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Ultrasound- and Microwave-Assisted Extraction of Pectin from Apple Pomace and Its Effect on the Quality of Fruit Bars

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Abstract: The article investigates the process of pectin extraction using ultrasonic and microwave techniques from apple pomace generated during juice production in the context of circular bioeconomy. The extraction yield, equivalent mass, content of methoxyl groups, content of anhydrogalacturonic acid, and degree of esterification of pectin were investigated. These indicators varied depending on the parameters and extraction method. The resulting pectin displayed a co-extracted total polyphenol content (TPC) ranging from 2.16 to 13.05 mg GAE/g DW and a DPPH radical inhibition capacity of 4.32–18.86 µmol TE/g. It was found that the antioxidant activity of raw pectin is correlated with TPC and with the content of terminal groups released during the polysaccharide degradation process. The extracted pectin was used as a binding and coating agent for dried fruit bars. Evaluation of water activity (a_w), TPC and total flavonoid content (TFC), together with sensory and microbiological analyses of the fruit bars over a period of 360 days, revealed a protective effect of pectin: reducing moisture loss, minimizing the degradation of bioactive compounds during storage, and maintaining the potential antioxidant activity of the product.

Keywords: apple pectin; ultrasound; microwave; extraction; phenolic content; antioxidant effect; biopolymer coating; dried fruits; quality

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1. Introduction

Apples are some of the most widespread fruits, with multiple benefits for the consumer’s health. In the Republic of Moldova, in 2017, apple production reached 430,000 tons from a total orchard area of 56,000 hectares. It was forecasted that the cultivated area for apple trees would increase by 52,400 hectares during the period of 2017–2027, resulting in a total apple production of 793,000 tons [1]. Significant amounts of apple pomace (globally, 4 million tons/year) are produced as a byproduct during the processing of apples for jams, juices, and fermented products. Despite the fact that apple pomace is primarily used as animal feed or fertilizer, it is a substantial source of functional components such as carbohydrates, dietary fibers (including pectin), phenolic compounds, and others [2]. The pectin derived from apple pomace is used in the pharmaceutical, food, cosmetic, and other industries, where it serves as a biopolymer, preservative, antioxidant, anticorrosive agent, protective agent for diverse surfaces, etc. [2,3]. Fibers obtained from fruits offer an advantage over cereal fibers due to their superior solubility, lower phytic acid content, and the presence of bioactive molecules associated with antioxidant activity [4]. Pectin is industrially obtained from apple pomace through conventional extraction (CE) methods, such as using hot acidified water with either mineral acids (sulfuric, hydrochloric, nitric) or organic acids (citric, malic, oxalic) from pH 1.5 to 3.0 and temperatures ranging from 60 to 100 °C for 0.5 to 6 h, followed by alcoholic precipitation [2,5,6]. The cost-effectiveness and optimization of pectin extraction can be improved through application of unconventional extraction techniques such as the microwave-assisted extraction (MAE) [7], ultrasound-assisted extraction (UAE) [8,9], pulsed electric field extraction [10], subcritical water extraction [11], enzyme-assisted extraction [12], as well as combinations of different extraction methods [13–15]. The sustainability of unconventional methods such as UAE and MAE were proved, as the methods exhibit reduced energy and reagent consumption, shorter processing times (15–30 min as opposed to 1–3 h), and improved quality and yield of the final product compared to conventional methods [16–18].

Several studies have confirmed that the antioxidant activity (AA) of pectin is influenced by the structure and composition of its chains, as well as by the presence of co-extracted contaminants in the polysaccharide matrix, which are associated with polyphenols, proteins, and other antioxidants [19–22]. Apple pectin, depending on its concentration, exhibited an approximately 5-fold greater DPPH radical-scavenging effect compared to other polysaccharides [23].

The pectin extraction method also influences AA. Pectin obtained by unconventional methods from various sources, with lower degree of esterification (DE) and higher anhydrogalacturonic acid (AUA) content, exhibits a higher AA compared to pectin extracted through CE [11,24,25]. Wang et al. [26] reported that pectic polysaccharides extracted with hot-compressed water from apple pomace showed in vitro AA and an inhibitory effect on free radicals. The IC_{50} values of such pectin oscillated between 1.4–3.5 mg/mL for 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging and about 1 mg/mL for 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS).

Recent studies have shown that modified pectin obtained through unconventional methods displays different structural features [26–28]. It contains a higher amount of galactoside residues compared to xylan and arabinan [28] and shows more advanced radical-scavenging and anticancer activities compared to native pectin and pectin extracted through conventional methods [29,30]. Hydrolytic degradation of polysaccharides during unconventional extraction is accompanied by the formation of several reducing terminal groups, respectively, by the improvement of the antioxidant potential of pectin [29,30].

