variations were observed during the flowering to seed ripening phase, which ranged from 30 to 48 days. 'Vkus Korici' had the shortest flowering to seed ripening period at 30 days (Table 2). The early-flowering varieties might be preferred for quick seed production, while later-flowering varieties may be suited for extended green mass production. Considering this, 'Vkus Korici' and 'Rozi' may be recommended for seed production, while the cultivation of 'Kanach Burmunq' and 'Manushakaguin teghakan' will lead to more substantial biomass accumulation and green mass production.

Table 2: Duration of transition of basil cultivars to phenophases

Basil varieties	Number of days from germination to		Mass flowering-seed ripening, days	Vegetation period, days
	Bud-formation	Flowering		
Manushakaguin teghakan	40	58	43	100
Kanach burmunq	43	65	48	113
Kitroni burmunq	33	43	37	79
Karamelniy	35	45	39	84
Vkus korici	36	47	30	77
Rozi	38	50	32	80

Varieties were further categorized based on their ripening periods under the conditions of the Ararat Valley: 'Vkus Korici' and 'Kitroni Burmunq' were early ripening, 'Karamelniy', 'Rozi', and 'Manushakaguyn teghakan' were mid-ripening, and 'Kanach Burmunq' was late ripening. These characteristics are crucial for selecting basil varieties suitable for different agricultural zones and cultivation purposes. Describing phenological stages helps in selecting varieties best suited to specific climatic and environmental conditions, ensuring that the plants can thrive and produce optimally in their intended growing regions. In regions with shorter growing seasons, early maturing varieties are advantageous, while in regions with longer seasons, late-maturing varieties can be used to extend the harvest period. Early varieties like 'Vkus Korici' and 'Kitroni Burmunq' are ideal for early green mass production and microgreens cultivation, as well as seed production in lowland conditions. For seed production in foothills and mountainous regions, mid-ripening and late-ripening varieties are recommended.

The studied cultivars also exhibited variations in yield indicators and quality characteristics. These variations are crucial for assessing their potential as functional foods, as higher yield indicators often correlate with greater availability of bioactive compounds in horticuture crops, which enhance the nutritional and health benefits of the food [25, 26]. Among the varieties studied, yield indicators ranged from 0.6 to 2.0 kg/m² (weight of above-ground fresh mass per sq. m). Notably, the 'Manushakaguyn teghakan ' variety stood out with the highest yield, which was 3.3 times greater than the lowest yielding variety, 'Kitroni Burmunq'. Additionally, the 'Manushakaguyn teghakan ' variety showed a relatively larger above-ground fresh biomass (Table 3).

Table 3: Effectiveness and quality indicators of basil varieties

Varieties	Yield of ground mass, kg/m2	Fresh weight of one plant, g	Dry matter, %	Crude protein, %	Sugars, %
Manushakaguyn teghakan	2.0±0. 1	80±0. 07	9.1±0.3	15.8±0.8	3.6±0.2
Kanach burmunq	1.4±0. 06	56±0. 01	9.5±0.2	14.7±1.1	2.5±0.2
zKaramelniy	1.7±0. 08	68±0. 05	10.8±0.3	15.4±0.5	2.5±0.1
Kitroni burmunq	0.6±0. 01	24±0. 02	10.3±0.2	16.2±0.5	2.7±0.2
Vkus korici	0.8±0. 02	32±0. 03	9.3±0.3	15.5±0.7	3.0±0.2
Rozi	1.3±0. 05	61±0. 05	9.8±0.4	15.0±1.0	3.2±0.1

Dry matter content represents the portion of the plant that remains after water has been removed. A higher dry matter content typically indicates a higher concentration of nutrients, such as vitamins, minerals, and bioactive compounds, per unit weight [27]. Consequently, higher dry matter content can enhance the intensity of flavors and aromatics in basil, making it more desirable for culinary uses. Besides, varieties with higher dry matter content can be more economically efficient for producers, as they yield more marketable product by weight after drying processes [28]. The biochemical analysis results revealed distinct characteristics among the basil varieties. 'Karamelniy' and 'Kitroni Burmunq' exhibited the highest dry matter contents at 10.8% and 10.3%, respectively, while 'Manushakaguyn teghakan ' had the lowest, although the difference is not significant.

