Designing of new food products using vegetable oils industry by-products

Proiectarea de noi produse alimentare folosind produse secundare din industria uleiurilor vegetale

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Introduction

Competition on resources (raw materials, soil, water, energy) **will increase** within the food system level, due to a combination of factors such as population growth, changing dietary patterns, urbanization, and climate change.

Food waste quantity **is also increasing.** Reducing food waste is critical to address the challenges associated with its accumulation, handling, and disposal. This can involve various strategies, including improving supply chain management, reducing overproduction, educating consumers on the value of food, and diverting food waste from landfills towards more sustainable alternatives such as composting or anaerobic digestion.

Some of the food waste categories are byproducts containing **valuable nutritive compounds** → can be considered new raw materials and re-introduced in the food system.

During the process of obtaining vegetable oils, high amounts of waste and byproducts are generated → they are important due to their high value-added substances, and they represent an excellent source of bioactive components, such as antioxidants[1].

Byproducts such as flour, **meals**, and groats resulting from the vegetable oil industry are considered economic resources due to the antioxidant compounds, which have attracted interest in making functional products with a higher nutritional value, satisfying consumer demand for such products[1].

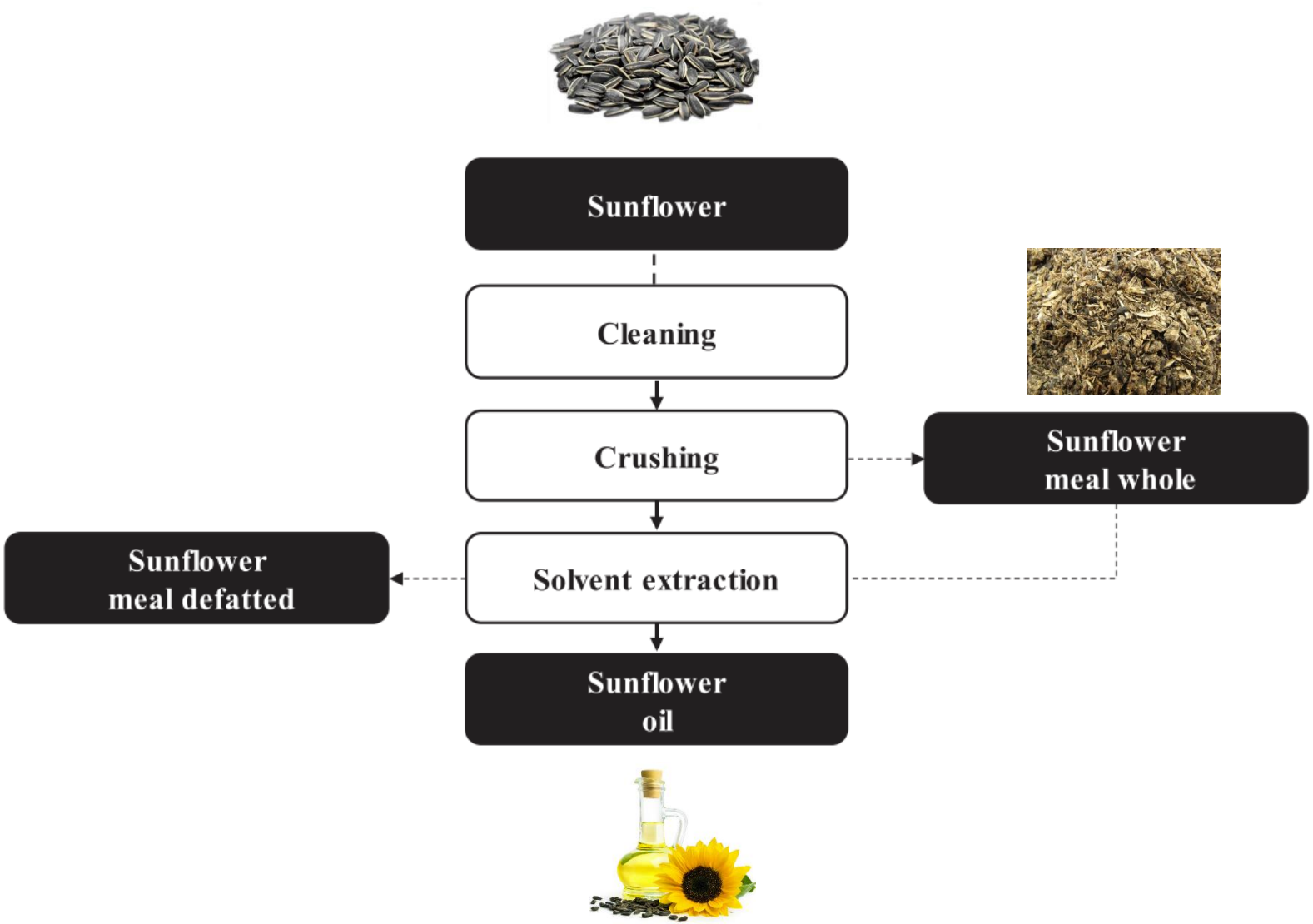
The potential safety concerns about such vegetable oil byproducts should be emphasized and discussed while they are being valorized for human consumption[2].

