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TECHNOLOGIES FOR OBTAINING DIETARY FIBRES FROM HORTICULTURAL SOURCES

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Summary of the doctoral thesis in engineering sciences

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CONTENTS

CONCEPTUAL POINTS OF THE RESEARCH

The reasoning for choosing this subject. Reuse of agro-industrial waste is of significant importance from an ecological, economic and social point of view. The apple pomace (AP) formed after processing the juice is a source of agro-industrial waste rich in carbohydrates, vitamins, minerals, biologically active substances (BAC) and, of course, soluble and insoluble dietary fiber (Erșova et al., 2024). The use of AP for food purposes includes the production of jams and marmalades, alcoholic beverages, ingredients used in the bakery, confectionery and meat industries, etc (Shalini & Gupta, 2010). The reuse of AP for the extraction of pectin is an excellent example of the valorisation of agro-industrial waste. Pectin extracted from AP is a natural ingredient valued for its gelling and stabilizing properties in the food industry. The use of pectin as protective films represents a wide range of advantages, being a biodegradable product, it is an ecological alternative for packaging food products. Also, protective films are used as a barrier in the microbiological stability of food (Gurev et al., 2023a). The extraction of pectin by non-conventional techniques involves innovative techniques that are more efficient, faster and more ecological than conventional ones. The advantages of these methods are: the extraction process is ecological; reduction of extraction time and solvent consumption; high extraction yield with retention of BAC in the product; obtaining the quality product.

Relevance and importance of the topic addressed. The food fibers obtained from agro-industrial waste can be used to create texture compositions with the aim of substituting synthetic food additives as thickening agents, gelling agents, stabilizers, etc. (Vendruscolo et al., 2008). AP is a secondary product of the apple juice or cider industry, being a rich source of phytonutrients. (Ersova et al., 2024). In this context, research has been initiated on the use of AP as a functional ingredient in different types of food with the aim of fortification, increasing their nutritional and biological value (Bhushan et al., 2008). Pectin presents a soluble dietary fiber with multifunctional applications in the food, pharmaceutical, etc. industries. (Harholt et al., 2010). The gelling activity of pectin is influenced by a number of factors such as pH, the presence of other solutes, molecular weight, degree of methoxylation, number and arrangement of side chains, and molecular charge density. In the food industry, pectin is used in jams, frozen foods and, more recently, in reduced-calorie products as a substitute for fat or sugar (Schmidt et al., 2015). Various emerging technologies are used to extract pectin from agro-food waste, such as enzyme-assisted extraction, subcritical fluid extraction, ultrasound-assisted extraction (UAE), microwave - assisted extraction (MAE) or a combination of several methods (Adetunji et al., 2017). Extraction by non-conventional methods (MAE and UAE) is characterized by a high yield of pectin extraction with a high degree of esterification, which can be successfully used in the food industry. The variety of extraction parameters: hydro modulus (LSR), solvent composition, extraction temperature, pH, duration of ultrasound and microwave application, allow obtaining pectin with different properties (Pereira et al., 2016). According to the Food and Agriculture Organization, the United Nations and the European Union, pectin of standardized quality must contain ≥ 65% galacturonic acid (GalA).

The carboxyl groups of GalA molecules can be methylated, and the proportion of methylated GalA units determines the degree of methoxylation (Chalapud et al., 2023).

The purpose of the research is to evaluate the composition of apple pomace, the extraction of pectin with high biological value by non-conventional extraction techniques - UAE, MAE and their use in the manufacture of new food products.

The general objective of the work is to obtain pectin from AP with high biological and antioxidant value by unconventional extraction methods UAE and MAE; the use of pomace as a functional ingredient and pectin as a binding and coating agent in the manufacture of new food products.

To achieve the goal, the following **operational objectives were formulated**:

1. Research on the influence of the temperature of the thermal agent on the kinetics of convective drying, the kinetic characteristics, the biological and antioxidant value of AP as a source of obtaining pectin.

2. Establishing the mathematical models of the kinetics of the AP drying process at different temperatures of the thermal agent based on the empirical mathematical models.

3. Determination of the influence of UAE conditions (ultrasonic application duration (τ_{UAE})) and MAE conditions (microwave application duration (τ_{MAE}), magnetron power), the pH of the solvent and hydro module (LSR) on the physicochemical parameters (extraction yield, equivalent weight, content of methoxyl groups, the degree of esterification, the content of anhydrogalacturonic acid, the biological value (the total content of polyphenols (TPC)) and the antioxidant activity (AA) of pectin from apple pomace, as well as establishing the optimal extraction conditions.

4. Comparison of non-conventional extraction methods UAE and MAE of pectin from AP in terms of physicochemical characteristics, biological value and antioxidant activity.

5. The application of pectin as a binding and coating agent in the manufacture of vegetable bars and the research of its influence on the sensory, physicochemical parameters, microbiological stability, biological and antioxidant value of the finished product during the storage period.

6. The influence of AP powder as a stabilizer in yogurt manufacturing on sensory characteristics, physicochemical, textural, color parameters and antioxidant activity during the storage period of the fermented product.

7. The effect of AP powder when replacing sugar in the manufacture of biscuits on the sensory, physicochemical and color quality during the storage period of the flour confectionery product.

The research hypothesis consists in the fact that both the AP and the pectin contained in the pomace in significant quantities can be extracted by non-conventional extraction methods, can be applied as functional ingredients (binding agent, coating, stabilization and substitute of sugar) in the manufacture of new food products. The basic problem consists in modelling the extraction conditions in such a way that the pectin obtained is of standardized quality.

Synthesis of research methodology and justification of chosen research methods. Traditional and non-conventional physicochemical methods, such as UAE and MAE extraction, were applied to carry out the work. UV/Vis spectroscopy and capillary electrophoresis were applied for the characterization of AP extracts, pectin and the obtained products. Antioxidant activity (DPPH) was determined for both plant extracts and processed food products. Sensory, physicochemical, textural and color parameters, microbiological stability analysis methods were applied. Methods of statistical processing and mathematical modelling of experimentally obtained results were applied.

The theoretical importance and scientific innovation of the work consists in determining the optimal conditions for preserving AP through convective drying with the preservation of biological value and antioxidant activity; identification of the optimal extraction conditions by MAE and UAE of pectin from AP of standardized quality with high antioxidant potential; arguing for the use of AP and pectin as natural additives in the manufacture of new food products.

Theoretical significance: for the first time, the kinetics of the convective drying process of Golden Delicious apple cores was simulated at different temperatures of the heating agent, with the application of seven empirical mathematical models; optimal conditions of UAE and MAE of pectin from AP were established and the application of mutual information analysis regarding the influence of extraction conditions on the physicochemical characteristics, biological value and antioxidant activity of pectin; new product manufacturing technologies were developed in which AP and pectin were applied as natural food additives with different actions.

The work was carried out on the basis of the research and experience gained in carrying out the following national and international research projects:

20.80009.5107.09 of the State Project "Improving food quality and safety through biotechnology and food engineering" (2020-2023).

AUF-ECO_RI_SRI_2021_20_USAMVIIBI_ZERODECHET "Horticultural waste for the benefit of health and the environment, a new approach to the principle of "zero waste"" (2021-2022).

AUF - DRECO-7863_SER-ECO_USVIIBI_DECHETJUS "Total reuse of fruit and vegetable waste from juice production: pigments and antioxidants for functional foods and biomaterials for water purification" (2023-2024).

Approval of the work at national and international scientific forums. The results obtained during the realization of the work were presented and discussed at 12 national and international conferences.

Publications on the topic of the thesis. The research results and the issues addressed in the thesis were published in 19 scientific works, including a chapter in a collective monograph, 6 scientific articles, 2 invention patents, 9 articles in collections and summaries at national and international scientific events.

Summary of thesis chapters. The work is presented on 118 typewritten pages and includes the following chapters: annotation in Romanian and English, introduction, 4 chapters, conclusions and recommendations, bibliography with 316 sources. The work is illustrated with 34 tables and 46 figures.

Keywords: apple pomace, ultrasound-assisted extraction, microwave - assisted extraction, pectin, biologically active compounds, mathematical modelling, vegetable bars, yogurt, biscuits, quality**.**

THESIS CONTENT

1. APPLE POMACE - IMPORTANT SOURCE OF DIETARY FIBER AND PHYTONUTRIENTS FOR THE FOOD INDUSTRY

The first chapter represents the analysis of information related to the general characteristic of AP with the description of its physicochemical composition, phytonutrient content, benefits on the human body and its use in the manufacture of new food products or their fortification. At the same time, the study of the information that characterizes pectin as a soluble fiber extracted from apple pomace, the description of conventional and non-conventional methods of pectin extraction, the influence of extraction parameters on the extraction yield and the physicochemical properties of the extracted pectin, the benefits of pectin for the health of the consumer is reflected and its use in the manufacture of new foods. Chapter one ends with conclusions and the formulation of objectives, based on the analysis of bibliographic sources, which reflect the problem of the reuse of AP as agro-industrial waste and the extraction of pectin from it by non-conventional methods. The bibliographic study demonstrated the possibility of using AP and pectin in the formation of new food products with high biological value.

2. RESEARCH MATERIALS AND METHODS

Chapter 2 contains the description of the raw material used to obtain apple pomace, the raw and auxiliary material for the manufacture of new food products with AP or pectin extracted from it, the reagents and the methods that were applied to determine the sensory characteristics, physicochemical parameters and color, rheological properties and microbiological stability. AP for research was obtained after squeezing juice from Golden Delicious apples. The following temperatures of the thermal agent were applied to investigate the kinetics of the AP drying process: 60, 70 and 80 °C. The obtained results were processed with the help of graphic and mathematical methods, on the basis of which the drying curves and the drying speed of AP were built according to the temperature of the heating agent. The drying coefficients in the first and second drying periods were calculated K_I and K_{II}. Unconventional extraction methods UAE and MAE were used to obtain pectin from apple pomace. The influence of UAE conditions was investigated: duration of ultrasound application (τ_{UAE} - 15 and 30 min), solvent pH (1.5; 2.0; 2.5, adjusted with citric acid) and hydro module (LSR – 1:10; 1:15; 1:20) on the extraction yield, equivalent weight (EW), content of methoxyl groups (MeO), the degree of esterification (DE), the content of anhydrogalacturonic acid (AGA), TPC and AA of apple pomace. In the case of microwaves, the influence of microwave application duration (τ_{MAE} - 5 and 10 min), magnetron power (450 and 650 W), solvent pH (1.5; 2.0; 2.5) and hydro module (LSR – 1:10; 1:15; 1:20).

For the production of the vegetable bars, the local vegetable matter was used: the dried fruits of apples, cherries, plums and rosehip powder. Pectin extracted by the MAE method was used as a binding and coating agent. Milk with a fat content of 2.5%, lyophilized starter cultures of type FD-DVS and YAB 352B were used for the manufacture of yogurt. AP powder was used as a stabilizer in amounts of 0.2%; 0.4%; 0.6%; 0.8% and 1% in relation to the yogurt mass. For the manufacture of biscuits, the raw material was used: high quality wheat flour, butter from sweet cream with a fat content of 82.5%, granulated sugar and baking powder. AP powder was used as a sugar substitute in amounts of 25%, 50%, 75% and 100%. Sensory characteristics, physicochemical, rheological, color parameters, microbiological stability and AA were analysed for the manufactured products.

