molecules

MDPI

*Article*

# Stabilization of Sunflower Oil with Biologically Active Compounds from Berries

**Aliona Ghendov-Mosanu [1], Violina Popovici [1], Cristina Gabriela Constantinescu (Pop) [2], Olga Deseatnicova [1], Rodica Siminiuc [1], Iurie Subotin [1], Raisa Druta [1], Adela Pintea [3], Carmen Socaciu [3] and Rodica Sturza [1,*]**

[1] Faculty of Food Technology, Technical University of Moldova, MD-2045 Chisinau, Moldova; aliona.mosanu@tpa.utm.md (A.G.-M.); violina.popovici@toap.utm.md (V.P.); olga.deseatnicova@toap.utm.md (O.D.); rodica.siminiuc@adm.utm.md (R.S.); iurie.subotin@fta.utm.md (I.S.); raisa.druta@fta.utm.md (R.D.)
[2] Faculty of Food Engineering, Ştefan cel Mare University of Suceava, 720229 Suceava, Romania; gabriela.constantinescu@fia.usv.ro
[3] Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine, 400374 Cluj-Napoca, Romania; apintea@usamvcluj.ro (A.P.); carmen.socaciu@usamvcluj.ro (C.S.)
* Correspondence: rodica.sturza@chim.utm.md

**Abstract:** Sunflower oil (*Helianthus annuus*) contains a rich concentration of polyunsaturated fatty acids, which are susceptible to rapid oxidative processes. The aim of this study was to evaluate the stabilizing effect of lipophilic extracts from two types of berries, sea buckthorn and rose hips, on sunflower oil. This research included the analysis of sunflower oil oxidation products and mechanisms, including the determination of chemical changes occurring in the lipid oxidation process via LC-MS/MS using electrospray ionization in negative and positive mode. Pentanal, hexanal, heptanal, octanal, and nonanal were identified as key compounds formed during oxidation. The individual profiles of the carotenoids from sea buckthorn berries were determined using RP-HPLC. The influence of the carotenoid extraction parameters ascertained from the berries on the oxidative stability of sunflower oil was analyzed. The dynamics of the accumulation of the primary and secondary products of lipid oxidation and the variation of the carotenoid pigment content in the lipophilic extracts of sea buckthorn and rose hips during storage demonstrated good stability at 4 °C in the absence of light for 12 months. The experimental results were applied to mathematical modeling using fuzzy sets and mutual information analysis, which allowed for the prediction of the oxidation of sunflower oil.

**Keywords:** sunflower oil; carotenoids; sea buckthorn; rose hips; lipid oxidation; oxidative stability

check for updates

**Citation:** Ghendov-Mosanu, A.; Popovici, V.; Constantinescu (Pop), C.G.; Deseatnicova, O.; Siminiuc, R.; Subotin, I.; Druta, R.; Pintea, A.; Socaciu, C.; Sturza, R. Stabilization of Sunflower Oil with Biologically Active Compounds from Berries. *Molecules* **2023**, *28*, 3596. https://doi.org/10.3390/molecules28083596

Academic Editor: Guoxu Ma

Received: 21 February 2023
Revised: 12 April 2023
Accepted: 17 April 2023
Published: 20 April 2023



## 1. Introduction

A permanent concern in the modern food industry is to ensure an optimal shelf life of food products. The main factor that leads to food spoilage is oxidation [1,2]. Oxidation is a chemical process involving the modification of fatty acids, amino acids, and vitamins, which, in turn, affects the organoleptic and nutritional characteristics of food [3,4].

The oxidation of lipids in food is a complex process that is influenced by various factors, such as the chemical structure of the food; the food's physical condition; the quantity and quality of substances that act as antioxidants in food; and the processing, packaging, and storage conditions of the food. Lipids are an easily alterable fraction of food, so their storage conditions largely depend on their nature and concentration. The consequences of this process, which are precipitated by the degradation of some easily oxidizable constituents of the lipid fraction in food, can include the appearance of a rancid odor, color changes, and, in some cases, changes in food texture, which negatively influence the sensory parameters of food [5]. The nutritional value of foods subjected to oxidative degradation of their lipid fraction can also be affected to a considerable extent. However, the most important risk is the ingestion of lipid oxidation products because they present enormous toxicological risks and, in the case of long-term use, can lead to the appearance of degenerative pathologies such as arteriosclerosis, cancer, etc.