Crude protein content in basil contributes significantly to its nutritional and functional value [29], providing essential amino acids and promoting satiety. When combined with the plant's bioactive compounds, high-protein basil can be an excellent addition to functional foods aimed at enhancing overall health and well-being. Higher crude protein content means basil can contribute more significantly to daily protein requirements, making it a valuable addition to diets, especially for vegetarians and vegans. Additionally, some bioactive peptides derived from proteins can have antioxidant properties, contributing to the overall health benefits of basil. Crude protein content in the studied varieties varied from 14.7% to 16.2%, with 'Kitroni Burmunq' showing the highest and 'Kanach Burmunq' the lowest amounts. However, like in case of content of dry matter, the difference is minor.

Assessing the vitamin C and carotene content in various basil varieties is essential for maximizing their functional value, promoting better health, and meeting the needs of both consumers and the agricultural sector. As a potent antioxidant, vitamin C plays a significant role in protecting the body against oxidative stress, boosting the immune system, and enhancing iron absorption from plant-based foods [30, 31]. Determining the vitamin C content in basil varieties can guide consumers and healthcare professionals in selecting basil with the highest nutritional benefits. Carotenes, including beta-carotene, are precursors to vitamin A, essential for maintaining healthy vision, skin, and immune function [32]. Evaluating carotene levels helps identify basil varieties that offer substantial health benefits and can contribute to a balanced diet [33]. Basil varieties rich in vitamin C and beta-carotene can be promoted as functional foods, providing added health benefits beyond basic nutrition. This can be particularly appealing to health-conscious consumers looking for natural sources of essential nutrients [34].

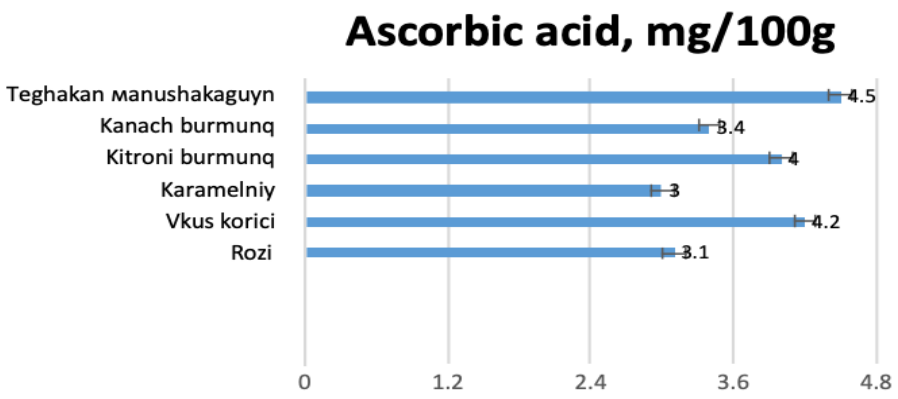

Figure 1. Ascorbic acid content in different basil varieties

In the context of the aforementioned varieties, 'Manushakaguyn teghakan ' and 'Vkus Korici' exhibited high levels of vitamin C and beta-carotene content, which are correlated with antioxidant properties. Specifically, 'Manushakaguyn teghakan' exhibited a vitamin C content of 4.5 mg/100g and β-carotene content of 145 mg/kg, while 'Vkus Korici' showed 4.2 mg/100g of vitamin C and 144.5 mg/kg of beta-carotene (Figure 1 and 2).

