

Valorisation of sunflower press cake from cold-pressed oil production

I. Jakab¹ , S. Homolya¹, M. Mardani¹ , J. Tormási² ,
K. Kóczán-Manninger¹  and K. Badak-Kerti^{1*} 

¹ Department of Cereal and Industrial Plant Processing, Institute of Food Science and Technology, Hungarian University of Agriculture and Life Sciences (MATE), Villányi út 29–43, 1118 Budapest, Hungary

² Department of Food Chemistry and Analytical Chemistry, Institute of Food Science and Technology, Hungarian University of Agriculture and Life Sciences (MATE), Villányi út 29–43, 1118, Budapest, Hungary

SHORT COMMUNICATION

Received: May 8, 2026 • Accepted: June 12, 2026

Published online: July 23, 2026

© 2026 The Author(s)



ABSTRACT

Sunflower press cake is an abundant by-product of cold-pressed oil production and is increasingly considered a promising source of ingredients for food applications. This study characterised cold-pressed sunflower press cake from a Hungarian small-scale producer, with the cold-pressed oil analysed in parallel. The press cake contained 41.1% crude protein, 24.5% dietary fibre, 8.67% residual oil, and 5.56% moisture. Glutamic acid, arginine, and aspartic acid were the most abundant amino acids, while lysine was the limiting essential amino acid. The presence of sulphur-containing amino acids (methionine, cystine), often deficient in legume proteins, suggests complementarity in plant-protein blends. A light colour ($L^* = 67.0$; $b^* = 29.4$) is favourable for fortification applications. Cold-pressing of the seeds (total oil content 53.67%) gave an oil yield of 83.85%. The oil was dominated by linoleic (56.32%) and oleic (31.36%) acids; the acylglycerol distribution (TAG 94.54%, DAG 2.51%, FFA 2.95%) and an oxidative induction time of 11.87 h at 110 °C indicated limited hydrolysis and adequate stability for a linoleic-rich oil. These data suggest that sunflower press cake from gentle solvent-free extraction is a promising candidate for development as a plant-protein and dietary-fibre ingredient.

KEYWORDS

cold-pressed oil, sunflower press cake, valorisation, plant protein, dietary fibre, amino acid profile

* Corresponding author. E-mail: Badakne.Kerti.Katalin@uni-mate.hu

1. INTRODUCTION

In the dynamic field of food and nutrition, there is a growing demand for minimally processed, nutrient-rich ingredients that support human health and align with sustainable practices. Cold-pressing, a mechanical operation that extracts oil from seeds, nuts, and fruits without excessive heat or chemical solvents, has attracted considerable interest from health-conscious consumers and the food industry alike. Owing to the gentle extraction at low temperatures, cold-pressing retains higher levels of bioactive compounds such as antioxidants, tocopherols, and essential fatty acids, while preserving the natural flavour and aroma profile of the raw materials (Konuskan, 2020; Jakab, 2025).

Compared with solvent-based extraction, mechanical pressing yields lower oil quantities, generating substantial volumes of press cake as a co-product. The valorisation of these press cakes extends beyond their traditional use as animal feed and incorporation into food formulations can enhance nutritional value while contributing to circular-economy approaches in the oilseed sector (Ferhat et al., 2007; Popović et al., 2020). Sunflower press cake in particular has been reported to combine high protein content (35–45%), notable dietary fibre, and a residual lipid fraction with retained bioactive compounds (de Oliveira Filho and Egea, 2021; Vidal et al., 2022).

Despite this, comprehensive physicochemical data on cold-pressed sunflower press cake from small-scale producers are limited, particularly when both the expressed oil and the resulting cake are characterised in parallel. The present study addresses this gap by characterising cold-pressed sunflower press cake obtained from a Hungarian small-scale producer, alongside the corresponding extracted oil. The aim is to provide an integrated dataset that supports informed valorisation of this co-product in food applications.