Calculations were performed in triplicate and are presented as mean values ± standard error of the mean. Microsoft Office Excel 2007 (Microsoft, Redmond, WA, USA) was used for statistical processing. One-way analysis of variance (ANOVA) according to Tukey's test at a significance level of $p \leq 0.05$ was calculated with Statgraphics software, Centurion XVI 16.1.17 (Statgraphics Technologies, Inc., The Plains, VA, USA). The MATLAB program (MathWorks, Inc., Natick, MA, USA) was applied for the mutual analysis of the obtained results and the mathematical modelling of the kinetics of the drying process of AP based on the changes in the reduced moisture (MR) ratio.

3. UNCONVENTIONAL METHODS OF EXTRACTION OF PECTIN FROM APPLE MARC AND ITS PHYSICOCHEMICAL CHARACTERISTICS

In this chapter, the kinetics of the AP drying process (drying curves and drying speed curves) were investigated and the coefficients K_I and K_{II} were determined at different temperatures of the heat agent. The influence of drying conditions on BAC and AA content was analysed. Seven empirical mathematical models describing the drying curves of AP at different temperatures were established. Pectin was extracted from dried AP by non-conventional methods (UAE and MAE) under different extraction conditions. The influence of the extraction conditions on the physicochemical characteristics, biological value and AA of the extracted pectin was investigated.

3.1 Study of the kinetics of the AP drying process depending on the temperature of the thermal agent

AP having a high humidity is subject to undesirable microbiological and biochemical (fermentation) processes that can affect the quality and safety of the extracted pectin. One of the methods of preservation of gooseberries is convective drying which has certain advantages: preservation of the biological value of BAC (polyphenols, flavonoids, tannins, carotenoids, etc.) and AA (Heras-Ramírez et. al., 2012); the degradation of enzymes responsible for the oxidative degradation of color pigments (ElGamal et. al., 2023); preventing the development of colonies of pathogenic microorganisms and fermentation processes.

For the convective drying of the apple core, the temperature of the heating agent was used in the range of 60 - 80 °C, the speed of the heating agent being 1.5±0.1 m/s. The initial moisture content of the pomace was 80.22±0.05%, and the final moisture content was 12.00±0.05%. In fig. 3.1 shows the drying curves of dried AP at temperatures of 60, 70 and 80 °C.

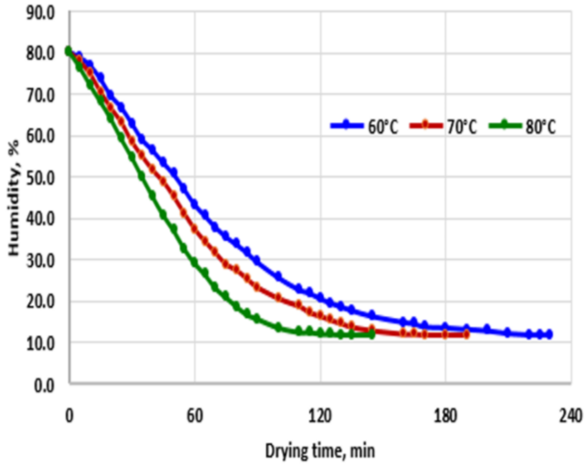


Fig. 3.1. Drying curves of apple pomace at different temperatures of the agent.

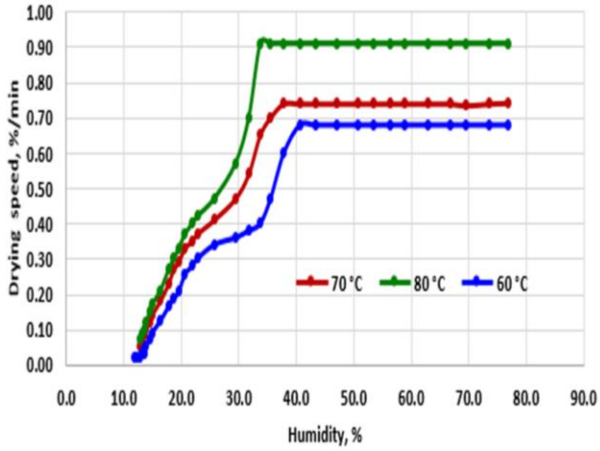
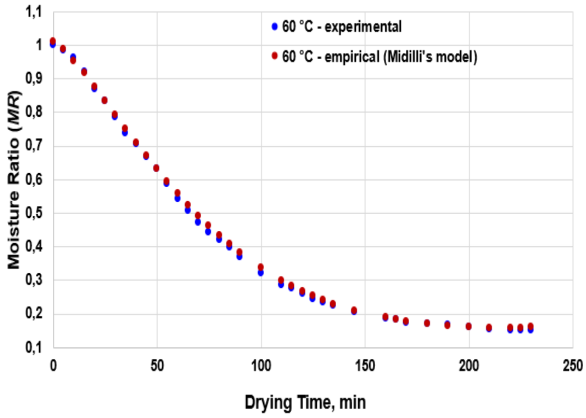


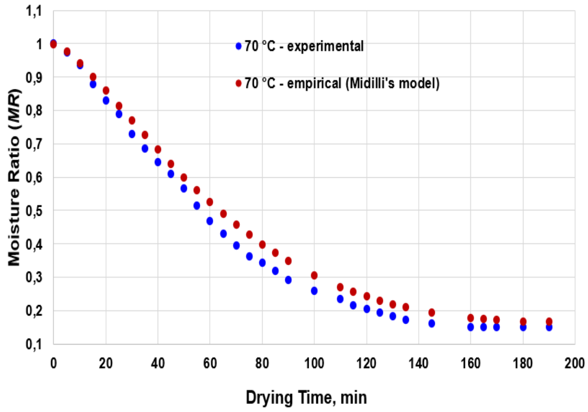
Fig. 3.2. Curves of the drying speed of apple pomace at different temperatures of the thermal agent.

Analysing the drying curves of apple pomace, it is found that the drying time decreases depending on the increase in the temperature of the heating agent. For the temperature of 60 °C the drying time was 230 min, for 70 °C – it was reduced to 190 min, and for 80 °C – 145 min. Thus, changing the temperature of the thermal agent from 60 to 80 °C reduced the drying time by 1.6 times. In fig. 3.2 shows the curves of the drying speed of AP at different temperatures of the thermal agent. The hot air convection drying process includes both heat and mass transfer, while water is removed by diffusion (Calín-Sánchez et al., 2020). The drying speed curves demonstrated the presence of the constant drying speed period (first period) and the variable drying speed period (second period). Following the analysis of the drying speed curves, the increase of the drying speed in the first period by 1.36 times was highlighted (0.66 %/min – 60 °C; 0.72 %/min – 70 °C; 0.90 %/min – 80 °C). At the same time, there is an increase in the drying coefficient in the first K_I period by 1.04 times and in the second K_{II} period by 1.49 times. Based on the results and graphs of drying curves and drying speed curves, the kinetic characteristics of the drying process were calculated. The results show that with the increase in the temperature of the thermal agent from 60 to 80 °C, the drying time was reduced in the first period by 15.4% and in the second - by 45.4%. Changing the drying temperature did not significantly influence the general character of the drying rate curves. Analysis of the graphs of the drying speed curves, during the variable drying speed period, revealed the second critical point which moved from 34% (60 °C) to 26% (80 °C). This demonstrated that with the increase in the temperature of the thermal agent, the increase in the values of the kinetic characteristics occurs. In the temperature range of the thermal agent 60 - 80 °C, in the case of the K_I coefficient the values increased by 4%, and for the K_{II} by 44%, thus demonstrating influence on the variable drying speed period (second period). It has been shown that during convective drying, the removal of moisture from AP is prevented due to the opposite orientation of the temperature and humidity gradient in the case of convective drying (Calín-Sánchez et al., 2020).

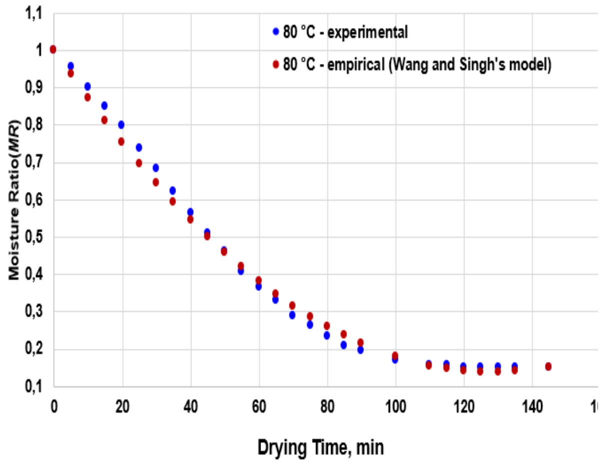
For mathematical modelling, the kinetics of the AP drying process was performed on the MR changes. Coefficients of determination (R^2) and root mean square error (RMSE) values were determined for seven empirical models at different coolant temperatures. In fig. 3.3 shows the comparison between experimental and empirical MR according to Midilli's model (a and b) for temperatures of 60 and 70 °C and Wang and Singh's model (c) for 80 °C.



a)



b)



c)

Fig. 3.3. Comparison between experimental and empirical MR according to Midilli's model for the two temperatures studied: a) 60 °C; b) 70 °C and to Wang and Singh's model: c) 80 °C.

The R^2 values, which indicate the effectiveness of the drying process at different temperatures of the thermal agent, were between 0.9848 and 0.9996 (at a temperature of 60 °C); 0.9862 and 0.9996 (at 70 °C temperature) and 0.9813 and 0.9937 (at 80 °C temperature). RMSE values were calculated in the range of 0.0056 to 0.0349 (at 60 °C); from 0.0061 to 0.0324 (at 70 °C) and from 0.0234 to 0.0394 (at 80 °C). The maximum fidelity to the experimental data was obtained by the Midilli's model, substantiated by a high R^2 value of 0.9996 (for 60 and 70 °C) and the Wang and Singh's model, R^2 being 0.9937 (for 80 °C).

The pre-eminent RMSE recorded within these models ranged from 0.0234 – 0.0061, affirming their optimal congruence with the empirical data.

3.2. Analysis of the influence of thermal agent on the BAC in apple pomace

AP is a rich source of BAC, health-beneficial nutrients having AA, anti-inflammatory, antibacterial and antiviral (Skinner et al., 2018). The influence of heat agent temperature on TPC, total carotenoid content (CTC), tannin content (TC) and AA was investigated. The research results are presented in table 3.1 (Ceşko et al., 2023a). Following the analysis of dried AP by the convective method at the temperature of the thermal agent 60 - 80 °C, it was demonstrated that the temperature of 70 ^{o}C is the optimum at which the highest yield of BAC was recorded.