After soybean oil, sunflower oil (*Helianthus annuus*) ranks second in the world in terms of the most-produced edible oils and is rightly considered to number among the preeminent vegetable oils for the human diet due to its nutritional value [6]. Sunflower oil contains a high concentration of polyunsaturated fatty acids (especially oleic and linoleic acids) that contribute to lowering cholesterol and reducing the risk of heart disease. However, polyunsaturated fatty acids are the site of rapid oxidative processes, especially in the presence of oxygen and light. Plant sterols or phytosterols are compounds with proven health benefits. Their richest natural sources are vegetable oils. In crude sunflower vegetable oil, phospholipids represent 0.8–1.2% of the total lipid fraction [7]. Unsaturated fatty acids esterified in phospholipids are major targets for oxidation. The hydrogen atoms on the methylene groups adjacent to the double bonds (allylic hydrogen atoms) present low C-H bond energies, and those located on the methylene between two double bonds (hydrogen bis- allylic) have even lower C-H bond energies. This fact allows them to be easily abstracted by reactive radical species, leading to the formation of phospholipid radical species with the radical centered on the allylic carbon atom. Refinement and deodorization processes considerably decrease the content of phospholipids (0.1–0.2%). This increases the stability of the oils upon oxidation but decreases their biological value [8].

In biological materials, lipids are protected from oxidation by the presence of antioxidants and cell membranes, which reduce the access of oxidants to easily oxidizable fractions [3]. In food, reducing the impact of lipid oxidation can only be ensured by the use of appropriate packaging and by the presence of antioxidants, which block the propagation or decomposition of hydroperoxides. Food products usually contain antioxidants of a synthetic origin (propyl gallate—E-311 or octyl gallate—E-312; butylhydroxyanisole (BHA)—E-320; etc.), but their effect on human health is debatable. One of the current strategies used in the food industry with the aim of inhibiting the lipid oxidation process is the use of natural antioxidants, which are compounds that increase the shelf life of food products following the oxidation process [9]. Lipophilic extracts from vegetable powders of berries, which are rich in biologically active compounds, are of particular interest [10–12].

Tocopherols are the most important antioxidants present in edible oil. Sunflower oil contains a high concentration of tocopherols (648.9 ppm). The refinement process, especially deodorization, reduces tocopherol content [13–15]. Carotenoids are a group of tetraterpenoids that are formed from isoprenoid units and have conjugated double bonds. In the co-presence of chlorophylls, β-carotene reduces the oxidation of edible oil by inhibiting $^1O_2$ [16,17]. Sea buckthorn (*Hippophae rhamnoides* L.) is a valuable plant due to its medicinal and nutritional potential, as it is a good source of bioactive compounds such as vitamins (C, E, and K; riboflavin; and folic acid), carotenoids (α-, β-, and δ-carotene; lycopene), tocopherols, phytosterols, organic acids (malic acid, oxalic acid, and citric acid), polyunsaturated fatty acids, and some essential amino acids [18–20]. Rose hip berries (*Rosa canina* L.) are rich in polyphenols, carotenoids, triterpenic acids, essential fatty acids, galactolipids, folates, vitamins C and E, minerals (Ca, Mg, K, S, Si, Se, Mn, and Fe), etc. [21]. It has been reported that rose hips can be used not only for direct consumption but also for the extraction of bioactive compounds (BC) [22].

The aim of this study was to assess the stabilizing effect of lipophilic extracts from berries-sea buckthorn and rose hips on sunflower oil. Firstly, we determined the optimal conditions for obtaining the lipophilic extracts from the berries. Secondly, an analysis of the products and mechanisms of sunflower oil oxidation was conducted. This included determining the chemical changes that occur in the process of a forced lipid oxidation analysis of the evolution of the stability parameters of the stabilized oils over a period of 12 months, mathematically modeling the oxidation processes, and determining the influencing factors.