The DE of pectin also influences its AA due to its ability to chelate heavy metal ions [31,32]. A study on the influence of modified citrus pectin on the oxidative stability of flaxseed/sunflower emulsions confirmed that low-methoxyl pectin (DE of 33%) exhibited a higher lipid antioxidant potential compared to high-methoxyl pectin (DE of 58%) [33].

Multiple research studies have shown the positive influence of pectin on health status [2,3,6,27]. Pectin has probiotic properties and contributes to the proper functioning of the intestine, as it retains water and various waste substances, facilitating the elimination of toxins and protecting the colon's mucus membrane [31,34]. Pectin can bind and remove heavy metals from the body [31,32,34] and lower the cholesterol level [34,35] and serum glucose level [36]. Additionally, it has the capacity to capture free radicals and reduce the risk of cancer [37]. Pectic polysaccharides reduce inflammation, have antibacterial properties [38], and stimulate the immune response [39].

Pectin is used in the food industry as a thickening additive; it acts as a protective and stabilizing colloid in food and beverages. Pectin with a DE > 50% (high-methoxyl pectin—HM) forms a gel in solutions with a high concentration of sugar or solid substances, at a pH lower than 3.5. This is applied in the production of jams and jellies, fruit fillings, desserts, etc. [3]. Pectin with a DE less than 50% (low-methoxyl pectin—LM) forms a gel in a wide pH range (2.0–6.0), in the presence of calcium ions or other multivalent cations. It is used in the production of dietetic dairy products, soy-based products, etc. [40]. Other properties associated with pectin are: protein stabilization, softness in texture, increase in volume, and syneresis control in low-calorie foods [4,6,41].

Studies conducted in recent years have highlighted the sustainability of using pectin for the formulation and preservation of functional foods and encapsulation of bioactive compounds [42]. The production of edible coatings based on pectin and other biodegradable polymers is encouraged by the United States Environmental Protection Agency (US EPA) program to minimize packaging waste. Pectin-based nanoemulsions play an important role in creating a new generation of active packaging with health benefits [43]. Pectin-based films are biodegradable and possess excellent mechanical properties, providing the possibility to extend the shelf life of packaged foods [44,45], control moisture loss, and reduce the degradation of bioactive compounds during storage [46,47].

The objective of this study was to examine the impact of unconventional extraction methods, such as ultrasound-assisted extraction (UAE) and microwave-assisted extraction (MAE), on the yield, properties, and antioxidant activity of raw pectin extracted from apple pomace. The study also aimed to assess the potential of pectin as a binding and coating agent in the production of dried fruit bars; the protective effect of pectin films on functional products during storage was also investigated.