1. Multescu, M.; Marinas, I.C.; Susman, I.E.; Belc, N. Byproducts (Flour, Meals, and Groats) from the Vegetable Oil Industry as a Potential Source of Antioxidants. *Foods.* **2022**, 11, 253.
2. Smeu, I.; Dobre, A.A.; Cucu, E.M.; Mustatea, G.; Belc, N.; Ungureanu, E.L. Byproducts from the Vegetable Oil Industry: The Challenges of Safety and Sustainability. *Sustainability*. **2022**, 14, 2039.

Sunflower seeds

In 2022, Romania ranked first in the EU for sunflower, both in terms of production and cultivated area, with a total harvest of 2.079 million tons from 1.082 million hectares, according to the provisional data published by the National Institute of Statistics (INS).

In terms of production, it is the third-most produced oilseed in the world, the fourth-most important culture in vegetable oil production and the third-most important culture in oilseed meal production.



Sunflower meal production from sunflower oil industry

de Oliveira Filho, J. G., & Egea, M. B. Sunflower seed byproduct and its fractions for food application: An attempt to improve the sustainability of the oil process. *J Food Sci.* 2021; 86: 1497–1510. https://doi.org/10.1111/1750-3841.15719

Samples of byproducts from sunflower oil industry

Code	Byproduct name	Hulling percentage
N	Sunflower meal obtained from whole seeds	0%
P	Sunflower meal made from partially dehulled seeds	50%
A	Sunflower meal obtained from completely dehulled seeds	100%

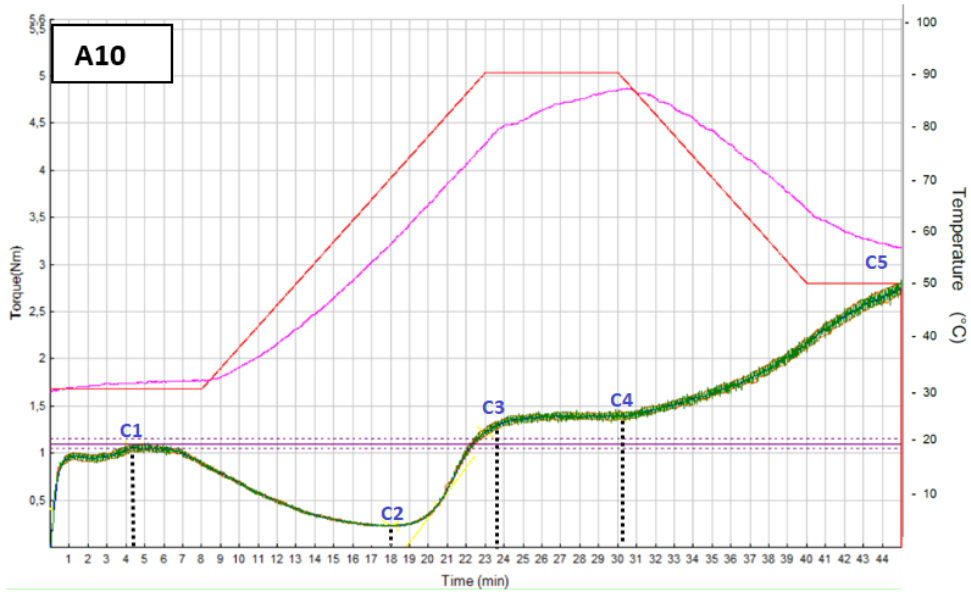
The sunflower meals were ground, and the obtained flour was analyzed from a microbiological and physicochemical point of view.