2. MATERIALS AND METHODS

2.1. Materials and sample preparation

Cold-pressed sunflower oil and press cake were obtained from Virgin Oil Press Ltd. (Budapest, Hungary). The processed seeds consisted of a mixture of hybrids of *Helianthus annuus* L. Oils were transferred into dark green glass bottles and stored at -80°C until analysis. Prior to measurements, all cake samples were ground to a particle size of 300–400 μm using a Retsch ZM 300 mill (Retsch, Haan, Germany).

2.2. Oil yield determination

Dried samples (15 g) were placed in paper thimbles and extracted using a Büchi B-811 Soxhlet apparatus with 100 mL of petroleum ether for 6 h. After evaporation, the mass of extracted oil was determined gravimetrically following drying at $103 \pm 1^{\circ}\text{C}$. The total oil content of the seeds, determined by this exhaustive Soxhlet extraction, was expressed as g/100 g of sample. The cold-pressed oil recovery was then calculated as the mass of oil recovered by mechanical cold-pressing of the seeds, expressed as a percentage of their total oil content determined by Soxhlet extraction.

2.3. Acylglycerol composition

Acylglycerol composition was determined by thin-layer chromatography. Each oil sample diluted in isopropanol (20 μL) was applied to silica gel 60 TLC plates (20 $\times$ 20 cm) and developed in n-heptane/diethyl ether/formic acid (55:45:2, v/v/v). Plates were stained with a copper acetate–phosphoric acid solution, dried, and heated at 180 °C for 15 min. Bands were identified using a commercial monoacylglycerol standard (DIMODAN[®] HP SG, Danisco, material no. 026754) and palmitic acid (99%, Sigma-Aldrich, catalogue no. 258725-2) as reference standards and band were identified in order of TAG > FFA > DAG > MAG. Lipid bands were quantified by densitometry using ImageJ software (Mardani et al., 2025).

2.4. Fatty acid composition

Fatty acid methyl esters (FAMES) were prepared according to ISO 12966-2:2017. Analysis was performed using an Agilent 6890 GC-FID (Agilent Technologies, Santa Clara, CA, USA) equipped with a Phenomenex Zebron ZB-FAME column (60 m $\times$ 0.25 mm $\times$ 0.20 μm ; cyanopropyl stationary phase). Hydrogen was used as the carrier gas at 1.2 mL min⁻¹; the inlet temperature was 250 °C, the detector temperature was 260 °C, the split ratio was 50:1, and the injected volume was 1 μL . The oven temperature programme was as follows: 100 °C for 3 min; increased to 166 °C at 20 °C min⁻¹ and held for 5 min; increased to 180 °C at 1 °C min⁻¹; then increased to 240 °C at 10 °C min⁻¹ and held for 3 min. A four-point calibration was prepared from a Supelco 37-component FAME mixture (0, 30, 60, 120 $\mu\text{g mL}^{-1}$) with methyl nonadecanoate as internal standard (1 mg mL⁻¹ in isooctane). C4:0 was excluded due to overlap with the solvent peak (ISO, 2017). Fatty acid results are reported as relative proportions of total FAME (normalised area percentages), in line with the conventional expression of fatty acid composition in accordance with ISO 12966; absolute quantification of individual fatty acids was not within the scope of the present characterisation.

2.5. Moisture content

Moisture content of ground press cake was determined gravimetrically by infrared drying using a Sartorius MA50 analyser (Sartorius, Göttingen, Germany), with the endpoint defined automatically when the rate of mass loss fell below the instrument threshold. Measurements were performed in triplicate.

2.6. Oxidative stability

Oxidative stability was evaluated using a Rancimat Model 743 (Metrohm, Herisau, Switzerland) at 110 °C with 2.5 ± 0.2 g of oil and an air flow of 2.5 mL s⁻¹ (Mardani et al., 2021).

2.7. Colour measurement

Colour of ground press cake was measured with a Minolta Chroma Meter CR-310 in the CIE Lab colour space, calibrated against a standard white tile (L^* 98.03, a^* -0.23, b^* 0.25).

2.8. Dietary fibre

Total dietary fibre was determined according to AOAC 985.29 (enzymatic–gravimetric method).