Table 3.1. The influence of the temperature of the heating agent on the content of CBA in apple pomace*

Temperature, ^{o}C	Total content of polyphenols, mg GAE/ 100 g DW	Tannin content, mg TAE/ 100 g DW	Total carotenoid content, mg/100g DW	Antioxidant activity (DPPH), µmol TE/100g DW
80	586.93±22.36 ^{a}	63.54±3.40 ^{a,b}	3.66±0.64 ^{a,b}	62.45±1.20 ^{a}
70	728.82±28.50 ^{c}	78.91±1.28 ^{c}	4.93±0.13 ^{c}	74.94±1.08 ^{b}
60	611.44±26.41 ^{a,b}	66.14±2.18 ^{b}	3.19±1.20 ^{a}	62.90±1.05 ^{a}

Values in the table represent the means of three replicated trials, standard deviation. Different letters ($^{a–c}$) designate statistically different results(p ≤0.05).

Thus, TPC was 728.82 mg GAE/100 g DW, TC - 78.91 mg TAE/100 g DW, CTC - 4.94 mg/100 g DW and AA - 74.94 µmol TE/100g DW. The temperature of 70 ^{o}C was considered optimal because it strikes a balance between the efficiency of the drying process and the maintenance of quality, ensures the preservation of CB and does not cause caramelization of sugars. Correlation analysis between TPC, TC, CTC and AA in dried AP over the range of heat agent temperatures 60-80 °C demonstrated that all correlations between BAC and AA are very good, with the coefficient of determination R2 being 0.983 (TPC-AA), 0.984 (TC-AA) and 0.915 (CTC-AA). For AP dried at the optimal temperature of 70 ^{o}C, where high values of BAC and AA content were obtained, the content of simple carbohydrates: fructose and glucose and organic acids: malic, lactic, citric, succinic was determined. Thus, the drying of AP by the convective method at different temperatures shows an important influence on the content of BAC and AA.

3.3. Ultrasound-Assisted extraction (UAE) of pectin from apple pomace

AP contains a variety of dietary fibers and is used to extract pectin, which gels when interacting with water, and in combination with sugar can be used as a thickening agent. UAE is a less destructive process for obtaining BAC, compounds that contribute to increasing the biological value of pectin when used as a natural additive. In UAE the result depends on the influence of several process parameters, the main ones being: ultrasonic amplitude, frequency, temperature, application time and solvent-sample interaction (De Oliveira et al., 2015). The aim of the study was to investigate the influence of UAE conditions: duration of ultrasound application (τ_{UAE} - 15 and 30 min), solvent pH (1.5; 2.0; 2.5, adjusted with citric acid) and hydro module (LSR – 1:10; 1:15; 1:20) on the extraction yield, EW, MeO, DE, AGA, TPC and AA of pectin from apple pomace.

The extraction yield of pectin with UAE is influenced by the pH of the solution and the extraction time. It was found that the highest pectin extraction yield (9.91%) was obtained at τ_{UAE} 30 min, amplitude 100% and frequency 37 kHz, LSR 1:20 and at pH 1.5. The lowest pectin extraction yield was recorded for (pH 2.5 and τ_{UAE} 15 min). The EW of pectin is an indicator of gel-forming ability. The EW analysis for the extracted pectin demonstrated that the values decrease with decreasing pH of the solution, but increase with decreasing τ_{UAE} and increasing LSR. Maximum value of EW - 1927 g/mol for conditions (pH~2.5, LSR 1:15 (*v/w*) and τ_{UAE} 15 min), and minimum value of EW was 378.3 g/mol under (pH conditions ~1.5, LSR 1:20 (*v/w*) and τ_{UAE} 30 min). The content of MeO expresses the ratio between methyl-esterified carboxyl groups and the total amount of galacturonic acid units, being one of the key parameters related to the gelling capacity of pectin (Xu F., 2023). The highest value was found to be 6.81% for (pH~2.5, LSR 1:20 (*v/w*), τ_{UAE} - 15 min), and the lowest value for MeO content was 5.05% in the case of (pH~1.5, LSR 1:20 (*v/w*), τ_{UAE} 30 min). The purity of the pectin extracted from the pomace is determined by the content of AGA, which must present values greater than 65% (National Academy, 1996). AGA was found to increase with decreasing pH, increasing LSR, and increasing ultrasound application time. It is confirmed that the maximum value of AGA (78.71%) was obtained under conditions of (pH~1.5, LSR 1:20 (*v/w*), τ_{UAE} 30 min), and the minimum value (49.16%) at (pH~ 2.5, LSR 1:15 (*v/w*), τ_{UAE} 15 min). The DE presents an important parameter for pectin applications in industry based on the technological characteristics of pectin solubility, emulsification capacity and the ability of polysaccharides to form gels (De Oliviera et al., 2015). It was demonstrated that DE, determined for pectin extracted by the UAE method, had values between 36.47 % (pH~1.5; LSR 1:20 (*v/w*), τ_{UAE} 30 min) and 73.78 % (pH~2.5; LSR 1:15 (*v/w*), τ_{UAE} 15 min), being influenced more by increasing the pH- of the solvent than by τ_{UAE} and LSR. BAC analysis demonstrated that it is important to select the optimal parameters in UAE (application time, solvent pH and LSR) to be consistent with the plant material chosen for research. The analysis of TPC and AA in the extracted pectin demonstrated the influence of both the pH of the extracting solvent and τ_{UAE}. Thus, in ultrasonically extracted pectin, the maximum value was 12.98 mg GAE/g DW (pH~2.5; LSR 1:10 (*v/w*), τ_{UAE} 30 min), and minimum of 2.16 mg GAE/g DW (pH~1.5; LSR 1:20 (*v/w*), τ_{UAE} 30 min). AA (DPPH) of pectin recorded values between 5.53 (pH~1.5; LSR 1:20 (*v/w*)) and 18.86 μmol TE/g DW (pH~2.5; LSR 1:15 (*v/w*)) for τ_{UAE} 15 min and values between 4.32 (pH~1.5; LSR 1:20 (*v/w*)) and 18.32 μmol TE/100 g DW (pH~2.5; LSR 1:10 (*v/w*)) for τ_{UAE} 30 min.

3.4. Microwave - Assisted extraction (MAE) of pectin from apple pomace

The extraction of pectin by MAE is an unconventional method characterized by rapidity, reduced consumption of solvents and energy as well as by the less destructive action on thermolabile constituents (Prakash et al., 2013). MAE improves the water absorption capacity and the capillary-porous components of plant parts and these changes contribute to the intensification of the hydrolysis processes and to the increase in the extraction yield of cellulose, hemicellulose and pectin (Maran et al., 2014). The influence of the extraction conditions of pectin from AP was investigated depending on the duration of microwave application 5 and 10 min, the power of the magnetron 450 W and 650 W at the frequency of 2450 MHz. According to the obtained results, it is confirmed that when applying MAE at the magnetron power of 450 W, the highest pectin yield (19.88%) was obtained at(LSR 1:20 (*v/w*) and a pH of 2.5, τ_{MAE} 10 min), and minimum 4.50% at (LSR 1:10 (*v/w*) at pH 1.5 in τ_{MAE} 5 min). In case of magnetron power of 650 W, τ_{MAE} 5 min, the maximum yield of 25.23% was obtained at (LSR 1:15 (*v/w*) and at pH 1.5), and the lowest 3.15% at (LSR 1:10 (*v/w*) at pH 2.0). It has been shown that there is a correlation between the pH of the solvent and the magnetron power. Thus, it was demonstrated that the pectin extraction yield increased as the magnetron power increased and the pH of the solvent decreased (Maric et al., 2018). EW is an important physicochemical parameter for pectin structure in determining its functional behaviour. The highest EW values were recorded for pH 2.5, at 450 W power, (τ_{MAE} 5 min and LSR 1:10 - 1:20 (*v/w*)), with values of 1879 – 2262 g/mol. In the case of pectin extraction at the magnetron power of 650 W, the highest values of EW were recorded at (pH 2 and τ_{MAE} 10 min) having the value of 1185 g/mol. The MeO in pectin is influenced by the parameters applied to MAE. The highest MeO content was obtained at 450 W magnetron power, at (pH~2.5, LSR 1:20 (*v/w*) and τ_{MAE} 5 min) constituted 6.39% and in the case of 650 W power, at (pH~ 1.5, LSR 1:15 (*v/w*), τ_{MAE} 10 min), being 8.92%. The lowest MeO content was obtained under the following conditions: magnetron power - 450W, (pH~ 1.5, LSR 1:20 (*v/w*) and τ_{MAE} 10 min), being 4.88% and at the magnetron power of 650W, at (pH~ 2.0, LSR 1:15 (*v/w*), τ_{MAE} 10 min), being 2.00%. It follows that at low pH, long microwave action time and higher magnetron power, more advanced pectin desertification occurs. The analysis of AGA content showed that the values increase with decreasing pH, increasing LSR and τ_{MAE}. Thus, at the magnetron power of 450 W, (τ_{MAE} 10 min, at pH ~ 1.5 and LSR 1:20 (*v/w*)), the maximum value of AGA was recorded - 73.02%, and (τ_{MAE} 5 min, pH ~ 2.5, LSR 1:10 (*v/w*)) recorded the minimum value of 47.31%. In the case of the magnetron power of 650W and τ_{MAE} 10 min, the minimum AGA value was 41.85%, being obtained at (pH ~ 2, LSR 1:10 (*v/w*)) and maximum of 79.89% at (pH ~ 1.5 and LSR 1:15 (*v/w*)). Microwave extraction of pectin from AP can reduce DE by rapidly heating polar water molecules, which in the presence of acid will more easily break the ester bonds in pectin macromolecules. The decrease in the DE values of pectin occurs when the τ_{MAE} and LSR increase and the pH of the solvent decreases. Thus, the DE of pectin extracted at 450 W magnetron power recorded minimum values of 38.69% (pH 1.5, LSR 1:20 (*v/w*), τ_{MAE} 10 min) and maximum values of 71.37% (pH ~2.5, LSR 1:10 (*v/w*), τ_{MAE} 5 min). For pectin extracted at 650 W, the minimum values of 33.87% (pH~1.5, LSR 1:10 (*v/w*), τ_{MAE} 5 min) and maximum values of 73.29% (pH~2, LSR 1:10 (*v/w*), τ_{MAE} 10 min).

The recorded experimental data demonstrate that TPC and AA of apple pectin depend less on LSR under the same extraction conditions. It is confirmed that under the extraction conditions: at the magnetron power of 450W and (τ_{MAE} 5 min, at pH~2, LSR 1:10 (*v/w*)), the minimum value of TPC was 2.28 mg GAE/g DW and maximum of 13.05 mg GAE/g DW at (pH~2.5, LSR 1:20 (*v/w*)). For pectin extracted at 650 W power, the minimum value of 1.83 mg GAE/g DW was recorded (pH~2, LSR 1:15 (*v/w*), τ_{MAE} 5 min) and maximum of 5.75 mg GAE/g DW (pH~2, LSR 1:15 (*v/w*), τ_{MAE} 10 min). AA of pectin extracted by MAE at magnetron power 450 W and τ_{MAE} 5 min, recorded the minimum value of 7.85 μmol TE/g DW (pH~2, LSR 1:10 (*v/w*)) and max 16.39 μmol TE/g DW (pH~2.5, LSR 1:20 (*v/w*)) τ_{MAE} 5 min, being influenced by the increase in pH and LSR values. For pectin extracted at 650W power, the minimum AA value was 7.01 µmol TE/g DW (pH~1.5, LSR 1:10 (*v/w*), τ_{MAE} 5 min) and maximum - 10.27 µmol TE/g DW (pH~2, LSR 1:15 (*v/w*), τ_{MAE} 10 min).