## References


1. Siró, I.; Kápolna, E.; Kápolna, B.; Lugasi, A. Functional Food. Product Development, Marketing and Consumer Acceptance—A Review. *Appetite* **2008**, *51*, 456–467. [CrossRef] [PubMed]
2. Kaur, D.; Wani, A.A.; Singh, D.P.; Sogi, D.S. Shelf Life Enhancement of Butter, Ice-Cream, and Mayonnaise by Addition of Lycopene. *Int. J. Food Prop.* **2011**, *14*, 1217–1231. [CrossRef]
3. Ghorbani Gorji, S.; Smyth, H.E.; Sharma, M.; Fitzgerald, M. Lipid Oxidation in Mayonnaise and the Role of Natural Antioxidants: A Review. *Trends Food Sci. Technol.* **2016**, *56*, 88–102. [CrossRef]
4. Caleja, C.; Barros, L.; Antonio, A.L.; Oliveira, M.B.P.P.; Ferreira, I.C.F.R. A Comparative Study between Natural and Synthetic Antioxidants: Evaluation of Their Performance after Incorporation into Biscuits. *Food Chem.* **2017**, *216*, 342–346. [CrossRef]
5. Anguelova, T.; Warthesen, J. Degradation of Lycopene, β-Carotene, and α-Carotene during Lipid Peroxidation. *J. Food Sci.* **2000**, *65*, 71–75. [CrossRef]
6. Khan, S.; Choudhary, S.; Pandey, A.; Khan, M.; Thomas, G. Sunflower Oil: Efficient Oil Source for Human Consumption. *Emergent Life Sci. Res.* **2015**, *1*, 1–3.
7. Lamas, D.L.; Crapiste, G.H.; Constenla, D.T. Changes in quality and composition of sunflower oil during enzymatic degumming process. *LWT-Food Sci. Technol.* **2014**, *58*, 71–76. [CrossRef]
8. Reis, A.; Spickett, C.M. Chemistry of phospholipid oxidation. *Biochim. Biophys. Acta Biomembr.* **2012**, *1818*, 2374–2387. [CrossRef]
9. Popovici, V.; Radu, O.; Hubenia, V.; Kovaliov, E.; Capcanari, T.; Popovici, C. Physico-Chemical and Sensory Properties of Functional Confectionery Products with *Rosa canina* Powder. *Ukr. Food J.* **2019**, *8*, 815–827. [CrossRef]
10. Ghendov-Mosanu, A.; Cristea, E.; Patras, A.; Sturza, R.; Niculaua, M. Rose Hips, a Valuable Source of Antioxidants to Improve Gingerbread Characteristics. *Molecules* **2020**, *25*, 5659. [CrossRef]
11. Ghendov-Moşanu, A.; Sturza, R.; Opriş, O.; Lung, I.; Popescu, L.; Popovici, V.; Soran, M.-L.; Patraş, A. Effect of Lipophilic Sea Buckthorn Extract on Cream Cheese Properties. *J. Food Sci. Technol.* **2020**, *57*, 628–637. [CrossRef]
12. Cristea, E.; Ghendov-Mosanu, A.; Patras, A.; Socaciu, C.; Pintea, A.; Tudor, C.; Sturza, R. The Influence of Temperature, Storage Conditions, PH, and Ionic Strength on the Antioxidant Activity and Color Parameters of Rowan Berry Extracts. *Molecules* **2021**, *26*, 3786. [CrossRef] [PubMed]
13. Jung, M.Y.; Yoon, S.H.; Min, D.B. Effects of Processing Steps on the Contents of Minor Compounds and Oxidation of Soybean Oil. *J. Am. Oil Chem. Soc.* **1989**, *66*, 161–180. [CrossRef]
14. Reische, D.; Lillard, D.; Eitenmiller, R. Antioxidants. In *Food Lipids*, 2nd ed.; Akoh, C., Min, D., Eds.; Marcel Dekker, Inc.: New York, NY, USA, 2002; pp. 507–535.
15. Eidhin, D.N.; Burke, J.; O'Beirne, D. Oxidative Stability of Ω3-Rich Camelina Oil and Camelina Oil-Based Spread Compared with Plant and Fish Oils and Sunflower Spread. *J. Food Sci.* **2003**, *68*, 345–353. [CrossRef]
16. Rastogi, A.; Yadav, D.K.; Szymańska, R.; Kruk, J.; Sedlářová, M.; Pospíšil, P. Singlet Oxygen Scavenging Activity of Tocopherol and Plastochromanol in *Arabidopsis Thaliana*: Relevance to Photooxidative Stress: $^1O_2$ Scavenging by Tocopherol and Plastochromanol. *Plant Cell Environ.* **2014**, *37*, 392–401. [CrossRef]
17. Mordi, R.C.; Ademosun, O.T.; Ajanaku, C.O.; Olanrewaju, I.O.; Walton, J.C. Free Radical Mediated Oxidative Degradation of Carotenes and Xanthophylls. *Molecules* **2020**, *25*, 1038. [CrossRef]