2.9. Protein content

Protein content was determined by the Kjeldahl method. Digestion was performed with concentrated sulphuric acid in the presence of copper sulphate as the catalyst and potassium sulphate as the boiling point elevator. Released ammonia was distilled into boric acid and titrated with 0.05 M sulphuric acid. Total nitrogen was converted to crude protein using a factor of 6.25 (Langyan et al., 2022).

2.10. Amino acid composition

Prior to analysis, samples were hydrolysed with 6 M HCl at 110 °C for 24 h under nitrogen, and the dried hydrolysate was redissolved in lithium-citrate buffer before injection. Amino acids were quantified using an AAA 400 Automatic Amino Acid Analyzer (Ingos Ltd., Czech Republic) on an Ionex Ostion LCP 5020 ion-exchange column with lithium citrate buffer gradient. Separated amino acids were detected after post-column derivatisation with ninhydrin, with absorbance measured at 570 nm and at 440 nm for proline. Data were processed with Chromulan V 0.82 (PIKRON, Czech Republic).

2.11. Statistical analysis

All measurements were performed in triplicate. Data are presented as mean ± standard deviation. Statistical analyses were carried out in SPSS v. 21 (IBM Corp., Armonk, NY, USA).

3. RESULTS AND DISCUSSION

3.1. Oil yield

The total oil content of the sunflower seeds was 53.67%, while cold-pressed oil extraction efficiency was 83.85% (Table 1), within the 70–86% range typically reported for small scale sunflower oil production, where yield depends on seed variety, moisture content, and pressing parameters (Kabutey et al., 2023). The seed moisture observed in the analytical samples (2.35%) was below the typical pressing optimum (6–8%), suggesting that mild conditioning could further improve recovery (Holser, 2002; Mridula et al., 2013; Gaber et al., 2020).

3.2. Press cake composition

Sunflower press cake composition is summarised in Table 2. Residual oil (8.67%) was within the 5.9–14% range reported for cold-pressed sunflower cake; this variation is attributable to differences in seed structure, pressing parameters, and seed moisture (Masmoudi et al., 2021). The fatty acid profile of the residual lipid fraction was equivalent to that of the expressed oil

Table 1. Oil and moisture contents of sunflower seeds and press cake, and oil recovery by cold pressing

	Oil content (%)	Moisture content (%)	Oil recovery (%)
Sunflower seed	53.67 ± 0.58	2.35 ± 0.30	83.85
Sunflower press-cake	8.67 ± 0.58	5.56 ± 0.25	

Table 2. General properties of sunflower press cake (mean $\pm$ SD, $n = 3$)

Parameter	Sunflower press cake
Moisture (%)	5.56 $\pm$ 0.25
Residual oil (%)	8.67 $\pm$ 0.58
Crude protein (%)	41.1 $\pm$ 2.19
Dietary fibre (%)	24.5 $\pm$ 0.50
Colour, L*	67.0 $\pm$ 1.1
Colour, a*	−0.3 $\pm$ 0.04
Colour, b*	29.4 $\pm$ 1.4

and was therefore not represented separately. Moisture (5.56%) was within the typical range for stored press cake (de Oliveira Filho and Egea, 2021).

3.3. Acylglycerol composition of cold-pressed oil

Triacylglycerols dominated the cold-pressed oil (TAG 94.54%; Table 3), slightly below the 96–98% range reported for other cold-pressed vegetable oils (Kabutey et al., 2023). Diacylglycerols accounted for 2.51%, while monoacylglycerols were not detected. The free fatty acid fraction was 2.95%. Together, these values suggest only minor hydrolysis and indicate that the gentle, low-temperature extraction preserved the native triglyceride structure (Shimizu et al., 2008; Konuskan et al., 2018). The thin-layer chromatographic procedure applied here was developed for neutral lipids and resolved triacylglycerols, diacylglycerols, monoacylglycerols, and free fatty

Table 3. Fatty acid composition, acylglycerol composition, and oxidative stability of sunflower press-cake oil

