	20.56±0.51
Ash (%)	1.75±0.03	1.89±0.03	2.02±0.03	2.18±0.03	2.30±0.03
Protein (%)	14.92±0.22	15.16±0.23	15.45±0.23	15.81±0.24	16.06±0.24
Fat (%)	19.59±0.25	19.63±0.26	19.67±0.26	19.79±0.26	19.87±0.26
Carbohydrates (%)	44.30±0.53	43.67±0.52	42.86±0.51	42.10±0.50	41.21±0.49
Available carbohydrates (%)	38.52±0.46	37.63±0.45	36.65±0.44	35.45±0.43	34.29±0.41
Soluble sugars (%)	33.03±0.20	33.12±0.20	33.35±0.20	33.17±0.20	33.60±0.20
Total fiber (%)	5.78±0.10	6.04±0.10	6.31±0.11	6.65±0.12	6.92±0.12
Energy value (kcal/100g)	402	400	398	396	394
Energy value (kJ/100g)	1680	1672	1664	1657	1647

It is worth noting that the product "Minicake fortified with cauliflower leaf powder" (fortification levels according to the provisions of Regulation (EC) NO. 1924/2006 of the European Parliament and of the Council, is a source of protein because at least 12% (15.16-16.30%) of its energy value is represented by proteins and, at the same time, a source of fibers, as they have a fiber content of at least 6% (6.04-6.92%).

The ash content of the product "Minicake fortified with cauliflower leaves powder" is about 1.69 times higher than that reported by Na et al. (2023) in the case of rice muffins fortified with tigernut dietary fiber (Ash = 1.11-1.36%).

The product "Minicake fortified with cauliflower leaves powder" (fortification levels 4-23%) has a higher protein and total fiber content than that reported by Catană et al. (2021), in the case of the product "Minicake fortified with *Aronia melanocarpa* pomace powder" (Protein = 10.35%; Total fiber = 5.29%). At the same time, the product "Minicake fortified with *Aronia melanocarpa* pomace powder" (fortification levels 9-23%) has a lower carbohydrate and available carbohydrates content, compared to that reported by these authors (Carbohydrates = 42.43%; Available carbohydrates = 37.14%).

It is worth noting that the product "Minicake fortified with cauliflower leaves powder" (fortification level 4-23%) has a higher protein and fiber content compared to that reported by Tukassar et al. (2023) in the case of muffins fortified with cauliflower by-products powder (Protein= 8.93-9.70%; Total fiber = 1.17-3.74%), and the carbohydrate content is lower, compared to that reported by these authors (Carbohydrates = 53.46-55.23%). At the same time, the product "Minicake fortified with cauliflower leaves powder" has a fiber content comparable to that reported by Sławińska et al. (2024), in the case of shortcakes fortified with *Agaricus bisporus* powder (Total fibers = 5.67-6.87%). A diet rich in fiber is essential for the proper functioning of the human body. Thus, a diet rich in fiber determines a adequate lipid profile, causing the reduction of total cholesterol and LDL cholesterol (Gulati et al., 2017). At the same time, a high intake of fiber in the diet determines the reduction of blood pressure (Streppel et al., 2008), the reduction of the level of inflammatory markers and the risk of developing cardiovascular diseases (Ma et al., 2006). Saboo et al. (2022) mention that a high-fiber diet is vital for people with diabetes and associated diseases, and also is recommended for the prevention and management of type 2 diabetes.

The fortification of the minicakes with cauliflower leaves powder causes an increase in

their content in mineral elements (K, Ca, Mg, Fe, Zn), compared to the Control sample (Figures 6 and 7). Among the analyzed mineral elements, in the case of fortified minicakes, potassium has the highest content. Thus, the potassium content of this product varied between 148.42-265.83 mg/100 g (the minimum value was recorded in the case of sample V1 - 4%, and the maximum in the case of sample V4 - 23%).