18. Pop, R.M.; Weesepoel, Y.; Socaciu, C.; Pintea, A.; Vincken, J.-P.; Gruppen, H. Carotenoid Composition of Berries and Leaves from Six Romanian Sea Buckthorn (*Hippophae rhamnoides* L.) Varieties. *Food Chem.* **2014**, *147*, 1–9. [CrossRef] [PubMed]
19. Criste, A.; Urcan, A.C.; Bunea, A.; Pripon Furtuna, F.R.; Olah, N.K.; Madden, R.H.; Corcionivoschi, N. Phytochemical Composition and Biological Activity of Berries and Leaves from Four Romanian Sea Buckthorn (*Hippophae rhamnoides* L.) Varieties. *Molecules* **2020**, *25*, 1170. [CrossRef]
20. Ghendov-Mosanu, A.; Cristea, E.; Patras, A.; Sturza, R.; Padureanu, S.; Deseatnicova, O.; Turculet, N.; Boestean, O.; Niculaua, M. Potential Application of *Hippophae rhamnoides* in Wheat Bread Production. *Molecules* **2020**, *25*, 1272. [CrossRef]
21. Skrypnik, L.; Chupakhina, G.; Feduraev, P.; Nataliia, C.; Maslennikov, P. Evaluation of the rose hips of *Rosa canina* L. and *Rosa rugosa Thunb.* as a valuable source of biological active compounds and antioxidants on the baltic sea coast. *Pol. J. Nat. Sci.* **2019**, *34*, 395–413.
22. Jiménez, S.; Jiménez-Moreno, N.; Luquin, A.; Laguna, M.; Rodríguez-Yoldi, M.J.; Ancín-Azpilicueta, C. Chemical Composition of Rosehips from Different *Rosa* Species: An Alternative Source of Antioxidants for the Food Industry. *Food Addit. Contam. Part A* **2017**, *34*, 1121–1130. [CrossRef] [PubMed]
23. Velasco, J.; Andersen, M.L.; Skibsted, L.H. Evaluation of Oxidative Stability of Vegetable Oils by Monitoring the Tendency to Radical Formation. A Comparison of Electron Spin Resonance Spectroscopy with the Rancimat Method and Differential Scanning Calorimetry. *Food Chem.* **2004**, *85*, 623–632. [CrossRef]
24. Miyazawa, T. Lipid hydroperoxides in nutrition, health, and diseases. *Proc. Jpn. Acad. Ser. B Phys. Biol. Sci.* **2021**, *97*, 161–196. [CrossRef] [PubMed]
25. Nawar, W.W. Thermal Degradation of Lipids. *J. Agric. Food Chem.* **1969**, *17*, 18–21. [CrossRef]
26. Frankel, E.N.; Selke, E.; Neff, W.E.; Miyashita, K. Autoxidation of Polyunsaturated Triacylglycerols. IV. Volatile Decomposition Products from Triacylglycerols Containing Linoleate and Linolenate. *Lipids* **1992**, *27*, 442–446. [CrossRef]
27. Choe, E.; Min, D.B. Mechanisms and Factors for Edible Oil Oxidation. *Comp. Rev. Food Sci. Food Saf.* **2006**, *5*, 169–186. [CrossRef]
28. Vichi, S.; Romero, A.; Tous, J.; Tamames, E.L.; Buxaderas, S. Determination of Volatile Phenols in Virgin Olive Oils and Their Sensory Significance. *J. Chromatogr. A* **2008**, *1211*, 1–7. [CrossRef]
29. Xu, L.; Yu, X.; Li, M.; Chen, J.; Wang, X. Monitoring Oxidative Stability and Changes in Key Volatile Compounds in Edible Oils during Ambient Storage through HS-SPME/GC–MS. *Int. J. Food Prop.* **2017**, *20*, S2926–S2938. [CrossRef]
30. Frankel, E. Chemistry of Autoxidation: Mechanism, Products and Flavor Significance. In *Flavor Chemistry of Fats and Oils*; Min, D.B., Smouse, T.H., Eds.; American Oil Chemists' Society: Champaign, IL, USA, 1985; pp. 1–37.