3.5. Mutual information analysis of pectin extraction from AP with the application of ultrasound and microwaves

Mutual information analysis was applied to determine the influence of pH on yield, EW, MeO, AGA, DE, TPC and AA of pectin obtained by UAE and MAE at all hydro module (1:10 , 1:15, 1:20 (*v/w*)). The data in Table 3.2 demonstrate that in the UAE extraction, for 15 and 30 min, the pH influences the significance of EW of pectin (mutual information being 0.998 bits for both cases), DE (0.995 and 0.996 bits) and MeO concentration (0.958 and 0.836 bits), respectively. Following in descending order is the influence on pectin yield (0.885 and 0.873 bits) and on AUA content (0.836 and 0.985 bits), respectively. In the case of a shorter time of ultrasound action (15 min), TPC does not increase proportionally with increasing pH of the medium (0.491 bits). Extending the ultrasound action time to 30 min shows a significant influence of pH on AA (0.915 bits) and less on TPC (0.812 bits).

In microwave extraction for 5 and 10 min at all hydro module, pectin yield decreases proportionally with increasing pH of the medium (0.998 bits), EW decreases with decreasing pH (0.996 and 0.982 bits, respectively), and MeO is more little influenced by pH change (0.755 bits).

Table 3.2 Results of mutual analysis of the influence of environmental pH (1.5; 2.0; 2.5) on pectin properties in all hydro modules (1:10; 1:15; 1:20)

Property	Influence of pH on pectin properties, bits			
	Ultrasound assisted extraction		Microwave assisted extraction	
	15 min	30 min	5 min	10 min
Pectin yield	0.885	0.873	0.998	0.998
Equivalent weight	0.998	0.998	0.996	0.982
Methoxyl content	0.958	0.836	0.755	0.755
Anhydrogalacturonic acid content	0.836	0.985	0.821	0.645
Degree of esterification	0.995	0.996	0.996	0.591
Total polyphenol content	0.491	0.812	0.916	0.522
Antioxidant activity	0.684	0.915	0.325	0.101

When microwaved for 5 min, pH influences more DE (0.996 bits), TPC (0.916 bits) and less AUA (0.821 bits) and AA (0.325 bits) concentration of pectin. The results of the information analysis show that when extending the microwave action time to 10 min, a reduced influence of pH on TPC (0.522 bits) as well as an insignificant influence on AA of pectin (0.101 bits) is observed.

3.6. Comparison of the results obtained by UAE and MAE extraction of pectin from apple pomace

The analysis of the conducted research demonstrated the influence of the UAE or MAE extraction method and the extraction parameters solvent pH, LSR and extraction time on the extraction yield, on the EW, MeO, AGA, DE, TPC and AA of the extracted pectin. Thus, for pH 1.5 and LSR 1:20 (*v/w*), the yield of pectin obtained by UAE at τ_{UAE} 30 min was 9.91%, and in the case of MAE at τ_{MAE} 10 min and magnetron power 450 W was 19.88%, i.e. it increased by 2.01 times. In the extraction of MAE, heat is generated which accelerates the extraction process creating increased mobility of molecules and disruption of plant cells. The results obtained from ME analysis demonstrated that in pectin extracted by UAE and MAE, EW decreases with decreasing pH, increasing extraction time and increasing LSR, recording values for UAE - 1927 g/mol (pH~2,5; LSR 1:15 (*v/w*), τ_{UAE} 15 min), and for MAE 2261 g/mol (pH~2.5; LSR 1:20 (*v/w*), τ_{MAE} 5 min) the increase in EW by 85%. The short duration of exposure to microwave extraction did not significantly influence the change in the properties of the extracted pectin. The content of MeO, determined in the pectin extracted from AP by UAE had a higher concentration, compared to the pectin extracted by MAE. The degree of methoxylation increased with increasing pH and decreasing extraction time, but was less influenced by LSR. At MAE extraction (450 W) the maximum value of 6.39% (pH~2.5; LSR 1:20 (*v/w*), τ_{MAE} 5 min) was recorded and for UAE of 6.81% (pH~2.5; LSR 1:20 (*v/w*), τ_{UAE} 15 min) 1.06 times lower, being dependent on the equivalent mass of extracted pectin. The analysis of AGA content in pectin obtained by UAE and MAE methods varies from one sample to another, being dependent not only on the method applied, but also on the extraction conditions. The purity of extracted pectin increased with decreasing pH, with increasing LSR and extraction time. The pectin obtained by UAE was characterized by a higher content of AUA, compared to the pectin by MAE and constituted 78.71 % (pH~1.5; LSR 1:20 (*v/w*), τ_{UAE} 30 min) and 73.02 % (pH~1.5; LSR 1:20 (*v/w*), τ_{MAE} 10 min) respectively, being 1.07 times higher. Due to UAE extraction, AGA integrity was maintained, and MAE influenced the cellular structure by releasing larger amounts of pectin, which cleaved less into AGA. DE determined for pectin obtained by UAE recorded the maximum value 73.78 % (pH~2.5; LSR 1:15 (*v/w*), τ_{UAE} 15 min), compared to pectin extracted by MAE, with 71.37 % (pH~2.5; LSR 1:10 (*v/w*), 5 min). In both techniques, DE recorded decreasing values with decreasing pH, increasing extraction time and LSR. The DE of pectin extracted by UAE is 1.03 times higher than in the case of the MAE method.

Experimental data demonstrated that TPC and AA of pectin were in a lower dependence on RSL at the same extraction parameters. It was found that the TPC of pectin decreases with decreasing pH, increasing extraction time, and decreasing ME, respectively. In UAE-extracted pectin, the maximum TPC was 12.98 mg GAE/g DW (pH~2.5; LSR 1:10 (*v/w*) τ_{UAE} 30 min) which constitutes 1.3%, and the pectin extracted by MAE had a value of 13.05 mg GAE/g DW (pH~2.5; LSR 1:20 (*v/w*), τ_{MAE} 5 min) or 1.31 %. Probably, more phenolic antioxidants were retained in the complex matrix of crude pectin macromolecules with high EW.

AA of pectin obtained by UAE and MAE evolved differently. The AA of pectin extracted at the same ultrasound frequency, for 15 and 30 min, increased proportionally (R^2=0.8316 and R^2=0.8961) with TPC, which are responsible for the antioxidant effect, figures 3.4(a) and 3.4 (b). The AA of pectin extracted for 5 min by MAE increased proportionally with the concentration of polyphenols (R^2=0.8209), fig. 3.4(c). In the case of pectin extracted by MAE for 10 min, AA did not increase proportionally with TPC (R^2=0.2779), fig. 3.4(d). This is explained by the advanced depolymerisation reactions of pectin with the release of functional groups (carbonyl, carboxyl) responsible for the AA effect.

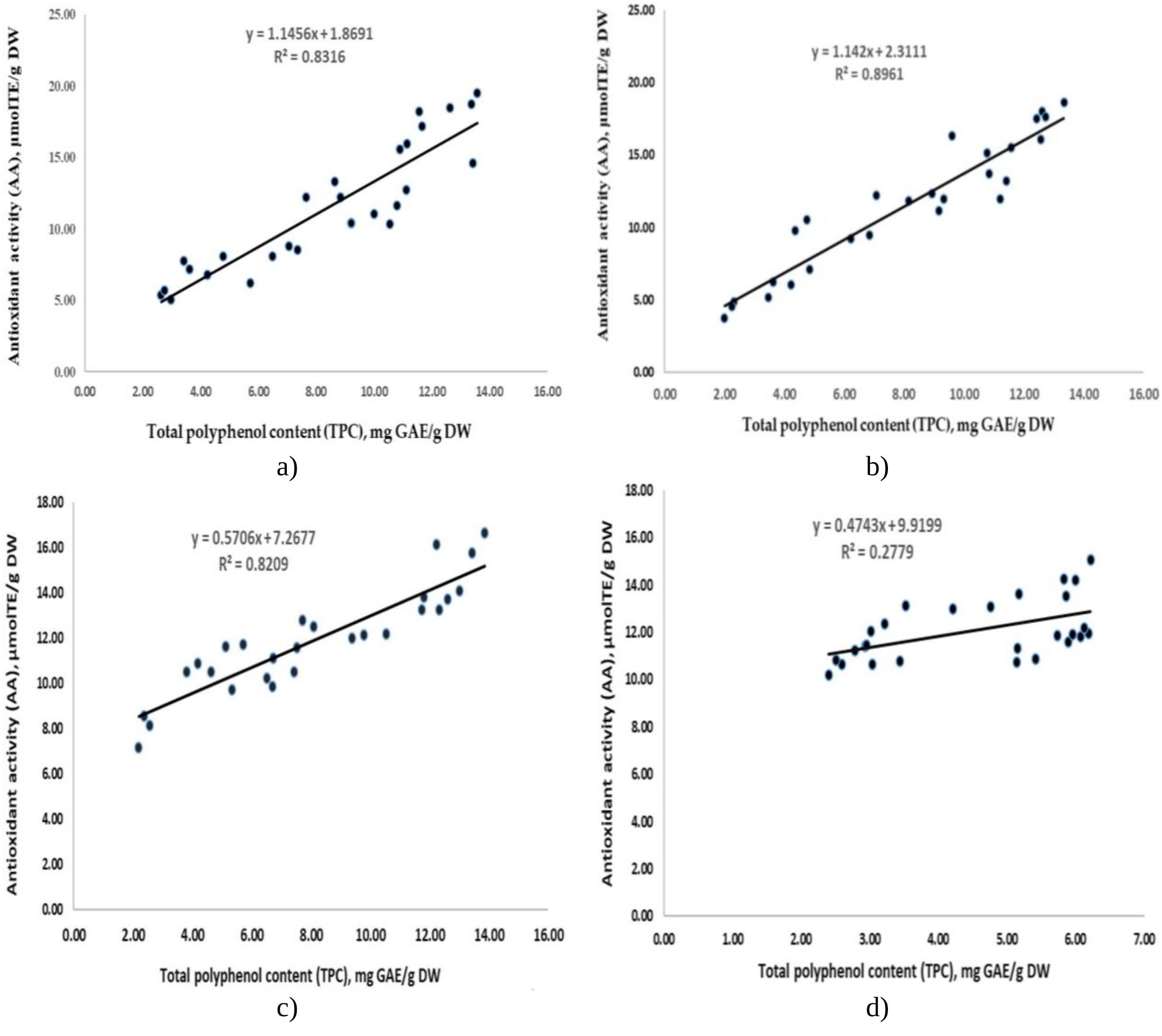


Fig. 3.4 Correlation between the total content of polyphenols and the antioxidant activity of pectin obtained by UAE for 15 min (a) and 30 min (b); MAE for 5 min (c) and 10 min (d).