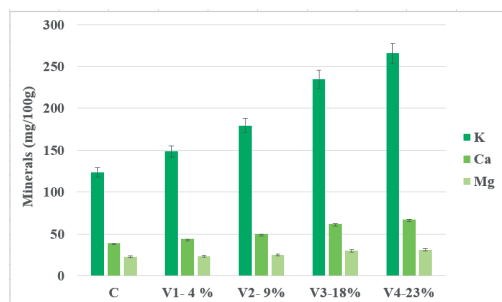


Figure 6. Mineral content (K, Ca, and Mg) of the products "Control Minicake" and "Minicake fortified with cauliflower leaves powder"

The potassium content of the product "Minicake fortified with cauliflower leaves powder" is higher compared to that reported by Tukassar et al. (2023) in the case of muffins fortified with cauliflower by-products (Potassium = 119.51-167.76 mg/100 g). These differences can be explained by the use in the composition of the product "Minicake fortified with cauliflower leaves powder" of some ingredients that come with an important intake of potassium: powder from apple waste, hemp seeds, dehydrated cranberries. The calcium content of the product "Minicake fortified with cauliflower leaves powder" varied in the range of 43.81-67.21 mg/100 g, and the magnesium in the range of 23.50-31.12 mg/100 g, being lower than those reported by Tukassar et al. (2023) in the case of muffins fortified with cauliflower by-products (fortification levels 10-30%): Calcium = 189.69- 244.56 mg/100 g; Magnesium=53.94-61.19 mg/100 g). The recorded differences can be explained by the fact that these authors used for fortification powder obtained from cauliflower by-products (leaves, stems, stalks) and not just cauliflower leaves powder, as in this experimental study, and the maximum fortification level of the

muffins was 30%. At the same time, it is worth noting that "Minicake fortified with cauliflower leaves powder" has a higher calcium and magnesium content than that reported by Sławińska et al. (2024), in the case of shortbread cookies fortified with *Agaricus bisporus* and *Pleurotus ostreatus* powders (Calcium = 35.70-37.81 mg/100 g d.w.; Magnesium = 11.98 – 15.28 mg/100 g d.w.).

Fortification of the minicakes with cauliflower leaves powder lead to a increase in iron content of 1.27-2.39 times compared to the Control sample. The iron content of the product "Minicake fortified with cauliflower leaves powder" (V4 - 23%) is comparable to that reported by Catană et al. (2021), in the case of the product "Minicake fortified with *Aronia melanocarpa* pomace powder" (Iron = 3.25 mg/100 g).

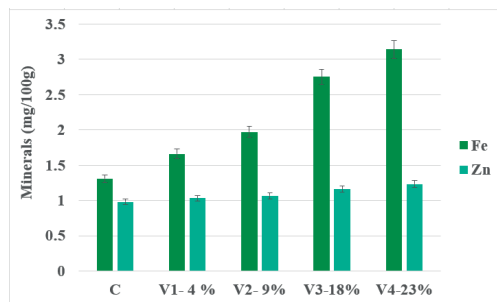


Figure 7. Mineral content (Fe and Zn) of the products "Control Minicake" and "Minicake fortified with cauliflower leaves powder"

It is worth noting that "Minicake fortified with cauliflower leaves powder" has a higher iron content of 2.24-3.24 times, compared to that reported by Sławińska et al. (2024), in the case of shortbread cookies fortified with *Agaricus bisporus* and *Pleurotus ostreatus* powders (Iron = 0.74-0.97 mg/100 g d.w.). At the same time, the iron content of the product "Minicake fortified with cauliflower leaves powder" (fortification levels 18 and 23%) is higher, compared to that reported by Catană et al. (2022) in the case of biscuits fortified with carrot pomace powder (Iron = 2.26 mg/100 g). Since the minicake is a product appreciated by several categories of consumers (children, teenagers, adults, elderly), its use as a vector for fortification with cauliflower leaves powder, for the purpose of prevention and diet

therapy of nutritional deficiencies, is of real interest.

The zinc content of the product "Minicake fortified with cauliflower leaves powder" varied between 1.03-1.23 mg/100g, being lower compared to that reported by Catană et al. (2021), in the case of the product "Minicake fortified with *Aronia melanocarpa* pomace powder" (Zinc = 1.62 mg/100 g).

Bioactive compounds content

The product "Minicake fortified with cauliflower leaves powder" stands out by its content in bioactive compounds: total polyphenols, glucosinolates, β -Carotene, chlorophyll a, chlorophyll b and α -Tocopherol (Table 3).

