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# Chokeberry pomace as a component of innovative edible casings

## Summary

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### Introduction

Nowadays, product innovations, which often appear on the food market, play an increasingly important role. The development of product innovations for entrepreneurs in the food sector is treated as a key challenge resulting from factors such as the rapidly changing fashion on the market, shortening the life cycle of most products as well as strong competition or changes in consumer lifestyles. Product innovations are becoming one of the conditions for the development of the food market, especially those that bring measurable benefits to consumers. An important direction that can affect the effectiveness and competitive advantage of an enterprise operating in the field of agri-food processing is the design of innovative products aimed at the introduction and popularisation of pro-health solutions.

In recent years, a clear research direction closely related to the production of environmentally friendly products has been observed. Many research works have been devoted to the search for and analysis of natural biopolymers, which are of great interest in various industries due to their properties such as: non-toxicity, biocompatibility and biodegradability. These features make them an attractive material for a number of applications, including the production of edible casings protecting food products. An analysis of literature data shows that edible casings based on natural biopolymers are characterised by certain functional limitations. One of the ways to improve the functional properties of edible cas-

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ings may be the cross-linking of polymers with the use of bioactive compounds which have antioxidant properties.

The idea of a circular economy encompasses minimising waste by reusing or recycling it, as well as implementing full waste recovery, which means, above all, treating the generated waste as a potential source of secondary raw materials. Among such secondary raw materials, valuable for shaping the health-promoting properties of food, are the by-products of chokeberry fruit processing. In fact, chokeberry pomace is a natural source of bioactive compounds. A substantial amount of research work has been devoted to assessing the potential of chokeberries and their juice. Studies on the functional properties of chokeberry fruit processing by-products, as well as their broader use as secondary raw materials, have a much smaller share in the literature.

The basic method of obtaining substances with health-promoting properties from various by-products is extraction. Management of the extraction process using statistical planning methods can lead to a significant improvement in the results of the process and affect its technological and economic aspects. Therefore, the author defined the aim of this research taking into account the development of the sector of product innovations on the market of casings intended for direct contact with food and a balanced approach to the use of by-products in accordance with the assumptions of environmental protection.

Thus, the aim of the work was to assess the usefulness of chokeberry pomace extract in the development of innovative biopolymer chitosan casings with enhanced functional properties.

Based on the analysis of data from the literature and preliminary experimental research, the following hypotheses were formulated:

1. Appropriate solvent concentration in the range of 60%–96% and the sonication time between 10 and 30 minutes in extraction processes will ensure the optimal extraction of biologically active compounds from chokeberry pomace.
2. Fractional separation of substances contained in chokeberry pomace extracts will allow to obtain a group of compounds with the highest antioxidant properties.
3. Addition of a fraction of chokeberry pomace extract at the level of 0.5%–1.5% to chitosan casings will allow to obtain innovative chitosan casings with improved functional properties.

## Scope of research undertaken to achieve the aim of the work

The first stage of the research included the preparation of chokeberry pomace extracts and optimisation of the extraction process. For this purpose, research material was obtained and prepared, i.e. pomace from two varieties of black

chokeberry. The obtained pomace was subjected to the process of lyophilisation. Next, from the obtained lyophilisates, extracts were prepared for the preliminary analysis of phenolic compounds and antioxidant properties, on the basis of which the Nero variety was selected for further research. In the subsequent stage of the research, the extraction process was optimised using the theory of planning experiments with the response surface method (RSM).

In the second stage of the research, fractional separation of chokeberry pomace extracts obtained under optimised extraction conditions was carried out. This step was aimed at obtaining an extract fraction with a high concentration of biologically active compounds which had antioxidant properties. First, the extracts were prepared under optimal extraction conditions, and then separated into fractions by column chromatography on two beds. The obtained fractions were subjected to preliminary qualitative analysis, analysis of antioxidant properties and analysis of the total content of phenolic compounds and saponins.

The third stage consisted of the development and technical testing of the concept of experimental edible casings with and without the addition of chokeberry pomace extract. In the first part of this stage, the concept of experimental edible casings was developed. This was followed by technical testing of the concept of experimental edible casings. The third stage of the research ended with estimating the direct costs of producing the experimental edible casings.

The fourth stage of the research entailed conducting individual in-depth interviews among selected entrepreneurs. For this purpose, the author developed a script and conducted interviews, together with transcripts of the recordings. Finally, an analysis of the collected information was carried out.

## Results and conclusions

The use of the designed experiment based on the response surface method (RSM) to optimise the extraction process from chokeberry pomace using ethyl alcohol and the ultrasonic technique made it possible to determine the influence of individual parameters of the extraction process on the total content of phenolic compounds, the total content of anthocyanins as well as the antioxidant properties. Based on the results obtained from the validation of the optimised model, it was found that the optimal conditions for the extraction of bioactive compounds from chokeberry pomace occur with the use of a 60% ethyl alcohol solution during 20-minute sonication. Therefore, the first research hypothesis has been verified positively.

In this work, the author has presented a procedure for obtaining and fractionating a group of compounds with high antioxidant properties. The developed fractionation method using two types of beds, i.e. LiChroprep RP-18 and poly-

amide-6, allowed to obtain a fraction with a high concentration of biologically active compounds which had antioxidant properties. The test results showed that the second fraction isolated from the chokeberry pomace extract obtained as a result of extraction with a 60% ethanol solution during 20-minute sonication on a polyamide bed was characterised by the highest antioxidant potential. The statistical analysis also confirmed that both the type of fraction and the type of bed, as well as their combinations, determine the level of the total content of phenolic compounds, the total content of anthocyanins and the antioxidant properties. The preliminary analysis regarding the identification of metabolites contained in fractions isolated on LiChroprep and polyamide beds from chokeberry pomace extract was carried out using two instrumental methods (HPLC-ESI-IT-MS and UPLC-Q-Orbitrap-MS).