31. Kiokias, S.; Varzakas, T.H.; Arvanitoyannis, I.S.; Labropoulos, A.E. Lipid Oxidation and Control of Oxidation. In *Advances in Food Biochemistry*; Yildiz, F., Ed.; CRC Press, Taylor & Francis Group: New York, NY, USA, 2010; 507p.
32. Beutner, S.; Bloedorn, B.; Frixel, S.; Hernández Blanco, I.; Hoffmann, T.; Martin, H.-D.; Mayer, B.; Noack, P.; Ruck, C.; Schmidt, M.; et al. Quantitative Assessment of Antioxidant Properties of Natural Colorants and Phytochemicals: Carotenoids, Flavonoids, Phenols and Indigoids. The Role of β-Carotene in Antioxidant Functions: Antioxidant Properties of Natural Colorants and Phytochemicals. *J. Sci. Food Agric.* **2001**, *81*, 559–568. [CrossRef]
33. Rodriguez-Amaya, D. *Food Carotenoids: Chemistry, Biology and Technology*; IFT Press: Chichester, UK; Wiley Blackwell: Hoboken, NJ, USA, 2016; 327p.
34. Wang, C.C.; Chang, S.C.; Inbaraj, B.S.; Chen, B.H. Isolation of Carotenoids, Flavonoids and Polysaccharides from *Lycium barbarum* L. and Evaluation of Antioxidant Activity. *Food Chem.* **2010**, *120*, 184–192. [CrossRef]
35. Rodriguez-Amaya, D.B. *A Guide to Carotenoid Analysis in Foods*; ILSI Press: Washington, DC, USA, 2001; 71p.
36. Popovici, V.; Ghendov-Mosanu, A.; Patraş, A.; Deseatnicova, O.; Sturza, R. Process for producing functional sauce. *Off. Bull. Intellect. Prop. (BOPI)* **2022**, *5*, 62–63.
37. GD No. 434 from 27.05.2010 for the Approval of the Requirements Regarding the Approval of the Technical Regulations Edible Vegetable Oils. Available online: https://www.legis.md/cautare/getResults?doc_id=86300&lang=ro (accessed on 5 January 2023). (In Romanian).
38. Kallio, H.; Yang, B.; Peippo, P. Effects of different origins and harvesting time on vitamin C, tocopherols, and tocotrienols in sea buckthorn (*Hippophae rhamnoides*) berries. *J. Agric. Food Chem.* **2002**, *50*, 6136–6142. [CrossRef] [PubMed]
39. Andersson, S.C.; Rumpunen, K.; Johansson, E.; Ollson, M.E. Tocopherols and Tocotrienols in Sea Buckthorn (*Hippophae rhamnoides* L.) Berries during Ripening. *J. Agric. Food Chem.* **2008**, *56*, 6701–6706. [CrossRef] [PubMed]
40. Barros, L.; Carvalho, A.M.; Ferreira, I. Exotic fruits as a source of important phytochemicals: Improving the traditional use of Rosa canina fruits in Portugal. *Food Res. Int.* **2011**, *44*, 2233–2236. [CrossRef]
41. Barouh, N.; Bourlieu-Lacanal, C.; Figueroa-Espinoza, M.C.; Durand, E.; Villeneuve, P. Tocopherols as antioxidants in lipid-based systems: The combination of chemical and physicochemical interactions determines their efficiency. *Compr. Rev. Food Sci. Food Saf.* **2022**, *41*, 642–688. [CrossRef] [PubMed]
42. Giuffrida, D.; Pintea, A.; Dugo, P.; Torre, G.; Pop, R.M.; Mondello, L. Determination of Carotenoids and Their Esters in Fruits of Sea Buckthorn (*Hippophae rhamnoides* L.) by HPLC-DAD-APCI-MS: Native Carotenoids Composition in Sea Buckthorn Berries. *Phytochem. Anal.* **2012**, *23*, 267–273. [CrossRef] [PubMed]
43. Ciuperca, O.T.; Tebrencu, E.; Volf, I. Polyphenolic content evaluation in branches of *Rosa canina* L. and *Hippophae rhamnoides* L. species. *Bull. Polytech. Inst. Iasi* **2017**, *63*, 49–58.