The microbiological analysis carried out showed that there is no contamination with pathogenic bacteria (*Escherichia coli*, *coagulase-positive Staphylococcus* and *Enterobacteriaceae*). The meal samples showed microbial growth in the case of aerobic bacteria (total number) and molds, but the indicated values do not exceed the limit allowed for the categories of edible seeds.

Rheology

- rheological tests were carried out to evaluate the compatibility between the raw materials and the obtained meal flours, and to establish the doses of meal flours added to the recipe.
- rheological measurements were carried out using the Mixolab system

The Mixolab curve represents the variation of the dough consistency at different temperatures, depending on time



Mixolab characteristics

Sample code	Byproduct code	Meal flour (%)	WA (%)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)
Control	-	0	56.00	1.07	0.42	1.70	1.95	3.17	9.87
N10	N	10	57.40	1.12	0.30	1.80	2.03	3.21	9.03
N15		15	57.90	1.09	0.30	1.95	1.87	3.12	9.12
N20		20	58.50	1.13	0.32	1.98	1.86	3.09	9.08
P10	P	10	53.00	1.11	0.27	1.36	1.65	2.89	7.28
P15		15	52.00	1.07	0.24	1.27	1.46	2.78	3.77
P20		20	51.00	1.10	0.25	1.22	1.37	2.59	3.43
A10	A	10	51.10	1.06	0.23	1.23	1.39	2.75	6.95
A15		15	48.90	1.07	0.21	1.13	1.26	2.54	5.70
A20		20	47.40	1.10	0.20	1.15	1.09	2.34	4.27

WA – water absorption capacity

C1 – dough development

C2 – proteins stability

C3 – starch gelatinization capacity

C4 – amylase activity

C5 – starch retrogradation

Recipes of the experimental bread sample

Sample	Wheat flour (g)	Sunflower meal (g)	Salt (g)	Yeast (g)	Water (mL)
M	2000	-	30	60	1200
N10	1800	200			1060
N15	1700	300			1100
N20	1600	400			1100
P10	1800	200			1000
P15	1700	300			930
P20	1600	400			890
A10	1800	200			970
A15	1700	300			930
A20	1600	400			890

N

P

A

Leavening – 40 minutes at 36 °C / 85% RH

Baking – 20 minutes at 230 °C

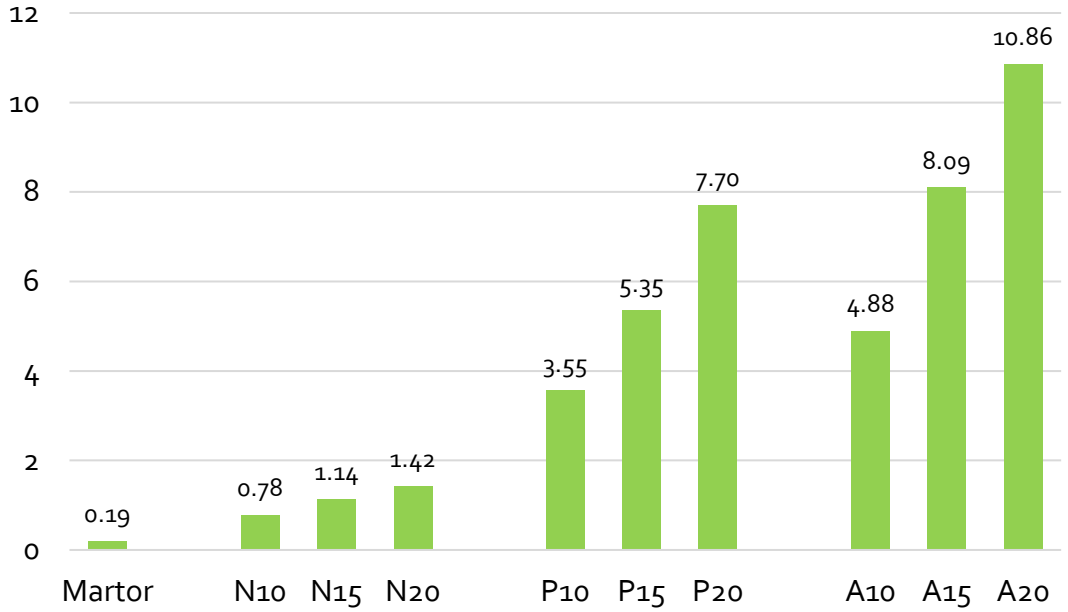
The new bread prototypes obtained were analyzed from a microbiological, physico-chemical and nutritional point of view.