References

1. The Study "Internal and External Analysis of the Fruit Production Sector in the Republic of Moldova". Available online: http://madrm.gov.md/sites/default/files/Documente%20atasate%20Advance%20Pagines/Studiu%20Sector%20Pomicol%20RM%20-%20%20APM_FARM%20final.pdf (accessed on 2 March 2023). (In Romanian)
2. Gołębiewska, E.; Kalinowska, M.; Yildiz, G. Sustainable Use of Apple Pomace (AP) in Different Industrial Sectors. *Materials* **2022**, *15*, 1788. [CrossRef]
3. Freitas, C.M.P.; Coimbra, J.S.R.; Souza, V.G.L.; Sousa, R.C.S. Structure and Applications of Pectin in Food, Biomedical, and Pharmaceutical Industry: A Review. *Coatings* **2021**, *11*, 922. [CrossRef]
4. Vergara-Valencia, N.; Granados-Perez, E.; Agama-Acevedo, E.; Tovar, J.; Ruales, J.; Bello-Péreza, L.A. Fibre concentrate from mango fruit: Characteri-zation, associated antioxidant capacity and application as a bakery productingredient. *LWT Food Sci. Technol.* **2007**, *40*, 722–729. [CrossRef]
5. Wicker, L.; Kim, Y.; Kim, M.J.; Thirkield, B.; Lin, Z.; Jung, J. Pectin as a bioactive polysaccharide extracting tailored function from less. *Food Hydrocoll.* **2014**, *42*, 251–259. [CrossRef]
6. Belkheiri, A.; Forouhar, A.; Ursu, A.V.; Dubessay, P.; Pierre, G.; Delattre, C.; Djelveh, G.h.; Abdelkafi, S.; Hamdam, N.; Michaud, P. Extraction, Characterization, and Applications of Pectins from Plant By-Products. *Appl. Sci.* **2021**, *11*, 6596. [CrossRef]
7. Arrutia, F.; Adam, M.; Calvo-Carrascal, M.Á.; Mao, Y.; Binner, E. Development of a continuous-flow system for microwaveassisted extraction of pectin-derived oligosaccharides from food waste. *Chem. Eng. J.* **2020**, *395*, 125056. [CrossRef]
8. Ponmurugan, K.; Al-Dhabi, N.A.; Maran, J.P.; Karthikeyan, K.; Moothy, I.G.; Sivarajasekar, N.; Manoj, J.J.B. Ultrasound assisted pectic polysaccharide extraction and its caracterization from waste heads of *Helianthus annus*. *Carbohydr. Polym.* **2017**, *173*, 707–713. [CrossRef]
9. Zhang, L.; Xinqian, Y.; Ding, T.; Sun, X.; Xu, Y.; Liu, D. Ultrasound effects on the degradation kinetics, structure and rheological properties of apple pectin. *Ultrason. Sonochem.* **2013**, *20*, 222–231. [CrossRef]
10. Vorobiev, E.; Lebovka, N. Pulse Eletric Field-Assisted Extraction. In *Enhancing Extraction Processes in the Food Industry*; CRC Press: Boca Raton, FL, USA, 2016; pp. 25–84.
11. Wang, X.; Chen, Q.; L¨u, X. Pectin extracted from apple pomace and citrus peel by subcritical water. *Food Hydrocoll.* **2014**, *38*, 129–137. [CrossRef]
12. Calvete-Torre, I.; Muñoz-Almagro, N.; Pacheco, M.T.; Ant´on, M.J.; Dapena, E.; Ruiz, L.; Margolles, A.; Villamiel, M.; Moreno, F.J. Apple pomaces derived from mono-varietal Asturian ciders production are potential source of pectins with appealing functional properties. *Carbohyd. Polym.* **2021**, *264*, 117980. [CrossRef]
