

A functional end-use of hemp seeds waste: technological, qualitative, nutritional and sensorial characterization of fortified bread

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Abstract: The edible portion of *Cannabis sativa* L. are the seeds.

The seeds are generally used for the production of hemp oil, appreciated for the high percentage of α -linolenic acid. The waste obtained after seeds oil extraction, reduced in fine powder, is the subject of this study.

Since hemp seeds are considered to be a source of many valuable bioactive compounds, the addition of hemp seed flour to durum wheat for making fortified bread could have an effect on the health of consumers.

The aim of this study was to use variable percentages of hemp seed flour for the production of bread, and to determine the fortification impact on chemicals, texture, organoleptic characteristics, crumb color, changes in crumb texture, total polyphenols, free radical scavenging activity and amino acids contents.

The rheological and chemical qualities of bread samples, obtained by using a durum wheat cultivar Ciclope fortified with defatted hemp seeds flours, were evaluated. The solid residue left after the extraction of the oil from seeds (generally thrown away as waste or added to feed) was shredded and sieved at 0.530 mm (Hemp 1) or 0.236 mm (Hemp 2). Samples of fortified breads were obtained by substitution of variable percentages of durum wheat flour with the two hemp flours (5%, 7.5%, and 10%).

Fortified bread's total phenolic content was in a range of 0.73 ± 0.017 and 1.73 ± 0.029 mg GAE/g and anti-radical scavenging activity was included in the range from 1.17 ± 0.099 and 3.18 ± 0.071 mmol TEAC/100g, according to the increasing fortification.

Comparison between bread made with Ciclope semolina and hemp flour fortified breads, showed a large increase in amino acid content in fortified samples ones. In particular, bread fortified with 10% Hemp 2 flour highlights a greater content of glutamic acid, tyrosine, proline and essential amino acids such as leucine and isoleucine, compared to the other samples with same percentage of substitution.

The amount of hemp seed flour influenced the color of the crumb by increasing the yellow index from 18.24 (100% Ciclope) to 21.33 (bread with Hemp 2 flour at 5%).

Table S1: Retention time (min.), coefficient of determination (R²) and linear regression model of external standards used for amino acids quantification

<i>Aminoacid</i>	<i>(RT min)</i>	<i>R²</i>	<i>Linear Regression</i>
L-Arginine	34.57	0.936	y=5080x-12.886
L-Serine	41.22	0.940	y=1E+03x-5.1252
L-Glutamine	42.20	0.951	y=4688x+40.672
L-Threonine	44.16	0.955	y=1E+03x-1.7525
L-Tyrosine	47.28	0.948	y=1430x+0.1383
L-Alanine	47.55	0.958	y=3542x-9.8959
L-Leucine	48.97	0.976	y=4316x+21.998
L-Methionine	51.13	0.961	y=8249x-2.4881
L-Valine	51.46	0.934	y=4547x+0.1747
L-Phenylalanine	52.51	0.952	y=3433x-6.8667
L-Isoleucine	52.64	0.935	y=2E+03x+21.421
L-Lysine	55.24	0.988	y=700x+13.888
L-Histidine	55.45	0.960	y=2838x+5.6484
L-Proline	56.80	0.939	y=901x-3.7975

Table S2: Chemical characterization of raw materials

Flour	Ciclope	Hemp 1	Hemp 2
TPC mgGAE/g	2.45 ± 0.001	6.38 ± 0.002	6.35 ± 0.001
DPPH _{TEAC} mmol TE /100g	1.35± 0.0355	3.94 ± 0.0178	3.75 ± 0.0179
% Scavenging	29.7	53.2	51.5
Fatty acid (Relative percentages %)			
Palmitic acid	17.6±0.30	9.04±0.17	9.10±0.057
Stearic acid	1.54±0.16	3.42±0.025	3.32±0.060
Oleic acid	17.3±0.51	14.6±0.062	14.5±0.081
Linoleic acid	59.9±0.89	53.7±0.35	53.7±0.17
γ linolenic acid	-	2.44±0.075	2.47±0.089
α linolenic acid	3.62±0.53	15.7±0.21	15.5±0.050
ω-6	59.95	56.12	56.13
ω-3	3.62	15.66	15.54
Amino acids (g/100 g)			
Arginine	0.34	0.52	0.58
Serine	1.59	2.00	1.89
Glutamine	2.90	4.96 b	5.38 a
Tyrosine	3.37	3.43	3.19
Alanine	0.85	1.37	1.84
Histidine	0.53	0.92	0.94
Proline	1.23	3.22	2.99
Threonine	1.80	1.97 b	2.51 a
Leucine	1.78	2.75	2.97
Methionine	0.14	0.61	0.83
Valine	0.58	1.17 b	2.00 a
Phenilalanine	0.25	0.40	0.45
Isoleucine	3.52	6.94	6.21
Lysine	0.16	2.07 b	2.58 a
Σ AA	19.0	32.3 b	34.36 a
Σ essential AA	8.23	15.9 b	17.6 a

Data are expressed as mean±SD of triplicate experiments.

Different letters indicated differences at P<0.05 between Hemp -1 and Hemp 2 flour samples. Values without letters are not statistically different