Table 3. Bioactive compounds content of the products "Minicake fortified with cauliflower leaves powder", compared to the control sample C

Bioactive compounds	Control	V1	V2	V3	V4
Total polyphenols (mg GAE/100g)	78.57±1.96	92.85±2.32	111.67±2.79	135.86±3.40	157.15±3.93
Glucosinolates (mmol/100g)	-	117.21±2.81	255.45±6.13	513.44±12.32	647.87±15.5
α -Tocopherol (mg/100g)	0.630±0.01	0.638±0.01	0.649±0.01	0.656±0.01	0.682±0.01
Total carotenoids (mg/100g)	0.10±0.001	0.74±0.007	1.70±0.017	3.32±0.033	4.27±0.042
β -Carotene (mg/100g)	0.04±0.00	0.24±0.005	0.58±0.013	1.12±0.025	1.43±0.031
Chlorophyll a (mg/100g)	-	1.09±0.011	2.31±0.023	4.50±0.045	5.75±0.058
Chlorophyll b (mg/100g)	-	1.76±0.018	4.03±0.04	7.86±0.079	10.06±0.01

The total polyphenol content of the product "Minicake fortified with cauliflower leaves powder" varied in the range of 92.6-157.15 mg GAE/100 g, the maximum value being recorded for the 23% fortification level. The content in total polyphenols of the product "Minicake fortified with cauliflower leaves powder" is higher compared to that reported by Troilo et al. (2022), in the case of muffins fortified with grape pomace powder (Total polyphenols = 64-69 mg/100 g) and that reported by Olawuyi and Lee (2019) in the case of functional rice muffins enriched with shiitake mushroom powder, fortification level 15% (Total polyphenols = 35.57 mg GAE/100 g). Polyphenols are phytochemicals that have numerous beneficial effects on the human body. Thus, polyphenols show antioxidant, immunomodulatory, antimicrobial and antiviral activity and also have anticancer properties. Polyphenols, such as catechins, flavonoids, phenolic acids and tannins, can be used as bio-preservative substances for food and beverages, causing an inhibition of stress oxidative, through various mechanisms (Rathod et al., 2023).

It is worth noting that the product "Minicake fortified with cauliflower leaves powder" is a source of glucosinolates, the content of these bioactive compounds, varying in the range of 117.21-647.87 mmol/100 g, the highest values being recorded in the case of experimental variant V3 (level of fortification 18%) and V4 (fortification level 23%). International studies (Connolly et al., 2021) highlight the fact that glucosinolates and their metabolites, isothiocyanates, are compounds with an important role in the prevention and treatment of chronic diseases. Thus, these compounds can improve the control of blood sugar, blood pressure and lipid profile. Glucosinolate metabolites, particularly sulforaphane, may also exert a beneficial effect on neurological and psychiatric conditions such as schizophrenia, depression, multiple sclerosis, autism, and Alzheimer's disease. Isothiocyanate, the main degradation product of glucosinolates, has been recognized for its anticancer potential (Rizwan et al., 2023).

At the same time, the product "Minicake fortified with cauliflower leaves powder" (fortification levels of 18% and 23%) has a high content of total carotenoids (3.32 mg/100 g, respectively, 4.27 mg/100 g) and β -Carotene (1.12 mg/100g and 1.43 mg/100 g, respectively). The total carotenoid content of this pastry product fortified with cauliflower leaves powder (18% and 23% fortification levels) is comparable to that reported by Olawuyi and Lee (2019) in the case of functional rice muffins enriched with carrot pomace, fortification level 5% (β -Carotene = 3.468 mg/100 g) and with that reported by Catană et al. (2022), in the case of "Biscuits fortified with carrot pomace powder" (β -Carotene = 1.30 mg/100 g).

International studies have revealed that carotenoids have various biological effects, such as antioxidant, anti-tumor, anti-diabetic, anti-aging and anti-inflammatory (Crup et al, 2023).

The α -Tocopherol content of the product "Minicake fortified with cauliflower leaves powder" varied in the range of 0.638-0.682 mg/100 g, being lower, compared to that reported by Lao et al. (2019), in the case of cakes fortified with sweet corn residue (α -Tocopherol = 0.937-1.022 mg/100 g).

It is worth noting that the product "Minicake fortified with cauliflower leaves powder" has a high content in chlorophyll a (1.09-5.75 mg/100 g) and chlorophyll b (1.76-10.06 mg/100 g). Studies by Martins et al. (2023) suggest that these pigments possess therapeutic properties: anticancer, antioxidant, antigenotoxic, antimutagenic and anti-obesity.