The research results demonstrated that the unconventional UAE and MAE extraction methods are easy to control and can be applied to obtain pectin with predicted properties.

Pectin, which contains polyphenolic compounds, obtained by UAE and MAE and applied in compositions as a binding and coating agent will have a wider spectrum of biological activity, to which antioxidant activity is added (Gurev et al., 2023b).

4. THE USE OF APPLE POMNCE AND PECTIN IN THE MANUFACTURE OF NEW FOOD PRODUCTS

The main objective of the research in the given chapter is to develop the technology for the manufacture of vegetable bars with the use of pectin extracted from AP as a binding and coating agent; the use of AP powder in the manufacture of yogurt as a thickener and stabilizer, and in biscuits to replace sugar as a sweetener. The research was carried out in the following directions: determining the influence of the 360 - days storage period on the sensory and physicochemical quality, the biological value of dried fruit bars with the use of pectin as a binding and coating agent; establishing the influence of the 20 - days storage period on the sensory characteristics, physicochemical parameters, texture and biological value of yogurt with the addition of AP powder; developing the technology for manufacturing biscuits with AP powder by replacing sugar and determining the sensory and physicochemical quality of the biscuits.

4.1. The use of pectin in the manufacture of dried fruit bars

Vegetable bars are a mixture of dried fruits (plums, cherries, apples and rosehip powder) with pectin as a binding and coating agent, obtained under optimal MAE extraction conditions: pH~2, LRS 1:20 (*v/w*), τ_{MAE} 10 min and magnetron power 450 W, which were manufactured according to (Ceşko et al., 2022a; Gurev et al., 2023b). Rosehip powder was applied to maintain the microbiological stability of the vegetable bars during storage. Analysis of sensory quality, physicochemical parameters, microbiological stability and biological value (TPC, TFC and AA) of the bars was done every 90 days.

The influence of storage time on the sensory parameters of vegetable bars. The use of pectin as a binding and coating agent favourably influenced both the sensory and physicochemical quality, microbiological stability and biological value of the stored bars 360 days. The sensory characteristics of the vegetable bars were assessed based on the quality of the dried fruits included in their composition in accordance with the quality requirements of the dried fruits. Appearance, consistency, color, smell and taste were evaluated. During storage, the sensory quality of the bars did not change essentially except for the taste, which at the end of the storage period (360 days) tasted predominantly of cherry fruit. The application of pectin minimized the level of damage to the bars and allowed them to be stored for a long time.

The evolution of the physicochemical parameters in vegetable bars during the storage period. During storage (360 days), with an interval of 3 months, physicochemical parameters, microbiological stability, biological value and antioxidant activity of vegetable bars were analysed, which are presented in table 4.1. The obtained results demonstrate that the physicochemical parameters, microbiological stability, biological value and AA of vegetable bars did not change significantly during storage. **The moisture content** during bar storage gradually decreased from 30.0% (1st day) to 23.6% (360th day), to 21.3%. This was due to pectin's property of gelling and retaining moisture inside the bars. The pectin protective film on the surface of the bars acted as a barrier in controlling moisture retention, it reduced the interaction processes between food molecules and the environment (Gurev et al., 2023a). **The evolution of pH** in vegetable bars during storage was due to plum and cherry fruits, citric acid used in the formation of pectin suspension and rosehip powder used for microbiological stability. During 3 months, the pH value did not change essentially. A slight increase in pH was observed from 3.64 (on the 180th day) to 3.95 (on the 360th day), and the treatable acidity of the samples decreased from 1.12% (on the first day) up to 0.83% relative to citric acid (360th day), due to the physicochemical transformations of the compounds that occurred in the vegetable bars during storage.

Table 4.1. Evolution of physicochemical parameters, biological value, antioxidant activity and microbiological stability in bars during the storage period

Parameters	Storage time, days				
	1	90	180	270	360
Moisture content, %	30.0 ± 0.1 ^{e}	28.5 ± 0.1 ^{d}	26.4 ± 0.0 ^{c}	25.1 ± 0.1 ^{b}	23.6 ± 0.1 ^{a}
pH	3.61 ± 0.03 ^{a}	3.61 ± 0.02 ^{a}	3.64 ± 0.0 ^{a}	3.75 ± 0.02 ^{b}	3.95 ± 0.01 ^{c}
Titratable acidity, % expressed in citric acid	1.12 ± 0.02 ^{c}	1.08 ± 0.01 ^{b}	1.05 ± 0.01 ^{b}	0.84 ± 0.02 ^{a}	0.83 ± 0.02 ^{a}
Water activity, c.u.	0.571 ± 0.002 ^{d}	0.565 ± 0.003 ^{d}	0.543 ± 0.001 ^{c}	0.510 ± 0.002 ^{b}	0.496 ± 0.001 ^{a}
Total polyphenol content, mg GAE/g DW	7.68 ± 0.12 ^{c}	7.63 ± 0.13 ^{c}	7.57 ± 0.11^{c}	6.24 ± 0.13 ^{b}	5.59 ± 0.07 ^{a}
Total flavonoid content, mg EQ/100 g DW	2.75 ± 0.05 ^{d}	2.71 ± 0.09 ^{d}	2.48 ± 0.02 ^{c}	2.13 ± 0.04 ^{b}	1.85 ± 0.05 ^{a}
Inhibition (DPPH), %	84.09 ± 1.33 ^{d,e}	82.62 ± 1.35 ^{d,e}	77.9 ± 0.48 ^{c,d}	72.29 ± 0.39 ^{b}	67.80 ± 0.56 ^{a}
Antioxidant activity (DPPH), µmol TE/g DW	24.85 ± 0.14 ^{d}	24.80 ± 0.09 ^{d}	23.52 ± 0.05 ^{c}	22.31 ± 0.07 ^{b}	20.14 ± 0.0 ^{a}
Total viable count (TVC), CFU/g	0 ± 0 ^{a}	2.0 ± 0.1 ^{b}	2.0 ± 0.1^{b}	2.0 ± 0.1 ^{b}	2.0 ± 0.1 ^{b}

Values in the table represent means of three replicate experiments ± standard deviation. Letters ($^{a–e}$) denote statistically different results ($p \leq 0.05$).

The water activity (a_w) determined in the vegetable sticks over a period of 360 days changed from 0.571 to 0.496 c.u., indicating a decrease of 14%. The aw values demonstrate the proper preservation of vegetable sticks, as well as the protective and stabilizing effect of pectin as a binding and coating agent. The pectin maintained the amount of water needed to keep the veggie bars fresh.

From the point of view of **microbiological standpoint**, the reduction of the moisture content of the dried fruits used, the low pH values, the use of pectin both as a binding agent and as a protective layer, as well as vacuum packaging stopped the growth of microorganisms during storage, thus microbiological stability being ensured throughout the storage period.

The analysis of biologically active compounds in the bars demonstrated that the inclusion of dried fruit and rosehip powder in the composition of the food, together with the use of pectin as a binding and coating agent, had a positive influence on the evolution of the antioxidant content during storage. TPC, including TFC, in the first six months of storage remained close to the initial values: 7.68 mg GAE/g DW (TPC) and 2.75 mg EQ/100 g DW (TFC). However, towards the end of storage, the BAC content decreased to 5.59 mg GAE/g DW (TPC) and 1.85 mg EQ/100 g DW (TFC). Pectin, with antioxidant intake, marked a role of stabilizer and protective barrier, significantly reducing the degradation process of BAC during storage of bars (Gurev et al., 2023a; Ceșko et al, 2022c)

The antioxidant activity (DPPH) in the bars initially had a value of 24.85 μmol TE/g DW, which decreased slightly during the first 6 months and reached 20.14 μmol TE/g DW at the end of one year of storage under suitable conditions. These values did not undergo significant changes during the storage period due to the increased content of polyphenols in the vegetable bars and the intake of antioxidants from fruits and pectin. The research of the present study demonstrated that the pectin extracted by MAE used subsequently as a binding and coating agent in the technological process of manufacturing bars, maintained the AA and the high functional value of the food during 12 months of storage.

4.2. The use of apple pomace in the manufacture of yogurt

Yogurt plays an essential role in dietary recommendations because it fulfils the function of providing nutrients and bioactive compounds essential for health: vitamins and mineral salts, lactose, bioactive proteins, lipids and live lactic bacteria beneficial to the gastrointestinal tract (Gómez-Gallego et al., 2018) . The main factors affecting the structure and texture of yogurt are: the protein and fat content, the technological process and the properties of the added ingredients (especially stabilizers). The manufacture of yogurt with the addition of AP powder (PAP) aims to investigate the influence of AP concentration on sensory characteristics, physicochemical and textural parameters and its antioxidant activity during the storage period. The use of YAP allowed the development of a yogurt with a structure and texture enriched with dietary fiber and BAC, also as a stabilizer (Popescu et al., 2022).

Pasteurized milk of 2.5% fat, PAP and lyophilized starter culture type FD-DVS and YAB 352B were used for the production of yogurt. Yogurt samples were obtained using 0.2; 0.4; 0.6; 0.8 and 1% YAP (0.2% YAP, 0.4% YAP, 0.6% YAP, 0.8% YAP and 1.0% YAP) (Popescu et al., 2022). To reach pH~4.6, the fermentation time of the yogurt samples varied between 7 and 8 h. The addition of AP powder was found to reduce the fermentation time from 8 h to 7.5 h in in the case of the yogurt sample 0.4% YAP and 0.6% YAP and up to 7 h in the case of 0.8% YAP and 1.0% YAP. In case 0.2% YAP no essential changes were observed during the fermentation time. The reduction in fermentation time in the case of samples 0.4% YAP - 1.0% YAP was probably due to the acidic character of AP due to the presence of organic acids (malic, lactic, citric and succinic).

Yogurt samples were evaluated on the first day after production (sensory quality, physicochemical, color parameters and antioxidant activity) and during storage on the 7th, 14th, 17th and 20th day (sensory quality, pH and texture parameters) . Sensory analysis of yogurt samples with and without YAP demonstrated that the characteristics correspond to the quality requirements for milk and dairy products. The highest score of general acceptability was obtained by the 0.6% YAP and

0.8% YAP samples, which were characterized by a clot of firm and creamy consistency, specific smell and taste of yogurt, with specific characters of lactic fermentation and apple.