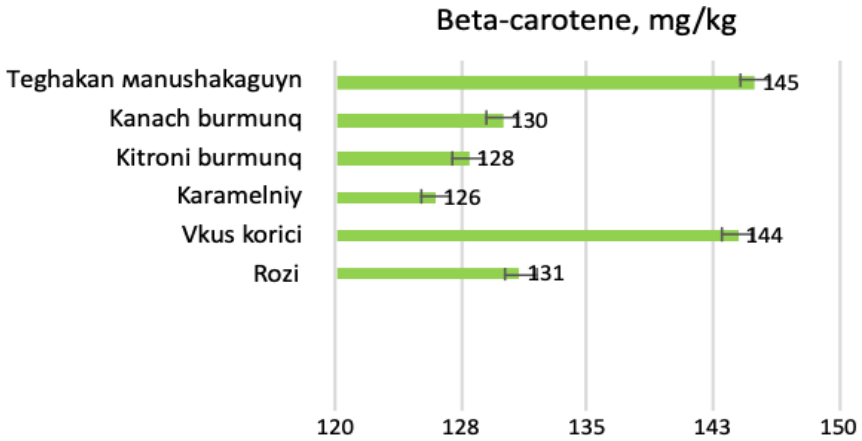

Figure 2. Beta-carotene content in different basil varieties

Essential oils in basil plays a crucial role in determining the plant's aromatic and medicinal properties. This oil, rich in compounds like linalool, eugenol, and methyl chavicol, contributes to basil's characteristic scent and flavor, and has been shown to possess antimicrobial, anti-inflammatory, and antioxidant properties [35]. Studying the total essential oil content in different varieties of basil is important for several reasons. It can help identify the most potent varieties for use in culinary, medicinal, and industrial applications. Moreover, understanding the variation in essential oil composition among basil varieties can aid in breeding programs aimed at enhancing specific desirable traits, such as increased oil yield or improved therapeutic properties. Essential oils contain biologically active compounds with diverse properties, including antimicrobial, anti-inflammatory, analgesic, and antioxidant effects [36, 37]. 'Manushakaguyn teghakan' (0.75%) and 'Kitroni Burmunq' (0.74%) were notable for their high total essential oil content, an important characteristic for the production of dried products and aromatic additives (Figure 3).

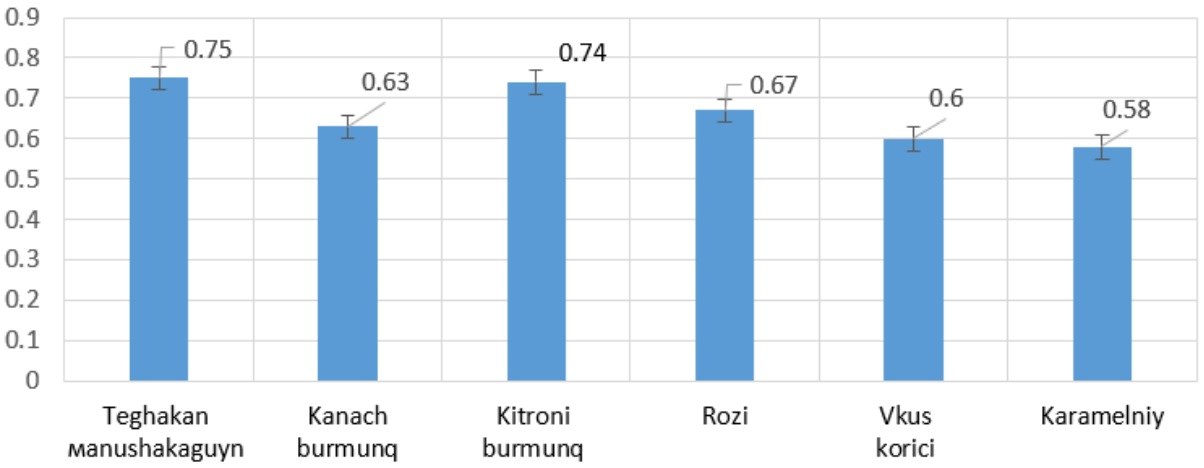

Figure 3. Essential oil content of studied varieties of basil (% of dry matter)

CONCLUSION

Basil, as a unique spice crop, holds significant potential for use in functional foods due to its antioxidant properties. Therefore, selecting the appropriate variety for cultivation is crucial, considering factors such as functional attributes, yield potential, and maturity period.

The results of investigations carried out by several researchers provide an overview of how yield and postharvest handling impact the quality and functional properties of horticultural crops [38, 39]. Environmental factors dependent on agro-climatic zones also affect yield and nutritional quality, thereby contributing to the functional properties of plants. Considering this correlation, the 'Manushakaguyn teghakan' variety stood out with the highest yield of 2.0 kg/m² and a plant fresh above-ground mass of 80g. This variety can be highlighted for its comparatively high functional value due to its yield indicators and bioactive compound availability.