The obtained breads were analyzed from a microbiological point of view during 5 days. The samples showed stability during the storage period, compared to the control sample which, on the 5^{th} day, showed visible mold colonies on the surface, also detected following the microbiological analysis.

Water activity that helps determine food stability and safety in terms of microbial growth and physical properties was also evaluated —> 0.95 ÷ 0.98

Physico-chemical composition

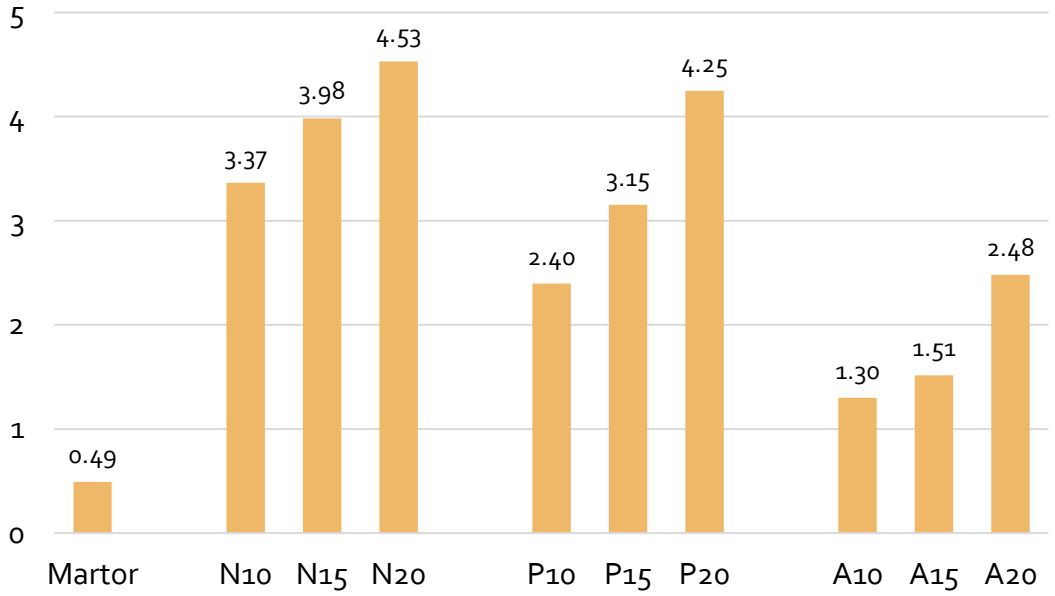
Sample	Moisture (%)	Starch (%)	Proteins (%)	Ash (%)	Crude fiber (%)	Lipids (%)	Energetic value (kcal/100g)
M	43.01	68.26	8.66	1.18	0.28	0.11	223
N10	42.07	56.34	9.58	1.44	1.95	0.45	224
N15	42.75	67.82	9.94	1.52	2.28	0.65	222
N20	43.05	53.40	11.04	1.63	2.58	0.81	220
P10	40.32	66.49	9.58	1.23	1.43	2.12	242
P15	39.41	62.22	9.85	1.46	1.91	3.24	249
P20	38.56	58.86	10.77	1.42	2.61	4.73	259
A10	39.20	66.49	9.63	1.23	0.79	2.97	252
A15	38.59	59.28	9.86	1.36	0.93	4.97	263
A20	37.47	54.66	10.24	1.47	1.55	6.79	275



The lipid content (% d.w.) of the bread samples

The lipid content increased with increasing degree of dehulling and with the percentage of meal added in the recipe

The crude fiber content decreased with increasing degree of dehulling and increased with the percentage of meal added in the recipe



Physico-chemical characteristics

Sample	Mass (g)	Acidity (°)	Volume (cm^3/ 100g)	Porosity (%)	Elasticity (%)
M	490.14	1.1	322	82	97
N10	488.86	2.2	323	80	92
N15	491.37	2.6	307	78	89
N20	499.60	3.2	244	75	75
P10	493.73	2.2	330	77	94
P15	494.80	2.4	367	84	92
P20	495.14	3.0	338	82	85
A10	480.22	1.9	422	84	98
A15	472.46	2.6	414	85	95
A20	492.91	2.4	387	84	86

By fortifying the breads with dehulled sunflower meal, the energy value of the breads increased.
By adding sunflower meal, the acidity increased as a result of the formation of organic acids.