The physicochemical analysis of the yogurt samples included the determination of dry matter content, fat content, total dietary and insoluble fiber content, as well as antioxidant activity. **The total solids content** of the yogurt varied between 14.40% (PAP) and 15.04% (YAP 1%). Increasing YAP content caused a non-essential increase in fat content from 0.15% (AP) to 0.18% (1% YAP). AP at 1% increased the level of insoluble fiber in yogurt by 0.14% compared to PAP. Cellulose, lignin, protopectin, etc. which are part of insoluble fibers in yogurt with YAP, are distributed in the serum phase of the casein network. These, being rehydrated, contributed significantly to the retention and immobilization of the whey, thus forming some colloidal networks. Both possible interactions suggest that AP acts as an active filler with additional stabilization of the serum phase in casein. **Regarding the total dietary fiber content**, the value increased by approximately 0.25% (0.4% YAP) and 0.63% (1% YAP) compared to PAP. Similarly, increasing YAP content in yogurt samples resulted in increased **antioxidant activity**. In the case of 1.0% YAP, the antioxidant activity reached the value of 29.8 μmol TE/100 g sample. Even the smallest amount of YAP (0.2%) caused an increase of 0.3 times the antioxidant activity compared to YP, and a 1% amount of YAP resulted in a 56-fold increase. **Yogurt color** is an important indicator that influences the quality, commercial value and acceptability of the product. As the amount of YAP increased from 0.2 – 1%, the luminance values (L*) of the samples decreased by 1.05 times, the values of the red-green component are located in the negative range, which confirms the presence of the tone green in all samples analysed. In the case of the yellow-blue component (b*), in all analysed samples the yellow color prevailed due to the addition of YAP. The overall color difference (ΔE*) of yogurt samples with PAP increased from 0.77 (0.2% YAP) to 4.5 (1.0% YAP). Thus, it was demonstrated that depending on the ΔE* values - 0.2% YAP was classified with imperceptible color differences (0.5-1.5), 0.4% YAP - with only visible differences (1.5- 3.0); 0.6% YAP; 0.8% YAP and 1.0% YAP with color marked differences (3.0-6.0).

During the storage period, the sensory quality of the yogurt samples did not change essentially, except for the 1.0% YAP sample. On the 20th day of storage, yogurt samples 0.4% YAP, 0.6% YAP and 0.8% YAP were rated the highest 4.82-4.83 because a curd was preserved of creamy consistency, smell and taste specific to yogurt and apple curd.

The evolution of pH during storage is also determined by the growth of lactic acid bacteria from the starter culture and AP in the yogurt. Cold storage time led to a gradual decrease in pH in all analysed samples, and the lowest pH value was recorded on the 20th day, the values being in the range of 4.24 (1% YAP) - 4.47 (YP).

Knowledge of the **rheological and especially textural properties** of yogurts is particularly important from a technological point of view. Addition of YAP led to lower gelation pH and shortened fermentation time (especially for 1% YAP), developing a firmer and more consistent gel during cold storage. YAP significantly influenced the textural properties of yogurt. As the amount of powders increased from 0.2 to 1%, the firmness values increased from 1297 g to 1944.

The stickiness of pomace yogurts showed a decreasing trend from 1306 g·s (0.2% YAP) to 1219 g·s (1.0% YAP). It is considered that the value of the yogurt's stickiness is inversely proportional to the consumption quality of the yogurt (Popescu et al., 2022). **Cohesion** is correlated with consumer acceptability of yogurt and is an important parameter for yogurt texture analysis. It was shown that the cohesion values of the yogurt samples increased with the increase in the concentration of YAP added, the maximum value (0.703%) being recorded in the case of YAP 1%. The increase in cohesion of the yogurt samples with YAP could be due to the viscosity imparted by the pomace, which could provide strength to the yogurt structure. It was found that the elasticity of the yogurt increased with the increase in the level of YAP addition, and the maximum value was recorded for yogurts with addition of 0.8-1.0%. The level of gumminess in yogurt influences consumer acceptability and can vary from person to person. The results of textural analysis during storage suggested that the addition of YAP led to the formation of a stable system and a strong three-dimensional network in the yogurt. Therefore, the increase in the degree of cross-linking of the gel network and as a result the formation of a firmer gel structure was demonstrated (Bulgaru et al., 2023). During the storage period (20 days) the yogurt samples fortified with YAP showed improved firmness, elasticity and cohesion, indicating a strengthening of the structure of the casein gels.

Syneresis occurs due to the inability of the yogurt gel to retain the serum phase and the weakening of the casein network leading to the release of the whey (Lucey, 2004). Thus, the highest value of 26.65% was recorded for YP. The addition of YAP to the yogurt structure reduced the whey separation capacity. In 1.0% YAP, the value of syneresis was the lowest at 24.38%, as it was the best whey retention. Vianna et al., (2017) reported that increasing the total solid content positively influences the network density and reduces the syneresis of fermented milk. The syneresis of YP showed an increasing trend, while the syneresis of yogurt samples with added powder decreased steadily during the 20 days of cold storage. Oliveira et al., (2015) established that the modification of syneresis can be related to the interaction between polyphenols-proteins, since the former have a high affinity for casein. Covalent or non-covalent interactions between polyphenols and proteins lead to the formation of stable soluble complexes. The interactions promote the strength of the casein network (hydrophobic interaction) and the formation of hydrogen bonds. A stronger influence on the parameters was observed at higher concentrations of AP.

In general, the textural parameters correlated with the sensory characteristics, except for the 1.0% YAP sample. This sample demonstrated the high values of the textural parameters but from the sensory point of view it was appreciated with a low score as a result of the appearance of the coarse sensation of the AP particles in the oral cavity. The addition of 0.6-0.8% YAP resulted in a yogurt with a firm texture, increased elasticity and cohesiveness, reduced gumminess and stickiness, and high acceptability suggesting that these are optimal concentrations for industrial manufacturing.

The analysis of mutual information regarding the influence of different YAP concentrations added in yogurt samples on the overall acceptability and textural parameters demonstrated that YAP concentrations in yogurt samples essentially influenced the sensory quality of yogurt and textural parameters table 4.2.

Table 4.2 Influence of storage time and PAP concentration (0,2%;0,4%;0,6%;0,8%;1%) on texture parameters and general acceptability of yogurt samples

Parameter	Parameter information analysis values, bits	
	Influence of storage time	Influence of PAP concentration
Firmness	0.122	0.595
Springiness	0.109	0.631
Cohesiveness	0.141	0.890
Adhesiveness	0.165	0.477
Gumminess	0.105	0.986
Syneresis	0.120	0.398
General acceptability	0.199	0.965

Guminess was most influenced (0.986 bits), followed by cohesion (0.890 bits) and elasticity (0.631 bits). For syneresis, the mutual information analysis value was the lowest (0.398 bits). PAP concentrations greatly influenced the quality of the yogurt samples, as the mutual information analysis value for overall acceptability was 0.965 bits. It was shown that the storage time (20 days) of yogurt without and with the addition of YAP in concentrations (0.2-1%) did not essentially influence the overall acceptability and textural parameters of the product. Information analysis values for textural features ranged from 0.105 bits for gumminess to 0.165 bits - tackiness, and for general acceptability it was 0.199 bits.

The influence of YAP addition and storage time on sensory analysis, physicochemical indicators and textural parameters of yogurt samples was analysed, finding the acceptability of using APin the production of a new yogurt enriched with dietary fiber and BAC (Popescu et al., 2022).

4.3. The use of apple pomace in the manufacture of biscuits

Biscuits are sweet flour products with a long shelf life, obtained by baking a loose dough made from wheat flour, water, sugar, fats, eggs, chemical leavening agents and various other types of matter that enrich the food value (Banu, 2002). The classic biscuit recipe was used to prepare the biscuits, which includes: high-quality wheat flour, granulated sugar, butter, table salt and sodium bicarbonate. For research AP was used as a substitute for granulated sugar in the biscuit recipe. The biscuit samples were coded as follows: BS - control sample with 100% sugar; BAP1 - substitution of 25% sugar with AP; BAP2 - substitution of 50% sugar with AP; BAP3 - substitution of 75% sugar with AP; BAP4 - sample with 100% AP. Sensory characteristics such as external appearance and section, color, aroma and taste that correspond to the quality requirements for confectionery products were evaluated. It was noted that the addition of powdered apples by replacing sugar in the BAP1 and BAP2 biscuit samples did not significantly differ from BS. In the samples of biscuits BAP3 and BAP4 there was a change in color, it being darker, and in its taste a note of apple fruits was sampled with the decrease from the initial sweetness. The smell was pronounced of apples. In the external aspect and in the section essential differences were not highlighted.

Color is an important indicator of quality that is attributed to the main signs of organoleptic properties for biscuits. It was found that the L* values of the biscuits showed a decreasing trend from 78.87 (BS) to 58.08 (BAP4), by 26.3%, with the increase in the level of sugar replacement with powdered AP. Lower L* values indicated that the cookies were darker in color at higher levels of sugar substitution with AP powder compared to BS. The values of the parameter a* were between 2.45 (BS) to 10.72 (BAP4), and b* values ranged from 29.83 (BS) to 34.96 (BAP4), demonstrating the predominance of red color over green and yellow color, in the disadvantage of blue, respectively. The resulting color of the biscuits was light yellow (BAP1) and dark yellow (BAP2, BAP3 and BAP4). Samples BAP 3 and BAP 4 had a higher content of apple pomace, which facilitated their browning. Change in color values C* from 29.93 (BS) to 36.57 (BAP4), demonstrated the increase in the intensity of the color of the biscuits with the increase in the concentration of AP powder. The values of the hue angle H* for all samples are in the first trigonometric quadrant, but for samples BS and BAP1 the light yellow color tone predominates, and for BAP2, BAP3 and BAP4 - the dark yellow color tone. ΔE* represents a dimensionless parameter, resulting from the combination of the L*, a* and b* values of the sample pairs, which indicates whether or not there are differences in the colors perceived by the human eye. For BAP1, the ΔE* value was in the range $6 < \Delta E^* < 12$, demonstrating a large color difference, and for BAP2- BAP4 samples the ΔE* values were > 12, completely different colors. The composition of AP significantly influenced the ΔE* values, since the baking conditions were the same for all samples obtained.

Physicochemical quality analysis (moisture content, swelling index and alkalinity) was done to investigate the influence of replacing sugar with AP powder on these indicators, table 4.3. The moisture content of AP powder biscuits decreased from 10.12% (BS) to 8.08% (BAP4). Probably, this decrease was influenced by the baking time, which increased with increasing concentration of sugar substitution with AP powder. The swelling index reflects aspects related to the quality, functionality and acceptability of the product. The swelling index of the biscuit samples increased from 114% (BS) to 132% (BAP4), by 15.8%. The substitution of sugar with AP powder in amounts of 25%, 50%, 75% and 100% increases the content of dietary fibers in biscuits, represented by cellulose, hemicellulose and pectin substances that have the capacity to absorb and retain water inside the biscuits, increasing the mass of the product. The values obtained for alkalinity were below the admissible limit and did not exceed the norms provided in the normative acts. According to the obtained data, it is confirmed that the alkalinity values decrease with the increase in the amount of AP powder from 1.98 (BS) to 1.8 (BAP4).

During the storage period of the biscuits for 30 days, samples BAP 1 and BAP 2 did not show significant changes in sensory characteristics, and BAP 3 and BAP 4 became more crumbly. Probably, during storage (30 days), the high dietary fiber content of AP released the physicochemical bound water, influencing the structure of the finished product.