	Sunflower press-cake oil
Acylglycerol composition (%):	
FFA	2.95 $\pm$ 0.25
MAG	0.00 $\pm$ 0.00
DAG	2.51 $\pm$ 0.08
TAG	94.54 $\pm$ 0.33
Fatty acid composition (%):	
C16:0	7.79 $\pm$ 4.97
C18:0	3.88 $\pm$ 1.34
C18:1n-9c	31.36 $\pm$ 13.63
C18:2n-6c	56.32 $\pm$ 8.23
SFA	9.51 $\pm$ 0.03
USFA	90.49 $\pm$ 0.00
MUFA	42.30 $\pm$ 0.04
PUFA	48.19 $\pm$ 0.03
Induction period (h):	11.87 $\pm$ 0.32

Saturated fatty acid (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), diacylglycerols (DAG), monoacylglycerols (MAG), triacylglycerols (TAG) free fatty acids (FFA).

acids; under the non-polar developing solvent the polar lipids, including phospholipids, remained close to the origin and were therefore not determined in this fraction.

3.4. Fatty acid composition of cold-pressed oil

Linoleic acid (C18:2n-6c, 56.32%) and oleic acid (C18:1n-9c, 31.36%) were the dominant fatty acids, while palmitic acid (C16:0, 7.79%) and stearic (C18:0, 3.88%) acid were present in lower proportions (Table 3). Saturated fatty acids accounted for 9.51% and unsaturated 90.49% (MUFA 42.30%; PUFA 48.19%). These values are typical of cold-pressed conventional linoleic-type sunflower oils (Konuskan et al., 2018).

3.5. Oxidative stability

The oxidative induction period of the cold-pressed sunflower oil was 11.87 h at 110 °C (Table 3), at the upper end of the 4.5–15.5 h range reported for sunflower oils at this temperature (Gharby et al., 2013). This relatively favourable stability despite linoleic acid dominance likely reflects the contribution of MUFA and naturally retained antioxidants, particularly tocopherols (vitamin E) and phospholipids (lecithins), and indicates that mechanical extraction imposed minimal oxidative pre-stress (Cai et al., 2021; Kaseke et al., 2021; Del Caño-Ochoa et al., 2022).

3.6. Dietary fibre

Total dietary fibre was 24.5%, within the 17–35% range reported for cold-pressed oilseed by-products (de Oliveira Filho and Egea, 2021). Fibre quantity and composition are influenced by pressing temperature, the proportion of seed hulls, and the degree of processing. High fibre content is technologically advantageous and improves water- and oil-holding capacity, contributes to texture, and supports emulsion stability (de Oliveira Filho and Egea, 2021). Mendes de Souza Mesquita et al. (2025) reported that incorporating sunflower flour into bread formulations increased fibre content by 28% without compromising sensory acceptability, supporting the ingredient potential observed here.

3.7. Colour

CIE Lab coordinates of the press cake ($L^* = 67.0$; $a^* = -0.3$; $b^* = 29.4$) indicate a light yellowish hue consistent with partial retention of carotenoids and flavonoids after gentle pressing (Li et al., 2024). The light shade is desirable for the fortification of bakery and snack products, where adverse effects on the appearance of the final product can limit ingredient acceptability.

3.8. Protein and amino acid composition

Crude protein content was 41.1%, at the upper end of the 35–45% range reported for sunflower press cake and considerably higher than that of many other oilseed by-products (de Oliveira Filho and Egea, 2021). Glutamic acid, arginine, and aspartic acid were the most abundant amino acids, contributing to a high biological value and favourable functional properties (Fig. 1). Among essential amino acids, leucine, valine, and phenylalanine were predominant; lysine was the limiting essential amino acid, as is typical for sunflower proteins. The relatively high content of sulphur-containing amino acids (methionine, cystine), often deficient in legume