13. Gharibzahedi, S.M.T.; Smith, B.; Guo, Y. Ultrasound-microwave assisted extraction of pectin from fig (*Ficus carica* L.) skin: Optimization, characterization and bioactivity. *Carb. Polym.* **2019**, *222*, 114992. [CrossRef]
14. Abou-Elseoud, W.S.; Hassan, E.A.; Hassan, M.L. Extraction of pectin from sugar beet pulp by enzymatic and ultrasound-assisted treatments. *Carbohydr. Polym. Technol. Appl.* **2021**, *2*, 100042. [CrossRef]
15. Liew, S.Q.; Ngoh, G.C.; Yusoff, R.; Teoh, W.H. Sequential ultrasound-microwave assisted acid extraction (UMAE) of pectin from pomelo peels. *Int. J. Biol. Macromol.* **2016**, *93*, 426–435. [CrossRef]
16. Wang, S.; Chen, F.; Wu, J.; Wang, Z.; Liao, X.; Hu, X. Optimization of pectin extraction assisted by microwave from apple pomace using response surface methodology. *J. Food Eng.* **2007**, *78*, 693–700. [CrossRef]
17. Rodsamran, P.; Sothornvit, R. Microwave heating extraction of pectin from lime peel: Characterization and properties compared with the conventional heating method. *Food Chem.* **2019**, *278*, 364–372. [CrossRef]
18. Muñoz-Almagro, N.; Montilla, A.; Moreno, F.J.; Villamiel, M. Modification of citrus and apple pectin by power ultrasound: Effects of acid and enzymatic treatment. *Ultrason. Sonochem.* **2017**, *38*, 807–819. [CrossRef]
19. Wikiera, A.; Kozioł, A.; Mika, M.; Stodolak, B. Structure and bioactivity of apple pectin isolated with arabinanase and mannanase. *Food Chem.* **2022**, *388*, 133020. [CrossRef]
20. Smirnov, V.V.; Golovchenko, V.V.; Vityazev, F.V.; Patova, O.A.; Selivanov, N.Y.; Selivanova, O.G.; Popov, S.V. The Antioxidant Properties of Pectin Fractions Isolated from Fruits Using a Simulated Gastric Fluid. *J. Chem.* **2017**, *2017*, 5898594. [CrossRef]
21. Karbuz, P.; Tugrul, N. Microwave and ultrasound assisted extraction of pectin from various fruits. *J. Food Sci. Technol.* **2021**, *58*, 641–650. [CrossRef] [PubMed]
22. Qadir, S.; Abidi, S.; Azhar, I.; Alam Mahmood, Z. Antioxidant activity and cytotoxicity of pectin extracted from orange peels. *Pak. J. Pharm.* **2019**, *36*, 15–24.
23. Ro, J.; Kim, Y.; Kim, H.; Jang, S.B.; Lee, H.J.; Chakma, S.; Jeong, J.H.; Lee, J. Anti-Oxidative Activity of Pectin and Its Stabilizing Effect on Retinyl Palmtiate. *Coreian Physiol. Pharmacol.* **2013**, *17*, 197–201.
24. Chen, R.; Jin, C.; Tong, Z.; Lu, J.; Tan, L.; Tian, L.; Chang, Q. Optimization extraction, characterization and antioxidant activities of pectic polysaccharide from tangerine peels. *Carbohydr. Polym.* **2016**, *136*, 187–197. [CrossRef]
25. Ogutu, F.O.; Mu, T.H. Ultrasonic degradation of sweet potato pectin and its antioxidant activity. *Ultrason. Sonochem.* **2017**, *38*, 726–734. [CrossRef] [PubMed]
26. Wang, X.; Lü, X. Characterization of pectic polysaccharides extracted from apple pomace by hot-compressed water. *Carbohydr. Polym.* **2014**, *102*, 174–184. [CrossRef] [PubMed]
27. Zhang, W.; Xu, P.; Zhang, H. Pectin in cancer therapy: A review. *Trends Food Sci. Technol.* **2015**, *44*, 258–271. [CrossRef]