Table 4.3 The evolution of the physicochemical parameters of biscuits with apple quince powder on the first day of manufacture and during the 30-day storage period.

Nr.	Physicochemical indices	Name of samples	Results obtained on the first day of manufacture	Results obtained after 30 days of storage
1	Moisture content, %	BS	10.12±0.01 ^{h}	10.06±0.01 ^{h}
		BAP 1	9.68±0.01 ^{f}	9.70±0.01 ^{f}
		BAP 2	9.17±0.02 ^{e}	9.28±0.02 ^{e}
		BAP 3	8.52±0.01 ^{c}	8.77±0.01 ^{d}
		BAP 4	8.08±0.01 ^{a}	8.30±0.01 ^{b}
2	Alkalinity, degrees	BS	1.98±0.01 ^{h}	1.96±0.01 $^{g.h}$
		BAP 1	1.93±0.01 $^{f.g}$	1.90±0.01 $^{e.f}$
		BAP 2	1.90±0.01 $^{e.f}$	1.88±0.01 $^{d.e}$
		BAP 3	1.87±0.01 $^{d.e}$	1.85±0.01 $^{c.d}$
		BAP 4	1.80±0.01 ^{b}	1.78±0.01 ^{a}
3	Swelling index, %	BS	114±1 ^{b}	111±1 $^{a.b}$
		BAP 1	120±2 $^{c.d}$	116±2 $^{b.c}$
		BAP 2	124±2 $^{d.e}$	119±3$^{c.d}$
		BAP 3	128±3 $^{e.f}$	122±1 ^{d}
		BAP 4	132±0 ^{f}	125±2 $^{d.e}$

Values in the table represent means of three replicate experiments ± standard deviation. Letters ($^{a–h}$) denote statistically different results ($p \leq 0.05$).

The storage time influenced the **moisture content** values in the studied samples. In BS, this indicator decreased by 0.6% compared to the values determined on the first day after production. In the case of samples in which sugar was substituted with apple pomace, moisture content increased in relation to the values determined on the first day after production: BAP1 with 0.21%, BAP 2 with 1.19%, BAP 3 with 2.93% and BAP 4 with 2.97%, probably due to the dietary fibers in the composition of the vegetable powder that retained the water inside the product. During the storage period the **alkalinity** of the biscuits decreased from 1.96 degrees (BS) to 1.78 degrees (BAP 4). Probably, the increase in moisture content and the presence of organic acids in AP led to the neutralization of sodium bicarbonate during the storage of biscuits. In the case of BS, the **swelling index** decreased by 2.63%, BAP 1 by 3.33%, BAP 2 by 4.03%, BAP 3 by 4.69% and BAP 4 by 5.30%. **The values of a_w**, of the biscuit samples kept for 30 days, varied in the range of 0.249 - 0.337 c.u. Ghendov-Mosanu et al., (2023) reported that a_w values less than 0.60 prevent microbial spoilage and show microbiological stability of the product. The analysis of the total number of microorganisms in the biscuits revealed acceptable values for the 30-day storage period, which fell within the allowed limits.

The research results show that the replacement of sugar with AP powder in optimal concentrations of 25 and 50% (BAP 1 and BAP 2) allowed to obtain biscuits in accordance with the normative documents. Biscuits rich in dietary fiber with low sugar content can be recommended to consumers suffering from some non-communicable diseases and to children.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The problems addressed in the thesis were aimed at the rational utilization of agro-industrial waste, especially AP and obtaining pectin for use in the formulation of new food products. Based on the main results of the research, the following conclusions were formulated:

1. In the convective drying process of apple pomace, increasing the temperature of the heat carrier in the range of 60-80 °C leads to a 1.6 times reduction in drying time. Analysis of the drying curves demonstrated a reduction in drying time in the first period by 15.4%, and in the second – by 45.4%. The drying speed values increased by 1.36 times, and the drying coefficient K_{II} increased by 1.49 times (Ceşko et al., 2023a; subchapter 3.1).

2. Seven empirical mathematical models were applied that described the kinetics of the convective drying process of AP based on MR changes. The maximum fidelity to the experimental data was obtained by the Midilli's model, the R^2 value was 0.9996 (60 and 70 °C) and the Wang and Singh's model, R^2 being 0.9937 (80 °C) (subchapter 3.1).

3. The temperature of the heat carrier influenced the BAC and AA content of dried apple pomace. The most optimal BAC values were recorded at a drying temperature of 70°C. The correlations between BAC and AA are high, the coefficient of determination R^2 being 0.983 (TPC-AA), 0.984 (TC-AA) and 0.915 (CTC-AA) (Ceşko et al., 2023a; subchapter 3.2)

4. The physicochemical parameters and biological value of pectin extracted by unconventional methods were significantly influenced by the pH value, the hydro modulus (LSR) and the extraction duration (τ). The maximum extraction yield was obtained in the case of MAE - 19.88 %, and in the case of UAE - 9.91%. In the MAE method, the highest values were determined for EW (2261 g/mol) and TPC 13.05 (mg GAE/g DW) and AA constituted 16.39 (μmol TE/g DW). When extracting pectin by UAE, higher values were obtained for MeO (6.81%), AUA (78.71%), DE (73.78%) and AA (18.86 μmol TE/g DW) (Gurev, Ceşko et al., 2023a; subchapter 3.2 and 3.3).

5. Mutual information analysis of the influence of pH of the extraction medium in the UAE method with the duration of ultrasound application τ_{UAE} 15 min and 30 min at all RSL demonstrated that EW and DE were considerably influenced, the values varying in the range of (0.995-0.998 bits), and TPC was moderately influenced, the values varying between (0.491 – 0.812 bits). In the case of MAE with the application of microwaves τ_{MAE} 5 min and 10 min, pH significantly influenced the yield – (0.998 bits), but less AA (0.101-0.325 bits) (Gurev, Ceşko et al., 2023b; subchapter 3.2 and 3.3).

6. The extraction method and duration influenced the AA of pectin differently. The AA values obtained through UAE time for 15 and 30 min increased proportionally (R^2=0.8316 and R^2=0.8961). In the case of MAE, when applying microwaves for 5 min, AA increased proportionally with the concentration of polyphenols (R^2=0.8209), and for 10 min, no direct correlation was revealed between AA and TPC (R^2=0.2779) (Gurev, Ceşko et al., 2023b; subchapter 3.5).

7. The applicability of pectin as a binding and coating agent for vegetable bars was demonstrated. Over a storage period of 360 days, no essential changes were observed in the sensory quality; the moisture content and AA of the bars were reduced by 1.4 times and 1.23 times, respectively; the pH increased by 1.08 times, and the water activity practically did not change. Pectin

positively influenced the physicochemical parameters and microbiological stability of the bars. (Gurev, Ceşko et al., 2023a; Ceşko et al., no. 10140 of 06.10.2022a, subchapter 4.1).

8. Sensory quality analysis of yogurt fortified with AP powder (YAP 0.6% and 0.8%) during storage (20 days) demonstrated a firm, creamy consistency, with a specific smell and taste of yogurt and apple. Increasing the AP content led to a reduction in fermentation time by 1 h; to increase the values of firmness by 1.61 times, cohesion - by 2.43 times, elasticity by 2.06 times and to significantly reduce syneresis - by 1.17 times, adhesiveness by 1.15 times and gumminess by 2.5 times compared to YP. A significant increase in AA was demonstrated, by 56 times for YAP 1.0% compared to YP (Popescu, Ceşko et al., 2022; subchapter 4.2).

9. AP powder was applied to the production of biscuits with sugar replacement in the proportion of 25 - 100%. During the storage of biscuits (30 days), no essential changes in color, taste, smell and appearance were observed, the humidity and alkalinity decreased by 1.25 and 1.12 times respectively, and the soaking index increased by 1.08 times due to the property of AP fibers to retain moisture. Microbiological stability during the storage period indicated values that were within the permissible limits. (Ceşko, 2021; subchapter 4.3).

Based on the research conducted, the following practical recommendations were formulated:

Optimal preservation conditions are created by convective drying of apple pomace, ensuring the preservation of biological value and antioxidant potential, at a temperature of 70 °C.

Extraction of pectin from AP can be achieved by non-conventional UAE and MAE methods. To obtain an increased yield of pectin through UAE, the following extraction parameters are recommended: frequency 37 kHz, pH~1.5; LSR 1:20 (*v/w*), τ_{UAE} 30 min, and for MAE the recommended magnetron power is 450 W, pH~1.5 or 2; LSR 1:20 (*v/w*), τ_{MAE} 10 min, which allow pectin extraction with high yield and appropriate biological value.

As part of the thesis, a number of technological processes for the production of new food products were developed, recommended for implementation in the food industry.

The technology of manufacturing vegetable bars using pectin as a binding and coating agent - according to the patent of invention.

Yogurt manufacturing technology with the addition of AP powder. The optimal concentrations of 0.6 and 0.8% AP powder are recommended to obtain yogurt with a firm, creamy consistency, a specific yogurt and apple smell and taste.

Biscuit manufacturing technology. Replacing sugar with AP powder in quantities of 25 and 50% allows obtaining a product with a low level of calories, but rich in dietary fiber, being recommended for consumers affected by some non-communicable diseases and for children.

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ABSTRACT

Ceşko Tatiana: "Technologies for obtaining dietary fibers from horticultural sources", PhD thesis in engineering sciences, Chisinau 2025.

Structure of the thesis: consists of introduction, 4 chapters, conclusions and recommendations, bibliography with 316 titles. The main text contains 118 pages, including 46 figures and 34 tables. The obtained results are published in 19 scientific papers.

Keywords: apple pomace, ultrasound-assisted extraction, microwave-assisted extraction, pectin, biologically active compounds, mathematical modeling, vegetable bars, yogurt, crackers, quality.

The purpose of the work: evaluation of apple pomace and obtaining pectin with high biological value by unconventional extraction methods UAE, MAE and their use in the manufacture of new food products.

The objectives of the paper: the research of the influence of the temperature of the thermal agent on the kinetics of convective drying, the kinetic characteristics, the biological and antioxidant value of apple pomace as a source of obtaining pectin; establishing the mathematical models of the kinetics of the process of drying apple pomace at different temperatures of the thermal agent based on empirical mathematical models; determining the influence of UAE and MAE conditions on the physicochemical parameters, biological value and antioxidant activity of pectin from apple pomace, establishing the optimal extraction conditions and comparing these extraction methods; the application of pectin as a binding and covering agent in the manufacture of vegetable bars and the research of its influence on the quality, microbiological stability and biological value during the storage period; the influence of apple pomace powder, as a stabilizer in yogurt manufacturing, on quality, textural parameters, color and antioxidant activity during storage; the effect of apple pomace powder when replacing sugar in biscuit manufacturing on quality and color during storage.

Scientific novelty and originality: for the first time, the modeling of the kinetics of the process of convective drying of the apple core of the Golden Delicious variety at different temperatures of the thermal agent was carried out, with the application of seven empirical mathematical models; optimal conditions of UAE and MAE of pectin from apple pomace were established and the application of mutual information analysis regarding the influence of extraction conditions on the physicochemical characteristics, biological value and antioxidant activity of pectin; new food manufacturing technologies were developed in which apple pomace and pectin were applied as natural food additives with different actions.