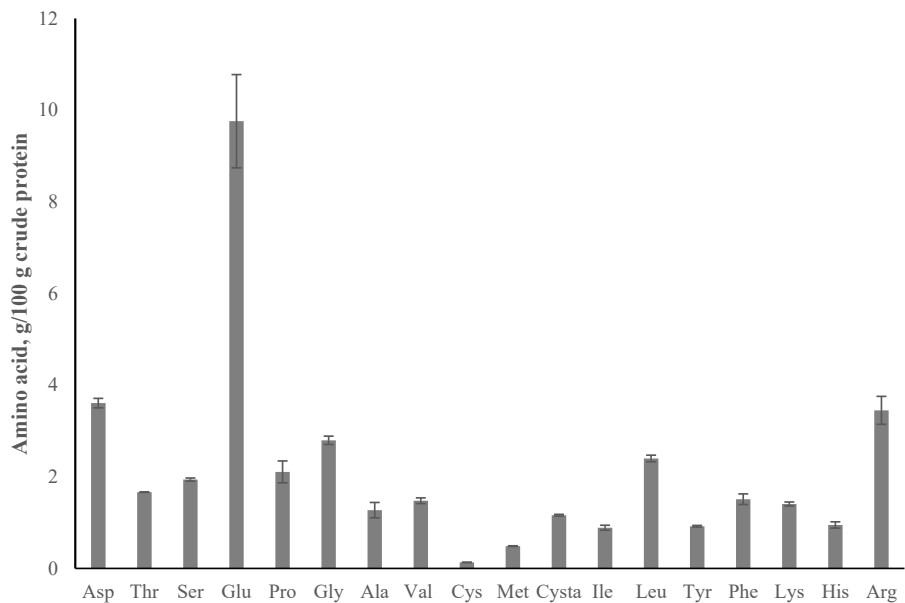


Fig. 1. Amino acid composition of sunflower seed press cake

Values are expressed as amino acids per 100 g crude protein; bars represent means $\pm$ standard deviation ($n = 3$)

proteins, suggests complementarity in plant-protein blends and may partially substitute for soy protein in meat-analogue formulations after appropriate processing (Zahari et al., 2022; Tantawy et al., 2025).

4. CONCLUSIONS

Cold-pressed sunflower press cake from a small-scale producer was characterised in parallel with the corresponding expressed oil. The press cake combined high crude protein (41.1%), substantial dietary fibre (24.5%), and residual lipid (8.67%) within a light-coloured matrix favourable for food incorporation; its amino acid profile, with notable sulphur-containing amino acids and a typical lysine limitation, supports its potential use in plant-protein blends. The cold-pressed oil was dominated by linoleic and oleic acids, while the high triacylglycerol content (94.54%) and induction time of 11.87 h at 110 °C suggest limited hydrolysis and support the gentle nature of the extraction. Together, these results support the development of cold-pressed sunflower press cake as a plant-protein and dietary-fibre ingredient. Application trials, including alkaline protein extraction with isoelectric precipitation, fortification of bakery and meat-analogue formulations, and sensory evaluation, are recommended to confirm functional viability across food categories. As the present work characterised a single press cake from one small-scale producer and benchmarked its properties largely against literature values, the findings should be regarded as a preliminary single-sample characterisation; the inclusion of comparative

samples and replication across batches and producers would be needed before the conclusions can be generalised more broadly.

Conflicts of interest: The authors declare no conflicts of interest.

ACKNOWLEDGEMENT

The authors are grateful to the Doctoral School of Food Sciences, Hungarian University of Agriculture and Life Sciences. This work was supported by the Cooperative Doctoral Program National Defense Subprogram and by the Flagship Research Groups Programme of the Hungarian University of Agriculture and Life Sciences.