28. Zhang, T.; Shuai, M.; Ma, P.; Huang, J.; Sun, C.h.; Yao, X.; Chen, Z.; Min, X.; Yan, S. Purification, chemical analysis and antioxidative activity of polysaccharides from pH-modified citrus pectin after dialyzation. *LWT* **2020**, *128*, 109513. [CrossRef]
29. Leclere, L.; Van Cutsem, P.; Michiels, C. Anti-cancer activities of pH-or heat-modified pectin. *Front. Pharm.* **2013**, *4*, 128. [CrossRef]
30. Wang, J.; Hu, S.h.; Nie, S.h.; Yu, Q.; Xie, M. Reviews on echanisms of In Vitro Antioxidant Activity of Polysaccharides. *Oxidative Med. Cell. Longev.* **2016**, *64*, 5692852.
31. Celus, M.; Kyomugasho, C.; van Loey, A.M.; Grauwet, T.; Hendrickx, M.E. Influence of pectin structural properties on interactions with divalent cations and its associated functionalities. *Compr. Rev. Food Sci. Food Saf.* **2018**, *17*, 1576–1594. [CrossRef]
32. Mahmoud, M.E.; Mohamed, A.K. Novel derived pectin hydrogel from mandarin peel based metal-organic frameworks composite for enhanced Cr(VI) and Pb(II) ions removal. *Int. J. Biol. Macromol.* **2020**, *164*, 920–931. [CrossRef]
33. Celus, M.; Salvia-Trujillo, L.; Kyomugasho, C.; Maes, I.; Van Loey, A.M.; Grauwet, T.; Hendrickx, M.E. Structurally modified pectin for targeted lipid antioxidant capacity in linseed/sunflower oil-in-water emulsions. *Food Chem.* **2018**, *241*, 86–96. [CrossRef] [PubMed]
34. McCann, M.J.; Gill, C.I.R.; Brien, G.; Rao, J.R.; McRoberts, W.C.; Hughes, P.; McEntee, R.; Rowland, I.R. Anti-cancer properties of phenolics from apple waste on colon carcinogenesis in vitro. *Food Chem. Toxicol.* **2007**, *45*, 1224–1230. [CrossRef] [PubMed]
35. Kumar, A.; Chauhan, G.S. Extraction and characterization of pectin from apple pomace and its evaluation as lipase (steapsin) inhibitor. *Carbohydr. Polym.* **2010**, *82*, 454–459. [CrossRef]
36. Ou, S.; Kwok, K.C.; Li, Y.; Fu, L. In vitro study of possible role of dietaryfibre in lowering postprandial serum glucose. *J. Agric. Food Chem.* **2001**, *49*, 1026–1029. [CrossRef] [PubMed]
37. Hosseini Abari, A.; Amini Rourani, H.; Ghasemi, S.M.; Kim, H.; Kim, Y.G. Investigation of antioxidant and anticancer activities of unsaturated oligo-galacturonic acids produced by pectinase of *Streptomyces hydrogenans* YAM1. *Sci. Rep.* **2021**, *11*, 8491. [CrossRef] [PubMed]
38. Minzanova, S.T.; Mironov, V.F.; Arkhipova, D.M.; Khabibullina, A.V.; Mironova, L.G.; Zakirova, Y.M.; Milyukov, V.A. Biological Activity and Pharmacological Application of Pectic Polysaccharides: A Review. *Polymers* **2018**, *10*, 1407. [CrossRef]
39. Popov, S.V.; Ovodov, Y.S. Polypotency of the immunomodulatory effect of pectins. *Biochemistry* **2013**, *78*, 823–835. [CrossRef]
40. Lootens, D.; Capel, F.; Durand, D.; Nicolai, T.; Boulenguer, P.; Langendorff, V. Influence of pH, Ca concentration, temperature and amidation on the gelation of low methoxyl pectin. *Food Hydrocoll.* **2003**, *17*, 237–244. [CrossRef]
41. Chandel, V.; Biswas, D.; Roy, S.; Vaidya, D.; Verma, A.; Gupta, A. Current Advancements in Pectin: Extraction, Properties and Multifunctional Applications. *Foods* **2022**, *11*, 2683. [CrossRef]