Antioxidant capacity

Due to its content in antioxidants, the product "Minicake fortified with cauliflower leaves powder" has antioxidant capacity. The antioxidant capacity of this product varied between 2.15-3.64 mg TE/g (the minimum value was recorded in the case of the experimental variant V1, and the maximum in the case of the experimental variant V4). The control sample of the minicakes recorded a value of the antioxidant capacity of 1.22-2.07 times lower compared to the fortified minicakes (Figure 8).

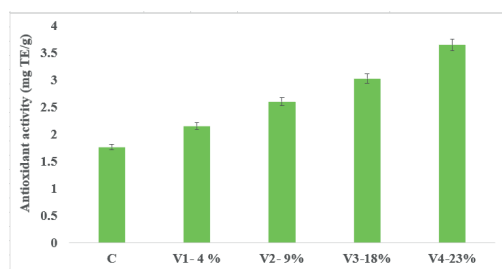


Figure 8. Antioxidant capacity of the products "Minicake fortified with cauliflower leaves powder", compared to the control sample C

It should be noted that in the case of the product "Minicake fortified with cauliflower leaves powder" between the total polyphenol content and antioxidant capacity it is a linear correlation ($y = 0.0234x - 0.0526$; $R^2 = 0.9979$)

Microbiological analysis

Following the microbiological analysis of the products "Control Minicake" and "Minicake fortified with cauliflower leaf powder" it was found that they fall within the provisions of the legislation in force (Table 4). The values recorded for the water activity were in the range of 0.690- 0.764.

Corroborating the results of the microbiological analysis with those of the sensory and physico-chemical analysis, the content in bioactive

compounds and the antioxidant capacity, the minimum period of validity of the product "Minicake fortified with cauliflower leaves powder", packed in a sealed polypropylene bag, was established at 15 days.

Table 4. Microbiological analysis of products "Minicake fortified with cauliflower leaves powder", compared to the control sample C

Microbiological indicators	Control	V1	V2	V3	V4
Yeast and molds (CFU/g)	< 10	< 10	< 10	< 10	< 10
<i>Enterobacteriaceae</i> (CFU/g)	< 10	< 10	< 10	< 10	< 10
<i>Escherichia coli</i> (CFU/g)	< 10	< 10	< 10	< 10	< 10
<i>Coagulase positive Staphylococcus</i> (CFU/g)	< 10	< 10	< 10	< 10	< 10
<i>Salmonella</i> , in 25 g	Absent	Absent	Absent	Absent	Absent
Water activity	0.690	0.713	0.745	0.757	0.764

CONCLUSIONS

The results revealed that cauliflower leaves powder is a valuable functional ingredient, which can be used for the fortification of pastry products, in order to increase the nutritional value, the content in bioactive compounds and the antioxidant capacity.

Corroborating the results of the sensory, physico-chemical analysis, the content in bioactive compounds and the antioxidant capacity, in the case of the "Minicake fortified with cauliflower leaves powder" product, the experimental variant V3, level of fortification with cauliflower leaves powder, was selected as the optimal variant, 18%. The product corresponding to this level of fortification stands out for its sensory qualities, ash content (2.18%), protein (15.81%), total fiber (6.65%), and according to the provisions of Regulation (EC) NO. 1924/2006 of the European Parliament and of the Council, is a source of protein and fiber.

At the same time, the product "Minicake fortified with cauliflower leaves powder" (fortification level 18%) stands out for its content in mineral elements (Potassium = 234.93 mg/100 g; Calcium = 62.25 mg/100 g; Magnesium = 29.74 mg/100 g; Iron = 2.75 mg/100 g; Zinc = 1.16 mg/100 g), bioactive compounds (Total polyphenols = 135.86 mg GAE/100 g; Glucosinolates = 513.44 mmol/100 g; α -Tocopherol = 0.656 mg/100 g; Total carotenoids = 3.32 mg/100 g; β - Carotene = 1.12 mg/100 g; Chlorophyll a = 5.75 mg/100 g; Chlorophyll b = 10.06 mg/100 g) and antioxidant capacity (3.02 mg TE/ 100 g).

The product "Minicake fortified with cauliflower leaves powder" (fortification level 18%) falls microbiologically within the sanitary provisions in force and has a minimum validity of 15 days.

Due to the superior sensory quality, the complex composition and the fact that it has antioxidant capacity, the product "Minicake fortified with cauliflower leaves powder" (fortification level 18%) can be included in a healthy diet.

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