Main results: convective drying of the gooseberry at the optimal temperature of the thermal agent allowed the preservation of the biological value and the antioxidant potential; the modeling of the kinetics of the process of convective drying of apple pomace was carried out, with the application of seven empirical mathematical models; the use of the UAE and MAE methods and the influence of the extraction conditions on the physicochemical parameters, biological value and antioxidant activity of pectin from apple pomace were argued, as well as establishing the optimal conditions for each method; the analysis of mutual information regarding the influence of UAE and MAE on the physicochemical characteristics, biological value and antioxidant activity of pectin was carried out; of apple pomace powder concentration and storage time of yogurt samples on overall acceptability and textural parameters; the application of pectin as a binding and coating agent in obtaining vegetable bars was argued; the effect of apple pomace powder as a stabilizer in yogurt production was demonstrated; the effect of apple pomace powder on the substitution of sugar in the manufacture of biscuits was elucidated.

Theoretical significance: for the first time, modeling of the kinetics of the process of convective drying of Golden Delicious apple cores at different temperatures of the thermal agent was carried out, with the application of seven empirical mathematical models; optimal conditions of UAE and MAE of pectin from apple pomace were established and the application of mutual information analysis regarding the influence of extract conditions on the physicochemical characteristics, biological value and antioxidant activity of pectin; new product manufacturing technologies were developed in which apple pomace and pectin were applied as natural food additives with different action.

Applicative value: procedures for obtaining new food products were realized 2 invention patents were obtained an act of implementation of the technology of industrial manufacturing of sugar cookies and apple purée were obtained. procedures for obtaining new food products were realized.

ADNOTARE

Ceşko Tatiana: „Tehnologii de obținere a fibrelor alimentare din surse horticole”, teză de doctor în științe inginerești, Chișinău 2025.

Structura tezei: constă din introducere, 4 capitole, concluzii şi recomandări, bibliografie cu 316 titluri. Textul de bază conține 118 pagini, inclusiv 46 de figuri și 34 de tabele.
Rezultatele obținute sunt publicate în 19 lucrări științifice.

Cuvinte-cheie: tescovina de mere, extracția asistată de ultrasunete, extracția asistată de microunde, pectina, compuși biologic activi, modelare matematică, batoane vegetale, iaurt, biscuiți, calitate.

Scopul lucrării: constă în evaluarea compoziției tescovinei de mere, extragerea pectinei cu valoare biologică ridicată prin metode neconvenționale de extracție - UAE, MAE și utilizarea acestora în fabricarea produselor alimentare noi

Obiectivele lucrării: cercetarea influenței temperaturii agentului termic asupra cineticii de uscare convectivă, caracteristicilor cinetice, valorii biologice și antioxidante a tescovinei de mere ca sursa de obținere a pectinei; stabilirea modelelor matematice a cineticii procesului de uscare a tescovinei de mere la diferite temperaturi ale agentului termic pe baza modelelor matematice empirice; determinarea influenței condițiilor de UAE și MAE asupra parametrilor fizico-chimici, valorii biologice și activității antioxidante a pectinei din TM; determinarea influenței condițiilor optime de extracție și compararea eficienței acestor metode; aplicarea pectinei în calitate de agent de legare și acoperire în fabricarea batoanelor vegetale și cercetarea influenței ei asupra calității senzoriale, fizico-chimice, stabilității microbiologice, valorii biologice și activității antioxidante pe perioada de păstrare; influența pudrei din TM în calitate de stabilizator în fabricarea iaurtului asupra caracteristicilor senzoriale, parametrilor fizico-chimici, texturali, de culoare și activității antioxidante pe perioada de păstrare; efectul pudrei din TM în substituirea zahărului în fabricarea biscuiților asupra calității senzoriale, parametrilor fizico-chimici și de culoare pe perioada de păstrare a produsului de cofetărie.

Noutatea și originalitatea științifică: pentru prima dată a fost realizată modelarea cineticii procesului de uscare convectivă a tescovinei de mere din soiul Golden Delicious la diferite temperaturi ale agentului termic, cu aplicarea a șapte modele matematice empirice; au fost stabilite condiții optime de UAE și MAE a pectinei din tescovina de mere prin aplicarea analizei informației mutuale privind influența condițiilor de extracție asupra caracteristicilor fizico-chimice, valorii biologice și activității antioxidante a pectinei; au fost elaborate tehnologii de fabricare a produselor alimentare noi în care tescovina de mere și pectina au fost utilizate drept aditivi alimentari naturali cu diferite acțiuni.

Rezultatele principale: uscarea convectivă a tescovinei la temperatura optimă a agentului termic a permis păstrarea valorii biologice și potențialului antioxidant; s-a realizat modelarea cineticii procesului de uscare convectivă a tescovinei de mere, cu aplicare a șapte modele matematice empirice; s-a argumentat utilizarea metodelor UAE și MAE și influența condițiilor de extracție asupra parametrilor fizico-chimici, valorii biologice și activității antioxidante a pectinei din tescovina de mere, precum stabilirea condițiilor optime pentru fiecare metodă; s-a efectuat analiza informației mutuale privind influența UAE și MAE asupra caracteristicilor fizico-chimice, valorii biologice și activității antioxidante a pectinei; concentrației pudrei de tescovina de mere și duratei de păstrare a probelor de iaurt asupra acceptabilității generale și parametrilor texturali; s-a argumentat aplicarea pectinei în calitate de agent de legare și acoperire în fabricarea batoanelor vegetale; s-a demonstrat efectul pudrei din tescovina de mere drept stabilizator pentru iaurt; s-a elucidat efectul pudrei din tescovina de mere la substituirea zahărului în fabricarea biscuiților.

Semnificația teoretică: pentru prima dată a fost realizată modelarea cineticii procesului de uscare convectivă a tescovinei de mere de soiul Golden Delicious la diferite temperaturi ale agentului termic, cu aplicare a șapte modele matematice empirice; au fost stabilite condiții optime de UAE și MAE a pectinei din tescovina de mere cu analiza informației mutuale a condițiilor de extracție asupra caracteristicelor fizico-chimice, valorii biologice și activității antioxidante a pectinei; au fost elaborate tehnologii de fabricare a produselor noi în care tescovina de mere și pectina au fost aplicate în calitate de aditivi alimentari naturali cu diferite acțiuni tehnologice.

Valoarea aplicativă: au fost realizate procedee de obținere a produselor alimentare noi. Au fost obținute 2 brevete de invenție și un act de implementare a tehnologiei de fabricare industrială a biscuiților zaharoși cu tescovina de mere.

АННОТАЦИЯ

Чешко Татьяна: «Технологии получения пищевых волокон из садоводческих источников», диссертация на соискание ученой степени доктора инженерных наук, Кишинэу, 2025.

Структура диссертации: состоит из введения, 4 глав, выводов и рекомендаций, библиография в 316 наименованиях. Основной текст содержит 118 страниц, в том числе 46 рисунков и 34 таблицы. Полученные результаты опубликованы в 19 научных статьях.

Ключевые слова: яблочные выжимки, ультразвуковая экстракция, микроволновая экстракция, пектин, биологически активные вещества, математическое моделирование, фруктовые батоны, йогурт, печенье, качество.

Цель работы: оценка яблочных выжимок и получение пектина с высокой биологической ценностью нетрадиционными методами экстракции - УЗЭ, МЭ и их использование при производстве новых пищевых продуктов.

Задачи работы: исследование влияния температуры термического агента на кинетику конвективной сушки, кинетические характеристики, биологическую и антиоксидантную ценность яблочных выжимок как источника получения пектина; создание математических моделей кинетики процесса сушки яблочных выжимок при различных температурах термического агента на основе эмпирических математических моделей; определение влияния условий УЗЭ и МЭ на физико-химические параметры, биологическую ценность и антиоксидантную активность пектина из яблочных выжимок, установление оптимальных условий экстракции и сравнение этих методов экстракции; применение пектина в качестве связующего и покрывающего агента при производстве фруктовых батонов и исследование его влияния на качество, микробиологическую стабильность и биологическую ценность в период хранения; влияние порошка яблочных выжимок как стабилизатора при производстве йогурта на качество, текстурные параметры, цвет и антиоксидантную активность при хранении; влияние порошка яблочных выжимок при замене сахара в производстве печенья на качество и цвет при хранении.

Научная новизна и оригинальность: впервые проведено моделирование кинетики процесса конвективной сушки выжимки яблок сорта Голден Делишес при различных температурах термического агента с применением семи эмпирических математических моделей; установлены оптимальные условия УЗЭ, и МЭ пектина из яблочных выжимок и применение взаимного информационного анализа относительно влияния условий экстракции на физико-химические характеристики, биологическую ценность и антиоксидантную активность пектина; были разработаны технологии производства новых пищевых продуктов, в которых яблочные выжимки и пектин использовались в качестве натуральных пищевых добавок различного действия.

Основные результаты: конвективная сушка яблочных выжимок при оптимальной температуре термического агента позволила сохранить биологическую ценность и антиоксидантный потенциал; выполнено моделирование кинетики процесса конвективной сушки яблочных выжимок с применением семи эмпирических математических моделей; обосновано использование методов УЗЭ, и МЭ и влияние условий экстракции на физико-химические показатели, биологическую ценность и антиоксидантную активность пектина из яблочных выжимок, а также установлены оптимальные условия для каждого метода; проведен анализ взаимной информации относительно влияния УЗЭ, и МЭ на физико-химические характеристики, биологическую ценность и антиоксидантную активность пектина; концентрации порошка яблочных выжимок и продолжительности хранения образцов йогурта на общую приемлемость и текстурные параметры; аргументировано применение пектина в качестве связующего и покрывающего агента при получении фруктовых батончиков; продемонстрировано влияние порошка яблочных выжимок в качестве стабилизатора при производстве йогурта; выяснено влияние порошка яблочных выжимок на замену сахара при производстве печенья.

Теоретическая значимость: впервые проведено моделирование кинетики процесса конвективной сушки яблочных выжимок сорта Голден Делишес при различных температурах термического агента с применением семи эмпирических математических моделей; установлены оптимальные условия УЗЭ, и МЭ пектина из яблочных выжимок и применение взаимного информационного анализа влияния условий экстракта на физико-химические характеристики, биологическую ценность и антиоксидантную активность пектина; разработаны технологии производства новых продуктов питания, в которых в качестве натуральных пищевых добавок различного действия применяются яблочные выжимки и пектин.

Прикладное значение: реализованы способы получения новых пищевых продуктов. Получено 2 патента на изобретения и акт на внедрение технологии промышленного производства сахарного печенья с добавлением яблочных выжимок.

CEȘKO TATIANA

TECHNOLOGIES FOR OBTAINING DIETARY FIBERS FROM HORTICULTURAL SOURCES

Specialty 253.01 Technology of food products of vegetable origin

Summary of the doctoral thesis in engineering sciences

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