42. Lee, Y.; Yoon, Y.R.K.; Chang, H. Effect of pectic oligosaccharide on probiotic survival and physicochemical properties of hydrogel beads for synbiotic encapsulation of *Lactobacillus bulgaricus*. *Food Biosci.* **2023**, *51*, 102260. [CrossRef]
43. Rehman, A.; Ahmad Rana, T.; Aadil Maria, M.; Spotti Amr, J.; Bakry Imran, M.; Khan, M.; Zhao, L.; Riaz, T.; Tong, Q. Pectin polymers as wall materials for the nano-encapsulation of bioactive compounds. *Trends Food Sci. Technol.* **2019**, *90*, 35–46. [CrossRef]
44. Rohasmizah, H.; Azizah, M. Pectin-based edible coatings and nanoemulsion for the preservation of fruits and fruits: A review. *Appl. Food Res.* **2022**, *2*, 100221. [CrossRef]
45. Mendes, J.F.; Norcino, L.B.; Manrich, A.; Pinheiro, A.C.M.; Oliveira, J.E.; Mattoso, L.H.C. Characterization of pectin films integrated with cocoa butter by continuous casting: Physical, thermal and barrier properties. *J. Polym. Environ.* **2020**, *28*, 2905–2917. [CrossRef]
46. Eça, K.S.; Machado, M.T.C.; Hubinger, M.D.; Menegalli, F.C. Development of active films from pectin and fruit extracts: Light protection, antioxidant capacity, and compounds stability. *J. Food Sci.* **2015**, *80*, 2389–2396. [CrossRef]
47. Muñoz-Labrador, A.; Moreno, R.; Villamiel, M.; Montilla, A. Preparation of citrus pectin gels by power ultrasound and its application as an edible coating in strawberries. *J. Sci. Food Agric.* **2018**, *98*, 4866–4875. [CrossRef] [PubMed]
48. *ISO 750:1998*; Fruit and Fruit Products—Determination of Titratable Acidity. International Organization for Standardization: Geneva, Switzerland, 1998.
49. Nollet, L.M.L. *Handbook of Food Analysis*, 2nd ed.; Dekker, M., Ed.; CRC Press: Boca Raton, FL, USA, 2004; p. 912.
50. *ISO 659:2009*; Oilseeds—Determination of Oil Content (Reference Method). International Organization for Standardization: Geneva, Switzerland, 2009.
51. *ISO 20483:2013*; Cereals and Pulses—Determination of the Nitrogen Content and Calculation of the Crude Protein Content—Kjeldahl Method. International Organization for Standardization: Geneva, Switzerland, 2013.
52. *AOAC 985.29*; Total Dietary Fibre in Foods. Enzymatic-Gravimetric Method. Official Methods of Analysis. 14th ed. Association of Official Analytical Chemists: Washington, DC, USA, 1985.
53. *AOAC 991.42*; Insoluble Dietary Fibre in Foods and Food Products. Enzymatic-Gravimetric Method. Official Methods of Analysis. 14th ed. Association of Official Analytical Chemists: Washington, DC, USA, 1985.
54. Ranganna, S. *Handbook of Analysis and Quality Control of Fruit and Fruit Products*; Tata McGraw Hill Publishing Co., Ltd.: New Delhi, India, 1986; p. 1112.
55. Suhaila, M.; Zahariah, H. Extraction and characterisation of pectin from various tropical agrowastes. *ASEAN Food J.* **1995**, *2*, 43–50.
56. *ISO 8586:2012*; Sensory Analysis General Guidelines for the Selection, Training and Monitoring of Selected Assessors and Expert Sensory Assessors. Technical Committee, ISO/TC 34/SC 12 Sensory Analysis. International Organization for Standardization: Geneva, Switzerland, 2012.