REFERENCES

- AOAC. (2005). Method 985.29, Total dietary fibre in foods, enzymatic–gravimetric method. In: *Official methods of analysis of AOAC International*, 18th ed. Gaithersburg, MD, USA: AOAC International.
- Cai, Z., Li, K., Lee, W.J., Reaney, M.T.J., Zhang, N., and Wang, Y. (2021). Recent progress in the thermal treatment of oilseeds and oil oxidative stability: a review. *Fundamental Research*, 1(6): 767–784, <https://doi.org/10.1016/j.fmre.2021.06.022>
- de Oliveira Filho, J.G. and Egea, M.B. (2021). Sunflower seed byproduct and its fractions for food application: an attempt to improve the sustainability of the oil process. *Journal of Food Science*, 86(5): 1497–1510, <https://doi.org/10.1111/1750-3841.15719>
- Del Caño-Ochoa, S., Ruiz-Aracama, A., and Guillén, M.D. (2022). Individual and joint effect of alpha-tocopherol and hydroxytyrosol acetate on the oxidation of sunflower oil submitted to oxidative conditions: a study by proton nuclear magnetic resonance. *Antioxidants*, 11(6): 1156, <https://doi.org/10.3390/antiox11061156>
- Ferhat, M.A., Meklati, B.Y., and Chemat, F. (2007). Comparison of different isolation methods of essential oil from *Citrus* fruits: cold pressing, hydrodistillation and microwave ‘dry’ distillation. *Flavour and Fragrance Journal*, 22(6): 494–504, <https://doi.org/10.1002/ffj.1829>
- Gaber, M.A.F.M., Mansour, M.P., Trujillo, F.J., and Juliano, P. (2020). Microwave pre-treatment of canola seeds and flaked seeds for increased hot expeller oil yield. *Journal of Food Science and Technology*, 58(1): 323–332, <https://doi.org/10.1007/s13197-020-04545-9>
- Gharby, S., Harhar, H., Guillaume, D., Roudani, A., Boulbaroud, S., Ibrahimi, M., Ahmad, M., Sultana, S., et al. (2013). Chemical investigation of *Nigella sativa* L. seed oil produced in Morocco. *Journal of the Saudi Society of Agricultural Sciences*, 14(2): 172–177, <https://doi.org/10.1016/j.jssas.2013.12.001>
- Holser, R. (2002). Seed conditioning and meadowfoam press oil quality. *Industrial Crops and Products*, 17(1): 23–26, [https://doi.org/10.1016/s0926-6690\(02\)00055-9](https://doi.org/10.1016/s0926-6690(02)00055-9)
- ISO. (2017). *Animal and vegetable fats and oils - gas chromatography of fatty acid methyl esters - part 2: preparation of methyl esters of fatty acids*, ISO 12966-2:2017. International Organization for Standardization, Geneva, Switzerland.