In the analysed fractions, chemical structures were initially assigned based on mass fragmentation, high-resolution mass spectrometry and literature data. The presence of compounds from the group of phenolic acids, flavonols and anthocyanins was reported. On the basis of the obtained results and literature analysis, chemical structures for several metabolites, which have not been described in chokeberry fruits so far, were also assigned. Some peaks in the chromatogram correspond to molecular ions, which may suggest the presence of, among others, saponins so far unidentified in chokeberries. However, derivatives of triterpenoic acids have been observed in other plants belonging to the *Rosaceae* family, which also includes the chokeberry. The total content of saponins was the highest in the second fraction eluted with 40% ethyl alcohol on a polyamide bed. In brief, the above results positively verify the second hypothesis adopted in this work.

At the next stage, experimental edible casings based on chitosan with the addition of the second fraction of chokeberry pomace extract were developed. The addition of the second fraction of chokeberry pomace extract at the level of 0.5%–1.5% to chitosan casings allowed to obtain innovative chitosan casings with increased functional and health-promoting properties. This was confirmed in the tests of the functional properties of the casings under analysis. With the increase in the volume of the second fraction of the chokeberry pomace extract, the UV-Vis barrier of the tested casings increased. However, increasing the addition of the second fraction of the chokeberry pomace extract resulted in a decrease in water vapour permeability. The addition of 0.5% to 1.5% of the second fraction from the chokeberry pomace extract slightly increased the solubility of the casings in water. However, with the increase in the addition of the second fraction, the oxygen permeability of chitosan casings decreased. This suggests that the biologically active compounds with antioxidant properties contained in the second fraction of chokeberry pomace extract can significantly improve the oxygen barrier properties of the chitosan casing. All tested casings showed

antioxidant properties, but their activity varied. It was observed that the antioxidant potential of the casing increased with the increase in the amount of extract in the sample. Determining the optimal amount of the addition of the second fraction of the chokeberry pomace extract is a complex process in which a number of factors must be taken into account, e.g. the type of product to be coated with the casing, the form of casing application, organoleptic characteristics as well as the expected period of extending the shelf life of the product. The conducted research may be a starting point for further research on the development and evaluation of prototypes of edible casings for selected food products. In sum, the obtained results make it possible to positively verify the third hypothesis.

At the last stage of the research, individual in-depth interviews were conducted to assess the perception of the development of innovative edible casings by selected representatives of different enterprises, depending on the industry and size of the enterprise. The respondents decided that the designed chitosan casings could be used in their industries as an internal innovative protective barrier and as a marketing distinguishing feature. Among the weaknesses, they mentioned concerns related to the application possibilities of this type of casing on products and the lack of knowledge about the costs of its use compared to the waxes they currently use. In turn, producers of films and casings as well as fruit and vegetable producers, mainly representatives of large and medium-sized enterprises, decided that the most important advantage in the context of the development of edible chitosan casings is the possibility of extending the shelf life of products. Their implementation would also have a strong impact on the competitiveness of non-degradable plastic casings. Among the weaknesses of this type of casings, they indicated the possible lack of their effectiveness as a barrier limiting the migration of water vapour. On the other hand, fruit and vegetable processing enterprises emphasised the fact that one of the key issues that may affect the development of chitosan edible casings with additional health-promoting features is the possibility of using some by-products obtained by them. Regardless of the industry, representatives of large enterprises declared the greatest interest in the potential application and development of chitosan edible casings, while representatives of micro-enterprises showed the least interest. Edible chitosan casings with health-promoting properties, despite the above-mentioned weaknesses, were considered by the respondents as a solution of the future, with great market potential. The direction of development was assessed as having a strong impact on the competitiveness of enterprises, primarily in relation to non-degradable plastic casings, but also casings that do not have additional health-promoting features. The results of the qualitative study in the area of perception of edible chitosan casings by entrepreneurs from the industries under analysis showed that the casings were assessed as an ecological and technological innovation that should promote the circular economy mainly

in large and medium-sized enterprises. Edible chitosan casings can contribute to an ecological and waste-free environment, as they are innovative products that reduce the release of harmful substances throughout the life cycle and contribute to better use of limited natural resources.

## Originality and value

The scientific monograph entitled "Chokeberry pomace as a component of innovative edible casings" is an interdisciplinary theoretical and empirical study of the use of chokeberry pomace as a component of innovative biopolymer edible casings with enhanced functional properties. A particular advantage of this monograph is its methodological pluralism manifested in the large number of methods used in the experiment, together with the manner and sequence of their planning. It also presents the method of conducting research, taking into account such goals as the standard of repeatability and reproducibility as well as an illustrative presentation of a correctly designed experiment. This book is of great importance for the circular economy paradigm in its economic and ethical aspects – it proposes a solution for the management of by-products of chokeberry processing as a component of innovative edible casings. The publication was intended to serve as a response to the needs and reinforcement of positive trends in science, technology, economy, marketing and consumer behaviour. The monograph is a contribution to the development of the discipline of management and quality science, and especially research on product development, product management and product quality in the context of one of the most urgent needs of the Polish and global economies, which is the need to reduce the amount of waste.

**Keywords:** chokeberry pomace, edible casings, design of experiment, innovative product design, product management, product quality management, product development, sustainable product, circular economy

*Translated by*
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