57. *ISO 1842:1991*; Fruit and Vegetable Products—Determination of pH. Technical Committee ISO/TC 34/SC 3 Fruits and Vegetables and Their Derived Products. International Organization for Standardization: Geneva, Switzerland, 1991.
58. *ISO 1026:1982*; Fruit and Vegetable Products—Determination of Dry Matter Content by Drying under Reduced Pressure and of Water Content by Azeotropic Distillation. Technical Committee ISO/TC 34/SC 9 Microbiology. International Organization for Standardization: Geneva, Switzerland, 1982.
59. *ISO 21807:2004*; Microbiology of Food and Animal Feeding Stuffs—Determination of Water Activity. Technical Committee, ISO/TC 34/SC 9 Microbiology. International Organization for Standardization: Geneva, Switzerland, 2004.
60. *ISO 21149:2017*; Microbiology—Enumeration and Detection of Aerobic Mesophilic Bacteria. Technical Committee ISO/TC 217, Cosmetics. International Organization for Standardization: Geneva, Switzerland, 2017.
61. *ISO 21527-2:2008*; Microbiology of Food and Animal Feeding Stuffs—Horizontal Method for the Enumeration of Yeasts and Mould. Technical Committee ISO/TC 34, Food Products, Subcommittee SC 9, Microbiology. International Organization for Standardization: Geneva, Switzerland, 2008.
62. Popescu, L.; Cesço, 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] [PubMed]
63. Bouyahya, A.; Dakka, N.; Talbaoui, A.; Moussaoui, N.E.; Abrini, J.; Bakri, Y. Phenolic contents and antiradical capacity of fruit oil from *Pistacia lentiscus* (L.). *J. Mater. Environ. Sci.* **2018**, *9*, 1518–1524.
64. Singleton, V.; Rossi, J. Colorimetry of total phenolic compounds with phosphomolybdic-phosphotungstic acid reagents. *Am. J. Enol. Vitic.* **1965**, *16*, 144–158. [CrossRef]
65. Waterman, P.G.; Mole, S. *Analysis of Phenolic Plant Metabolites*; Blackwell Scientific Publication: Oxford, UK, 1994; p. 248.
66. 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]
67. Britton, G.; Liaaen, S.; Pfander, H.P. *Carotenoids, Vol. 1A: Isolation and Analysis*; Birkhauser Verlag: Basel, Switzerland, 1995; pp. 104–107.
68. Paulpriya, K.; Packia Lincy, M.; Tresina Soris, P.; Veerabahu Ramasamy, M. In vitro antioxidant activity, total phenolic and total flavonoid contents of aerial part extracts of Daphniphyllum neilgherrense (wt.) Rosenth. Ethnopharm. *J. Bio Innov.* **2015**, *4*, 257–268.
69. Paninski, L. Estimation of entropy and mutual information. *Neural Comput.* **2003**, *15*, 1191–1253. [CrossRef]
70. Zhang, T.; Wei, X.; Miao, Z.; Hassan, H.; Song, Y.; Fan, M. Screening for antioxidant and antibacterial activities of phenolics from Golden Delicious apple pomace. *Chem. Cent. J.* **2010**, *10*, 47. [CrossRef] [PubMed]
71. Krasnova, I.; Segliņa, D. Content of phenolic compounds and antioxidant activity in fresh apple, pomace and pomace water Extract—Effect of cultivar. *Proc. Latv. Acad. Sci.* **2019**, *73*, 513–518. [CrossRef]
72. Ćetković, G.; Čanadanović-Brunet, J.; Djilas, S.; Savatović, S.; Mandić, A.; Tumbas, V. Assessment of Polyphenolic Content and in Vitro Antiradical Characteristics of Apple Pomace. *Food Chem.* **2008**, *109*, 340–347. [CrossRef]
73. Radenkovs, V.; Kviesis, J.; Juhnevica-Radenkova, K.; Valdovska, A.; Püssa, T.; Klavins, M.; Drudze, I. Valorization of Wild Apple (*Malus* spp.) By-Products as a Source of Essential Fatty Acids, Tocopherols and Phytosterols with Antimicrobial Activity. *Plants* **2018**, *7*, 90. [CrossRef]
74. Gorjanović, S.; Micić, D.; Pastor, F.; Tosti, T.; Kalušević, A.; Ristić, S.; Zlatanović, S. Evaluation of Apple Pomace Flour Obtained Industrially by Dehydration as a Source of Biomolecules with Antioxidant, Antidiabetic and Antiobesity Effects. *Antioxidants* **2020**, *9*, 413. [CrossRef]
75. Dranca, F.; Oroian, M. Ultrasound-Assisted Extraction of Pectin from Malus domestica 'Falticeni' Apple Pomace. *Processes* **2019**, *7*, 488. [CrossRef]
76. Bagherian, H.; Zokaee Ashtiani, F.; Fouladitajar, A.; Mohtashamy, M. Comparisons between conventional, microwave- and ultrasound-assisted methods for extraction of pectin from grapefruit. *Chem. Eng. Process. Process Intensif.* **2011**, *50*, 1237–1243. [CrossRef]
77. Hosseini, S.S.; Khodaiyan, F.; Kazemi, M.; Najari, Z. Optimization and characterization of pectin extracted from sour orange peel by ultrasound assisted method. *Int. J. Biol. Macromol.* **2018**, *125*, 621–629. [CrossRef]
78. Dranca, F.; Vargas, M.; Oroıan, M. Physicochemical properties of pectin from Malus domestica 'Fălticeni' apple pomace as affected by non-conventional extraction techniques. *Food Hydrocoll.* **2020**, *100*, 105383. [CrossRef]
79. Rascón-Chu, A.; Martínez-López, A.L.; Carvajal-Millán, E.; León-Renova, N.E.P.; Márquez-Escalante, J.A.; Romo, A. Pectin from low quality 'golden delicious' apples: Composition and gelling capability. *Food Chem.* **2009**, *116*, 101–103. [CrossRef]
80. Paniagua, C.; Pose, S.; Morris, V.J.; Kirby, A.R.; Quesada, M.A.; Mercado, J.A. Fruit softening and pectin disassembly: An overview of nanostructural pectin modifications assessed by atomic force microscopy. *Ann. Bot.* **2014**, *114*, 1375–1383. [CrossRef]
81. Yang, H.; Lai, S.; An, H.; Li, Y. Atomic force microscopy study of the ultrastructural changes of chelate-soluble pectin in peaches under controlled atmosphere storage. *Postharvest Biol. Technol.* **2006**, *39*, 75–83. [CrossRef]
82. Kute, A.; Mohapatra, D.; Babu, B.; Sawant, B. Optimization of microwave assisted extraction of pectin from orange peel using response surface methodology. *J. Food Res. Technol.* **2015**, *3*, 62–70.
83. Azad, A.; Ali, M.; Akter, M.S.; Rahman, M.J.; Ahmed, M. Isolation and characterization of pectin extracted from lemon pomace during ripening. *J. Food Nutr. Sci.* **2014**, *2*, 30–35. [CrossRef]