Observations on the duration of phenophases, especially from germination to budding and flowering, among the cultivars are essential for choosing basil varieties suitable for various agricultural zones and cultivation purposes. Under the low altitude conditions of Ararat Valley, among the six varieties studied, 'Vkus Korici' and 'Kitroni Burmunq' demonstrated early maturity; 'Karamelniy', 'Rozi', and 'Manushakaguin teghakan' exhibited medium maturity; and the 'Kanach Burmunq' variety showed late maturity. Early growth phases are generally more vigorous and suitable for quick turnover crops like microgreens, with early-flowering varieties preferred for quick seed production. Therefore, 'Kitroni Burmunq' and 'Karamelniy' are recommended for microgreens production, along with 'Vkus Korici' and 'Rozi' for early green mass and seed production in lowland areas of the Republic of Armenia. For seed production in foothill and mountainous regions, mid-ripening and late-ripening varieties such as 'Manushakaguyn teghakan' and 'Kanach Burmunq' are advised. Understanding phenological stages aids in selecting varieties that thrive and produce optimally in specific climatic and environmental conditions.

Both the 'Manushakaguyn teghakan' and 'Vkus Korici' varieties boasted high levels of vitamin C and beta-carotene, what determines antioxidant activity. 'Kitroni Burmunq' showed, with minor difference, the highest content of crude protein (16.2±0.5%). This makes 'Kitroni Burmunq' suitable for marketing as a functional food, offering not only traditional culinary benefits but also improved protein intake and associated metabolic advantages. Farmers and producers can benefit by

focusing on cultivating basil varieties with higher vitamin C and beta-carotene content to meet the growing demand for nutrient-rich herbs, thereby enhancing market value and consumer preference for these superior varieties.

Additionally, 'Manushakaguyn teghakan' and 'Kitroni Burmunq' stood out due to their high total essential oil content, a significant feature for the production of dried products and aromatic additives. These findings support the recommendation of all studied varieties of basil for functional food applications. Among them, 'Manushakaguyn teghakan' demonstrates a robust combination of high nutritional quality and economic viability, driven by substantial yield, positioning it as an ideal choice for maximizing both health benefits and profitability.

List of abbreviations: kg, kigogram; g, gram; m^2, square meter; mg, milligram

Competing interests: The authors declare that they have no competing interests.

Authors' contributions: LT, RB and AA designed the research. LT, IV and ZH performed biochemical analysis. GM performed statistical analyses. LT, RB, AA, ITs and GM participated in data collection and analysis of the results and drawing the graphs. GS contributed to writing the abstract and introduction. AA edited the article. All authors read and approved the final version of the manuscript.

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REFERENCES

1. Tadevosyan T, Martirosyan G, Tsereteli I, Vardanian I, Zadayan M, Avagyan A. Dynamics of bioactive substances accumulation during cauliflower maturation as a way to ensure crop functional properties. Functional Foods in Health and Disease. 2023, 13(11):584-594, DOI: https://www.doi.org/10.31989/ffhd.v13i11.1197
2. Otunola GA, Martirosyan D. Choosing suitable food vehicles for functional food products. Functional Foods in Health and Disease. 2021, 11(2):44-55. DOI: https://www.doi.org/10.31989/ffhd.v11i2.764
3. Martirosyan D, Kanya H, Nadalet C. Can functional foods reduce the risk of disease? Advancement of functional food definition and steps to create functional food products. Functional Foods in Health and Disease. 2021, 11(5):213-221. DOI: https://www.doi.org/10.31989/ffhd.v11i5.788
4. Temple NJ. A rational definition for functional foods: A perspective. Front. Nutr. 2022, 9:957516. DOI: https://www.doi.org/10.3389/fnut.2022.957516
5. Sachan KR, Kumar S, Kumari K, Singh D. Medicinal uses of spices used in our traditional culture: worldwide. Journal of Medicinal Plants Studies, 2018, 6(3): 116-122
6. Eneojo O, Martins E. Herbs and Spices-Based Value Addition for Nutritional and Healthy Living. Intech Open. 2024 DOI: https:/doi.org/10.5772/intechopen.1004345
7. Lawal TO, Patel SR, Mahady GB. Food and medicinal plants from Nigeria with anti-Helicobacter pylori activities induce apoptosis in colon and gastric cancer cell lines. Functional Foods in Health and Disease. 2022, 13(7): 372-387. DOI: https://www.doi.org/10.31989/ffhd.v13i7.1105
8. Sargsyan M. Usage of spicy aromatic plants of the flora of Armenia in the national cuisine. Regulatory Mechanisms in Biosystems. 2023, 14(3): 469-475. DOI: https://doi.org/10.15421/10.15421/022367
9. Murphy EW, Marsh AC, Willis BW. Nutrient content of spices and herbs. Journal of the American Dietetic Association. 1978, 72(2): 174-176. DOI: https://doi.org/10.1016/S0002-8223(21)05949-6
10. Martirosyan G, Sarikyan K, Adjemyan G, Pahlevanyan A, Kirakosyan G, Zadayan M, Avagyan A. Impact of green technology on content of bioactive components in eggplant. Bioactive Compounds in Health and Disease. 2023; 6(12): 351-363. DOI: https://www.doi.org/10.31989/bchd.v6i12.1261