- Jakab, I., Mardani, M., Tormási, J., Abrankó, L., and Badak-Kerti, K. (2025). Physicochemical characteristics of cold-pressed hemp, flax, hazelnut, and pumpkin seed oils and press cakes. *European Journal of Lipid Science and Technology*, 127(5): e70017, <https://doi.org/10.1002/ejlt.70017>
- Kabutey, A., Herák, D., and Mizera, Č. (2023). Assessment of quality and efficiency of cold-pressed oil from selected oilseeds. *Foods*, 12(19): 3636, <https://doi.org/10.3390/foods12193636>
- Kaseke, T., Opara, U.L., and Fawole, O.A. (2021). Novel seeds pretreatment techniques: effect on oil quality and antioxidant properties: a review. *Journal of Food Science and Technology*, 58(12): 4451–4464, <https://doi.org/10.1007/s13197-021-04981-1>
- Konuskan, D.B., Arslan, M., and Oksuz, A. (2018). Physicochemical properties of cold pressed sunflower, peanut, rapeseed, mustard and olive oils grown in the Eastern Mediterranean region. *Saudi Journal of Biological Sciences*, 26(2): 340–344, <https://doi.org/10.1016/j.sjbs.2018.04.005>
- Konuskan, D.B. (2020). Minor bioactive lipids in cold pressed oils. In: Ramadan, M.F. (Ed.), *Cold pressed oils*. Elsevier eBooks, pp. 7–14, <https://doi.org/10.1016/b978-0-12-818188-1.00002-5>
- Langyan, S., Bhardwaj, R., Radhamani, J., Yadav, R., Gautam, R.K., Kalia, S., and Kumar, A. (2022). A quick analysis method for protein quantification in oilseed crops: a comparison with standard protocol. *Frontiers in Nutrition*, 9: 892695, <https://doi.org/10.3389/fnut.2022.892695>
- Li, Z., Xiang, F., Huang, X., Liang, M., Ma, S., Gafurov, K., Gu, F., Guo, Q., and Wang, Q. (2024). Properties and characterization of sunflower seeds from different varieties of edible and oil sunflower seeds. *Foods*, 13(8): 1188, <https://doi.org/10.3390/foods13081188>
- Mardani, M., Badak-Kerti, K., Tormási, J., and Farmani, J. (2025). Selective partial hydrolysis as a novel strategy to produce specialty structured fats from vegetable oils: optimization of monoacylglycerol formation and assessment of the final product. *Food and Bioprocess Technology*, 18(1): 460–480, <https://doi.org/10.1007/s11947-024-03460-7>
- Mardani, M., Somogyi, L., Szedljak, I., Prauda, I., Farmani, J., and Badakné Kerti, K. (2021). Efficiency of sea buckthorn extract in oxidative stability improvement of high oleic sunflower oil. *Acta Alimentaria*, 50(4): 527–536, <https://doi.org/10.1556/066.2021.00080>
- Masmoudi, M., Baccouche, A., Borchani, M., Besbes, S., Blecker, C., and Attia, H. (2021). Physico-chemical and antioxidant properties of oils and by-products obtained by cold press-extraction of Tunisian *Opuntia* spp. seeds. *Applied Food Research*, 1(2): 100024, <https://doi.org/10.1016/j.afres.2021.100024>
- Mendes de Souza Mesquita, L., Aguiar, E.V., Contieri, L.S., Togni, V.B., Forli, B.C.A., Sanches, V. L., Santos, F.G., Da Silva, L.G.S., et al. (2025). Repurposing sunflower seed flour for nutritional and functional high-protein breads within a circular economy framework. *ACS Food Science and Technology*, 5(4): 1425–1435, <https://doi.org/10.1021/acsfoodscitech.4c01008>
- Mridula, D., Barnwal, P., and Singh, K.K. (2013). Screw pressing performance of whole and dehulled flaxseed and some physico-chemical characteristics of flaxseed oil. *Journal of Food Science and Technology*, 52(3): 1498–1506, <https://doi.org/10.1007/s13197-013-1132-6>
- Popović, S., Hromiš, N., Šuput, D., Bulut, S., Romanić, R., and Lazić, V. (2020). Valorization of by-products from the production of pressed edible oils to produce biopolymer films. In: Ramadan, M.F. (Ed.), *Cold pressed oils*. Elsevier eBooks, pp. 15–30, <https://doi.org/10.1016/b978-0-12-818188-1.00003-7>
- Shimizu, M., Kudo, N., Nakajima, Y., Matsuo, N., Katsuragi, Y., Tokimitsu, I., Barceló, I., Mateu, C., et al. (2008). Acidity and DAG content of olive oils recently produced on the island of Mallorca. *Journal of the American Oil Chemists Society*, 85(11): 1051–1056, <https://doi.org/10.1007/s11746-008-1292-0>
- Tantawy, A.A., Ali, M., Kurbonova, M., El-Messery, T.M., Baranenko, D.A., Hellwig, M., Abozed, S.S., El-Said, M.M., et al. (2025). Functional properties of sunflower protein concentrates extracted using

- different anti-greening agents- low-fat whipping cream preparation. *LWT – Food Science and Technology*, 218: 117456, <https://doi.org/10.1016/j.lwt.2025.117456>
- Vidal, N.P., Roman, L., Swaraj, V.S., Ragavan, K., Simsek, S., Rahimi, J., Kroetsch, B., and Martinez, M.M. (2022). Enhancing the nutritional value of cold-pressed oilseed cakes through extrusion cooking. *Innovative Food Science and Emerging Technologies*, 77: 102956, <https://doi.org/10.1016/j.ifset.2022.102956>
- Zahari, I., Östbring, K., Purhagen, J.K., and Rayner, M. (2022). Plant-based meat analogues from alternative protein: a systematic literature review. *Foods*, 11(18): 2870, <https://doi.org/10.3390/foods11182870>

Open Access statement. This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited, a link to the CC License is provided, and changes – if any – are indicated. (SID_1)