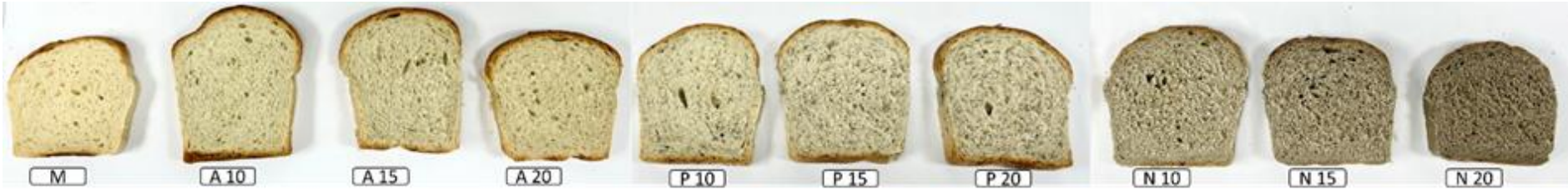
Antioxidant activity

Sample	DPPH	ABTS	FRAP
M	23.93 ± 2.91	287.22 ± 6.98	50.5 ± 2.89
N10	196.75 ± 3.85	664.04 ± 10.68	492.38 ± 3.45
N15	282.28 ± 5.52	910.01 ± 11.31	612.05 ± 6.02
N20	434.89 ± 9.63	1081.01 ± 7.32	1010.81 ± 8.91
P10	178.32 ± 5.31	606.28 ± 5.31	408.94 ± 7.32
P15	256.47 ± 7.95	806.06 ± 6.12	582.86 ± 4.13
P20	321.89 ± 8.16	894.13 ± 5.86	763.23 ± 6.29
A10	196.46 ± 5.31	663.03 ± 8.95	428.17 ± 2.98
A15	253.01 ± 6.25	795.56 ± 6.14	613.19 ± 4.32
A20	347.39 ± 9.16	898.42 ± 4.96	768.81 ± 6.21

	DPPH	ABTS	FRAP
Total polyphenols	0.9804	0.9609	**0.9879**
Total flavonoids	0.8821	0.8462	0.8888

Strong correlation between the content of total polyphenols and total flavonoids with the antioxidant activity of breads enriched with different concentrations of meal.

Sample	Firmness (N)	Cohesiveness	Gumminess (N)	Elasticity
M	3.55 ± 0.19	0.47 ± 0.07	1.66 ± 0.12	1.00 ± 0.02
N10	3.02 ± 0.11	0.50 ± 0.03	1.47 ± 0.03	0.98 ± 0.00
N15	3.80 ± 0.20	0.53 ± 0.07	1.99 ± 0.15	0.98 ± 0.00
N20	4.96 ± 0.23	0.42 ± 0.03	2.04 ± 0.06	0.98 ± 0.01
P10	2.28 ± 0.22	0.39 ± 0.04	0.88 ± 0.03	1.00 ± 0.02
P15	2.19 ± 0.38	0.34 ± 0.12	0.75 ± 0.38	0.98 ± 0.00
P20	1.85 ± 0.27	0.45 ± 0.01	0.82 ± 0.14	0.99 ± 0.00
A10	2.11 ± 0.07	0.55 ± 0.03	1.13 ± 0.03	0.98 ± 0.01
A15	1.65 ± 0.16	0.55 ± 0.05	0.90 ± 0.01	0.99 ± 0.00
A20	1.63 ± 0.21	0.54 ± 0.02	0.87 ± 0.15	0.98 ± 0.00



Following the hedonic test, the ordering of the samples according to the total score obtained is as follows:

M (79) →A10 (69) →A20 (67) →A15 (66) →P15 (55) →P10 (53) →P20 (47) →N15 (43) →N10 (41) →N20 (33)

The bread with the best acceptability and the closest color values was the one made by fortification with fully dehulled sunflower meal.

Conclusions:

Health concerns have driven consumer demand for foods with a high content of bioactive compounds that are influential in maintaining health status.

The results revealed that by substituting wheat flour with sunflower meal, the content of proteins, fibers, lipids and compounds with antioxidant activity increased.

With the increase in the percentage of sunflower meal addition in the recipe, the nutritional quality of the bread prototypes obtained was improved.

Acknowledgments

This work was supported by a grant from the Romanian National Authority for Scientific Research and Innovation, CCDI-UEFISCDI, project number: ERANET-COREORGANIC & SUSFOOD-PROVIDE-1, within PNCDI III, contract no. 184/2020

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