11. Mohamed AA, Alotaibi BM. Essential oils of some medicinal plants and their biological activities: a mini review. J. Umm Al-Qura Univ. Appll. Sci. 2023, 9: 40-49 DOI: https://doi.org/10.1007/s43994-022-00018-1
12. Khan A, Ahmad M, Sultan A, Khan R, Raza J, Abidin SZ, Khan S, Zafar M, Uddin MN, Kazi M. Herbal Spices as Food and Medicine: Microscopic Authentication of Commercial Herbal Spices. Plants. 2024, 13(8):1067. DOI: https://doi.org/10.3390/plants13081067
13. Umbreen H, Khalid K, Khalid A, Noreen R, Marc RA. Sacred Basil. Essentials of Medicinal and Aromatic Crops. 2023. DOI: https://doi.org/10.1007/978-3-031-35403-8_25
14. Nadeem HR, Akhtar S, Sestili P, Ismail T, Neugart S, Qamar M, Esatbeyoglu T. Toxicity, Antioxidant Activity, and Phytochemicals of Basil (Ocimum basilicum L.) Leaves Cultivated in Southern Punjab, Pakistan. Foods. 2022, 11(9):1239. DOI: https://doi.org/10.3390/foods11091239
15. Shahrajabian MH, Sun W, Cheng Q. Chemical components and pharmacological benefits of Basil (Ocimum basilicum): a review. International Journal of Food Properties. 2020, 23(1):1961–1970. DOI: https://doi.org/10.1080/10942912.2020.1828456
16. Avagyan A, Sargsyan G, Balayan R, Tadevosyan L. Replenishment and rationalization of seed collections of pumpkin, vegetable marrow and summer squash for ex situ conservation and use for breeding. Genetic Resources. 2020, 1(1):49-52 DOI: https:/doi.org/10.46265/genresj.2020.1
17. Montgomery DC. Design and analysis of experiments, eighth edition, John Wiley & Sons, Inc. ISBN: 978-1-118-14692-7, 724p.
18. Sachivko TV. Evaluation of basil (Ocimum L.) source material and its use in breeding. Thesis Cand. of Agricultural Sciences, Belarusian state agricultural acad., Gorki, 2014. 143
19. MEBAK online. Method B-530.01.070. Soluble Dry Matter (Extract)-Refractometric Method. Rev. 2020-10. Mitteleuropäische Brautechnische Analysenkommission (MEBAK®) e.V., Freising, BY, Germany. https://www.mebak.org/en/methode/b-530-01-070/soluble-dry-matter-extract-refractometric-method/3079. Retrieved on September 3rd, 2024
20. Jamal SD, Jamil DM, Khidhir KZ. Protein Determination in some Animal Products from Sulaymaniyah Markets Using Kjeldahl Procedure. J. of Food and Dairy Sci., 2020, 11 (12):343-346
21. Kapur A, Hasković A, Čopra-Janićijević A, Klepo L, Topčagić A, Tahirović I, Sofić E. Spectrophotometric analysis of total ascorbic acid content in various fruits and vegetables, Bulletin of the Chemists and Technologists of Bosnia and Herzegovina. 2012, (38): 39-42
22. Stoyanova YAV, Strelyaeva AV, Kuznecov RM, Strelyaev ND. The study of the chemical composition of the essential oil of the raw material of the herb Tanacetum vulgare, obtained by different methods of hydrodistillation, Medical & pharmaceutical journal “Pulse". 2022, 24(5) DOI:http://dx.doi.org/10.26787/nydha-2686-6838-2022-24-5-29-36
23. Sawyer SF. Analysis of Variance: The Fundamental Concepts. Journal of Manual & Manipulative Therapy, 2009 17(2), 27E-38E. DOI: https://doi.org/10.1179/jmt.2009.17.2.27E
24. Hiltunen R. Holm Y. Basil: The Genus Ocimum. Phytochemistry. 2001, 58(3):533 DOI: https://doi.org/10.1016/S0031-9422(01)00229-1
25. García-Mier L, Guevara-González RG, Mondragón-Olguín VM, Del Rocío Verduzco-Cuellar B, Torres-Pacheco I. Agriculture and bioactives: achieving both crop yield and phytochemicals. Int J Mol Sci. 2013 Feb 20;14(2):4203-22. DOI: https://doi.org/10.3390/ijms14024203.
26. de la Rosa LA, Moreno-Escamilla JO, Rodrigo-García J, Alvarez-Parrilla E. Phenolic Compounds: Their Role in the Prevention and Treatment of Metabolic Diseases. Current Pharmaceutical Biotechnology. 2019, 20(15):1190-1215
27. Shipey B, Vu TT. Dry matter content as a measure of dry matter concentration in plants and their parts. New phytologist, 2002, 153 (2): 359-364 DOI: https://doi.org/10.1046/j.0028-646X.2001.00320.x
28. Calín-Sánchez Á, Lipan L, Cano-Lamadrid M, Kharaghani A, Masztalerz K, Carbonell-Barrachina ÁA, Figiel A. Comparison of Traditional and Novel Drying Techniques and Its Effect on Quality of Fruits, Vegetables and Aromatic Herbs. Foods. 2020; 9(9):1261. DOI: https://doi.org/10.3390/foods9091261
29. Calderón Bravo H, Vera Céspedes N, Zura-Bravo L, Muñoz LA. Basil Seeds as a Novel Food, Source of Nutrients and Functional Ingredients with Beneficial Properties: A Review. Foods. 2021, 10(7):1467. DOI: https://doi.org/10.3390/foods10071467.
30. Agwu E, Ezihe C, Kaigama G. Antioxidant Roles/Functions of Ascorbic Acid (Vitamin C). IntechOpen. 2024, DOI: https://doi.org/10.5772/intechopen.110589
31. Carr AC, Maggini S. Vitamin C and Immune Function. Nutrients. 2017, 9(11):1211. DOI: https:/doi.org/10.3390/nu9111211