44. Poiana, M.-A.; Alexa, E.; Munteanu, M.-F.; Gligor, R.; Moigradean, D.; Mateescu, C. Use of ATR-FTIR Spectroscopy to Detect the Changesin Extra Virgin Olive Oil by Adulteration Withsoybean Oil and High Temperature Heat Treatment. *Open Chem.* **2015**, *13*, 689–698. [CrossRef]
45. Machate, D.J.; Melo, E.S.P.; de Oliveira, L.C.S.; Bogo, D.; Michels, F.S.; Pott, A.; Cavalheiro, L.F.; Guimarães, R.d.C.A.; Freitas, K.d.C.; do Hiane, P.A.; et al. Oxidative Stability and Elemental Analysis of Sunflower (*Helianthus Annuus*) Edible Oil Produced in Brazil Using a Domestic Extraction Machine. *Front. Nutr.* **2022**, *9*, 977813. [CrossRef]
46. Sturza, R.; Druţă, R.; Covaci, E.; Duca, G.; Subotin, I. Mechanisms of sunflower oil transforming into forced thermal oxidation processes. *J. Eng. Sci.* **2020**, *47*, 239–251. [CrossRef]
47. Kaminskas, A.; Briedis, V.; Budrionienë, R.; Hendrixson, V. Fatty Acid Composition of Sea Buckthorn (*Hippophae rhamnoides* L.) Pulp Oil of Lithuanian Origin Stored at Different Temperatures. *Biologija* **2006**, *2*, 39–41.
48. Pénicaud, C.; Achir, N.; Dhuique-Mayer, C.; Dornier, M.; Bohuon, P. Degradation of β-Carotene during Fruit and Vegetable Processing or Storage: Reaction Mechanisms and Kinetic Aspects: A Review. *Fruits* **2011**, *66*, 417–440. [CrossRef]
49. Delgado-Vargas, F.; Jiménez, A.R.; Paredes-López, O. Natural Pigments: Carotenoids, Anthocyanins, and Betalains—Characteristics, Biosynthesis, Processing, and Stability. *Crit. Rev. Food Sci. Nutr.* **2000**, *40*, 173–289. [CrossRef] [PubMed]
50. Yanishlieva, N.V.; Marinova, E.M. Stabilisation of Edible Oils with Natural Antioxidants. *Eur. J. Lipid Sci. Technol.* **2001**, *103*, 752–767. [CrossRef]
51. Crapiste, G.H.; Brevedan, M.I.V.; Carelli, A.A. Oxidation of Sunflower Oil during Storage. *J. Am. Oil Chem. Soc.* **1999**, *76*, 1437–1443. [CrossRef]
52. Qiu, W.; Jiang, H.; Wang, H.; Gao, Y. Effect of High Hydrostatic Pressure on Lycopene Stability. *Food Chem.* **2006**, *97*, 516–523. [CrossRef]
53. Odriozola-Serrano, I.; Soliva-Fortuny, R.; Martín-Belloso, O. Changes of Health-Related Compounds throughout Cold Storage of Tomato Juice Stabilized by Thermal or High Intensity Pulsed Electric Field Treatments. *Innov. Food Sci. Emerg. Technol.* **2008**, *9*, 272–279. [CrossRef]
54. Schweiggert, R.M.; Kopec, R.E.; Villalobos-Gutierrez, M.G.; Högel, J.; Quesada, S.; Esquivel, P.; Schwartz, S.J.; Carle, R. Carotenoids Are More Bioavailable from Papaya than from Tomato and Carrot in Humans: A Randomised Cross-over Study. *Br. J. Nutr.* **2014**, *111*, 490–498. [CrossRef]
55. Ghendov-Mosanu, A.; Sturza, R.; Chereches, T.; Patras, A. A Fuzzy Logic Approach to Modeling of the Extraction Process of Bioactive Compounds. *J. Eng. Sci.* **2019**, *3*, 89–99. [CrossRef]
56. Popescu, L.; Cesco, T.; Gurev, A.; Ghendov-Mosanu, A.; Sturza, R.; Tarna, R. Impact of Apple Pomace Powder on the Bioactivity, and the Sensory and Textural Characteristics of Yogurt. *Foods* **2022**, *11*, 3565. [CrossRef]