84. *Food Chemical Codex*; IV monographs; according to the specifications on purity characteristics of the Joint FAO/WHO Expert 302 Committee on Food Additives and the European Commission; National Academy Press: Washington, DC, USA, 1996; p. 283.
85. Sengar, A.S.; Rawson, A.; Muthiah, M.; Kalakandan, S.K. Comparison of different ultrasound assisted extraction techniques for pectin from tomato processing waste. *Ultrason. Sonochem.* **2020**, *61*, 104812. [CrossRef] [PubMed]
86. Guandalini, B.B.V.; Rodrigues, N.P.; Marczak, L.D.F. Sequential extraction of phenolics and pectin from mango peel assisted by ultrasound. *Food Res. Int.* **2018**, *119*, 455–461. [CrossRef]
87. Canteri-Schemin, M.H.; Fertonani, H.C.R.; Waszczynskyj, N.; Wosiacki, G. Extraction of pectin from apple pomace. *Braz. Arch. Biol. Technol.* **2005**, *48*, 259–266. [CrossRef]
88. Hosseini, S.S.; Khodaiyan, F.; Yarmand, M.S. Optimization of microwave assisted extraction of pectin from sour orange peel and its physicochemical properties. *Carbohydr. Polym.* **2016**, *140*, 59–65. [CrossRef]
89. Lu, Y.; Foo, L.Y. Antioxidant and Radical Scavenging Activities of Polyphenols from Apple Pomace. *Food Chem.* **2000**, *68*, 81–85. [CrossRef]
90. 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] [PubMed]
91. Ghendov-Mosanu, A.; Cojocari, D.; Balan, G.; Patras, A.; Lung, I.; Soran, M.-L.; Opriş, O.; Cristea, E.; Sturza, R. Chemometric Optimization of Biologically Active Compounds Extraction from Grape Marc: Composition and Antimicrobial Activity. *Molecules* **2022**, *27*, 1610. [CrossRef]
92. Youssef, M.A.; EL Kady, A.A. Evaluation the Activity of Edible Coating for Maintenance the Shelf life of Raisins and Prunes. *Curr. Sci. Int.* **2016**, *5*, 103–110.
93. Jayeola, V.; Farber, J. Induction of the Viable but Non-Culturable State in Salmonella Contaminating Dried Fruit. *Appl. Environ. Microbiol.* **2021**, *88*, e0173321. [CrossRef]
94. Arendse, W.; Jideani, V. Storage Stability and Consumer Acceptability of Dried Apple: Impact of Citric Acid, Potassium Sorbate and Moringa oleifera Leaf Extract Powder. *Foods* **2022**, *11*, 984. [CrossRef]
95. Nunes, J.; Silva, P.; Gaspar, P.; Pires, L.; Andrade, L. The cherry drying as a complementary conservation process to conservation in cold. In Proceedings of the CYTEF 2016−VIII Congresso Ibérico, VI Congresso Ibero-Americano de Ciências e Técnicas do Frio, Coimbra, Portugal, 3–6 May 2016.
96. Quitral, V.; Sepúlveda, M.; Schwartz, M. Antioxidant Capacity and Total Polyphenol Content in Different Apple Varieties Cultivated in Chile. *Rev. Iberoam. Tecnol. Postcosecha* **2013**, *14*, 31–39.
97. Średnicka-Tober, D.; Ponder, A.; Hallmann, E.; Głowacka, A.; Rozpara, E. The Profile and Content of Polyphenols and Carotenoids in Local and Commercial Sweet Cherry Fruits (*Prunus avium* L.) and Their Antioxidant Activity In Vitro. *Antioxidants* **2019**, *8*, 534. [CrossRef] [PubMed]
98. Wojdyło, A.; Nowicka, P.; Laskowski, P.; Oszmiański, J. Evaluation of Sour Cherry (*Prunus cerasus* L.) Fruits for Their Polyphenol Content, Antioxidant Properties, and Nutritional Components. *J. Agric. Food Chem.* **2014**, *62*, 12332–12345. [CrossRef]
99. Prvulovic, D.; Malenčić, Đ.; Popović, M.; Ljubojević, M.; Ognjanov, V. Antioxidant properties of sweet cherries (*Prunus avium* L.)—Role of phenolic compounds. *World Acad. Sci. Eng. Technol.* **2011**, *59*, 1149–1152.
100. Zhang, H.; Pu, J.; Tang, Y.; Wang, M.; Tian, K.; Wang, Y.; Luo, X.; Deng, Q. Changes in Phenolic Compounds and Antioxidant Activity during Development of 'Qiangcuili' and 'Cuihongli' Fruit. *Foods* **2022**, *11*, 3198. [CrossRef]
101. Miletić, N.; Mitrović, O.; Popović, B.; Nedović, V.; Zlatković, B.; Kandić, M. Polyphenolics of Plums and Prunes. *J. Food Qual.* **2013**, *36*, 229–237. [CrossRef]
102. Ishiwata, K.; Yamaguchl, T.; Takamura, H.; Matova, T. DPPH Radical-Scavenging Activity and Polyphenol Content in Dried Fruits. *Food Sci. Technol. Res.* **2004**, *10*, 152–156. [CrossRef]
103. Orhan, D.D.; Özlük, Ö.; Coşkun, S.H. Antioxidant capacities, ascorbic acid and total phenol contents of the plants sold as rose hip in Turkey. *FABAD J. Pharm. Sci.* **2012**, *37*, 161–167.
104. Koczka, N.; Stefanovits-Bányai, É.; Ombódi, A. Total Polyphenol Content and Antioxidant Capacity of Rosehips of Some *Rosa* Species. *Medicines* **2018**, *5*, 84. [CrossRef] [PubMed]
105. Nowak, A.; Szatan, D.; Zielonka-Brzezicka, J.; Florkowska, K.; Muzykiewicz, A.; Klimowicz, A. Antioxidant Activity of Selected Parts of *Prunus domestica* L. Harvested at Two Ripening Stages. *Pomeranian J. Life Sci.* **2020**, *66*, 65–69. [CrossRef]