32. Krinsky NI, Johnson EJ. Carotenoid actions and their relation to health and disease. Mol Aspects Med. 2005,26(6):459-516. DOI: https:/doi.org/10.1016/j.mam.2005.10.001
33. Filip S. Basil (*Ocimum basilicum L.*) a Source of Valuable Phytonutrients. Int J Clin Nutr Diet, 2017, 3: 118. DOI: https://doi.org/10.15344/2456-8171/2017/118
34. Siddiqu A, Dini S, Esmaeili S, Roshanak Y, Ali Redha S, Wani S. Uses of carotenoid-rich ingredients to design functional foods: a review. Journal of Food Bioactives, 2023, 21. DOI: https://doi.org/10.31665/JFB.2023.18334
35. Sultan LJ, Fadhil WG, Hamid MM, Hadi ST. A comparative study of the effect of extracts extracted from Ocimum basilicum leaves using organic extract and essential oil. Functional Foods in Health and Disease. 2024, 14(6):380-387. DOI: https://doi.org/10.31989/ffhd.v14i6.1304
36. Haas RA, Crisan I, Vârban D, Stoie A, Vârban R. Melliferous Aromatic Plants, Hop and Medicinal Plants. 2023, 31 (1-2) DOI: https://doi.org/10.15835/hamp
37. Aboukhalaf A, Belkassem El, Amraoui BE, Tabatou M, Rocha JMF, Belahsen R. Screening of the antimicrobial activity of some extracts of edible wild plants in Morocco. Functional Foods in Health and Disease. 2020, 10(6): 265-273. DOI: https:/doi.org/10.31989/ffhd.v10i6.718
38. Dabulici CM, Sârbu I, Vamanu E. The Bioactive Potential of Functional Products and Bioavailability of Phenolic Compounds. Foods. 2020, 9(7):953. DOI: https://doi.org/10.3390/foods9070953.
39. Gil-Martín E, Forbes-Hernández T, Romero A, Cianciosi D, Giampieri F, Maurizio B. Influence of the extraction method on the recovery of bioactive phenolic compounds from food industry by-products. Food Chemistry, 2022, 378 (131918):1-39 DOI: https://doi.org/10.1016/j.foodchem.2021.131918