57. Bulgaru, V.; Popescu, L.; Netreba, N.; Ghendov-Mosanu, A.; Sturza, R. Assessment of Quality Indices and Their Influence on the Texture Profile in the Dry-Aging Process of Beef. *Foods* **2022**, *11*, 1526. [CrossRef] [PubMed]
58. Akbarzadeh, A.; Rezaei-Sadabady, R.; Davaran, S.; Joo, S.W.; Zarghami, N.; Hanifehpour, Y.; Samiei, M.; Kouhi, M.; Nejati-Koshki, K. Liposome: Classification, Preparation, and Applications. *Nanoscale Res. Lett.* **2013**, *8*, 102. [CrossRef] [PubMed]
59. Kucharski, H.; Zajac, J. (Eds.) *Handbook of Vitamin C Research: Daily Requirements, Dietary Sources and Adverse Effects*; Nutrition and diet research progress series; Nova Biomedical Books: New York, NY, USA, 2009; 415p.
60. Liu, X. Progress in the Mechanism and Kinetics of Fenton Reaction. *MOJ Ecol. Environ. Sci.* **2018**, *3*, 10–14. [CrossRef]
61. Timoshnikov, V.A.; Kobzeva, T.V.; Polyakov, N.E.; Kontoghiorghes, G.J. Redox Interactions of Vitamin C and Iron: Inhibition of the Pro-Oxidant Activity by Deferiprone. *Int. J. Mol. Sci.* **2020**, *21*, 3967. [CrossRef] [PubMed]
62. Zhang, D.; Gong, C.; Wang, J.; Mu, C.; Wang, W.; Zhang, X. Beyond Lipid Peroxidation: Distinct Mechanisms Observed for POPC and POPG Oxidation Initiated by UV-enhanced Fenton Reactions at the Air–Water Interface. *J. Mass Spectrom.* **2021**, *56*, e4626. [CrossRef]
63. Ayala, A.; Muñoz, M.F.; Argüelles, S. Lipid Peroxidation: Production, Metabolism, and Signaling Mechanisms of Malondialdehyde and 4-Hydroxy-2-Nonenal. *Oxid. Med. Cell. Longev.* **2014**, *2014*, 1–31. [CrossRef]
64. Zielinski, Z.A.M.; Pratt, D.A. Lipid Peroxidation: Kinetics, Mechanisms, and Products. *J. Org. Chem.* **2017**, *82*, 2817–2825. [CrossRef]
65. Britton, S.; Liaaen-Jenson, S.; Pfander, H. *Carotenoids*; Birkhauser Verlag: Basel, Switzerland, 1995; Volume 1A, pp. 210–214.
66. Ghendov-Mosanu, A. Obtaining and Stabilizing Dyes, Antioxidants and Preservatives of Plant Origin for Functional Foods. Ph.D. Thesis, Technical University of Moldova, Chisinau, Moldova, 2021.
67. Brand-Williams, W.; Cuvelier, M.E.; Berset, C. Use of a Free Radical Method to Evaluate Antioxidant Activity. *LWT-Food Sci. Technol.* **1995**, *28*, 25–30. [CrossRef]
68. AOCS. *Official Method Cd 3d-63, Acid Value of Fats and Oils*, 7th ed.; AOCS: Urbana, IL, USA, 1999.
69. AOCS. *Official Method 8-53, Peroxide Value-Acetic Acid-Chloroform Method*, 7th ed.; AOCS: Urbana, IL, USA, 2003.
70. AOCS. *Official Method Cd 18-90, p-Anisidine Value*, 7th ed.; AOCS: Urbana, IL, USA, 2017.
71. AOCS. *Official Method Cd 7-58, Polyunsaturated Acids, Ultraviolet Spectrophotometric Method*, 7th ed.; AOCS: Urbana, IL, USA, 2022.
72. Biehler, E.; Mayer, F.; Hoffmann, L.; Krause, E.; Bohn, T. Comparison of 3 Spectrophotometric Methods for Carotenoid Determination in Frequently Consumed Fruits and Vegetables. *J. Food Sci.* **2010**, *75*, C55–C61. [CrossRef]

73. Tesfaye, B.; Abebaw, A.; Reddy, M.U. Determination of Cholesterol and β-Carotene Content in Some Selected Edible Oils. *Int. J. Innov. Sci. Res. Technol.* **2017**, *2*, 14–18.
74. Paninski, L. Estimation of Entropy and Mutual Information. *Neural Comput.* **2003**, *15*, 1191–1253. [CrossRef]