October 12th, 2023

Thesis Report

Creation of high-quality plant-based powders with targeted health-oriented properties.

Dissertation for the award of the academic grade of Doctor, submitted at the Faculty of Biotechnology and Food Science of the Wrocław University of Environmental and Life Sciences, by M.Sc. Jessica Brzezowska.

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The thesis represents a contribution in the research field of plant-based powders obtained by different drying techniques and its benefit-risk evaluation depending on the matrix composition using holistic approach including physico-chemical and biological characterization, and to provide the recommendations for their production. Thus, different matrix from both pomaces and juice of chokeberry and cranberry pomaces, and Japanese quince, blackcurrant, haskap berry, rosehip, blueberry and beetroot juices were subjected to different pretreaments, extraction procedures, carrier agents and drying conditions.

In particular, in stage I of the thesis chokeberry and cranberry pomace were and extracted with 30% acetone, 50% ethanol and 50% ethanol acidified. Four carrier agents were employed (maltodextrin, inulin, trehalose and binary blends) and three drying techniques were applied: (i) freeze drying, (ii) vacuum drying at 60ºC and (iii) vacuum drying at 90ºC. Regarding stage II, Japanese quince, roseship, blackcurrant and haskap berry were subjected to different fractionation (whole fruit, juice, pomace and sugar free juice products), different carrier agents (no carrier, maltodextrin, inulin and trehalose) and different drying techniques (freeze drying, vacuum drying at 60ºC, vacuum drying at 90ºC and spray drying). Finally in stage III, blueberry juice from three cultivars and beetroot juice were subjected to different column chromatography and probiotic fermentation, respectively, then different carrier agents were employed (inulin, maltodextrin, oligofructose and Nutriose^{R}. All the samples were then dried using different drying techniques (freeze drying, vacuum drying at 50ºC, vacuum drying at 60ºC, vacuum drying at 90ºC and spray drying).

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All the samples obtained during the 3 stages of the thesis were analysed in terms of several quality attributes: physical attributes, (poly)phenolic profile, antioxidant activity, biological activity, etc. Besides, alterations of chemical properties, including formation of process contaminates were assessed in terms of furfural and hydroxymethyl-*L*-furfural (HMF) content.

The main result of stage I regarding chokeberry pomace showed that the incorporation of a maltodextrin-trehalose blend for lyophilization and vacuum drying at 90 °C resulted in the highest retention of (poly)phenols along with the lowest content of hydroxymethyl-*L*-furfural in chokeberry pomace preparation powders. However, achieving a high-quality, soluble type powdered product form fruit pomace requires a tailormade and comprehensive approach adjusted to particular plant-based matrix intended to be processed. On the other hand, acidified 50% ethanol should be considered for the extraction of cranberry pomace, as the highest retention of (poly)phenols and the lowest content of hydroxymethyl-*L*-furfural were observed for cranberry pomace extract powders when this solvent was used. Acetone can no longer be classified as an efficient extraction medium for this plant matrix. The addition of a carrier can be recommended when the minimization of HMF content is of high importance. It can be suggested that with appropriate optimization strategies, the proposed approach has promising prospects for application to the management of other types of wastes from the fruit and vegetable industry.

Regarding stage II, where results deal with the plant-based matrix complexity vs. bioactive response and process contaminants drivers as well as the matrix diversification and fractionation of Japanese quince, roseship, blackcurrant and haskap berry. Findings of this stage showed that still further research is needed in order to fully explain the mechanisms that drive these dependencies, including model fruit composition systems to specify the individual constituents responsible for the possible properties exerted by the resulting powders considering as a complex matrix. Perhaps and although no clear link has been found between ascorbic acid content and the formation of process contaminants, its influence should be taken into account, especially in complex plant matrices. Careful consideration should be given to the organic acid type present in the plant matrix being processed in terms of the possible excessive formation of hydroxymethyl-*L*-furfural.

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Finally, stage III results, where cross-factors affecting the biological properties of powdered plant products were studied, showed that the blueberry cultivar composition and its matrix modifications through inulin addition and drying technique can serve as a tool for designing products with programmed antimicrobial and anti-inflammatory potential with possible application in customized food production. However, this approach should be adapted to specific plant-based matrix composition as numerous bioactives components (qualitative and quantitative differences) may diversely interact under specific processing conditions. In other hand, the potential of beetroot powder was demonstrated especially as a possibly functional additives to a various foodstuff, giving an overview about pros and cons of their production form a processing point of view. Oligofructose should be carefully reconsidered for beetroot-originated matrix (and probably others) processing toward powders production as it turned out to not only drive the HMF formation, as well as, stimulate proliferation of cancerous cells in vitro. Nutriose® seems to be promising substance in the context of properties studied therein for beetroot juice matrix, however, each plant-based raw material constitutes an individual matrix that should be considered in light of its inherent complexity and characteristics, and therefore any processing should be carefully tailored.

The formal aspect of the PhD dissertation is satisfactory. The adequate review of the state of the art was followed by well defined objectives. These objectives have been achieved through properly applied methodology. The research performed by the candidate allows recommendation of optimal processing conditions, which is important in both, scientific and applied terms.

My overall view of the thesis is that it is well organized with a clear and logical structure. It provides a good introduction on the current situation of the research field and the basic concepts. The description of the preparation of the samples as well as of the protocol of processing conditions (carriers, drying techniques, etc.) contains all the necessary information and is well presented making the concept clear and easy to follow. The results are well analyzed and properly discussed contributing to a better understanding of the observed phenomena.

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As a conclusion, the thesis represents an innovative, systematic and consistent work in the field of plant-based powders. It presents interesting and valuable results important for the scientific community and to further application in the food industry. Taking into account scientific novelty, meritorious presentation and discussion of obtained results as well as that the thesis makes a significant original contribution to the subject area, I am pleased to recommend that it be approved for award of the Ph.D. degree by the Wrocław University of Environmental and Life Sciences.

Which I certify for the record by signing this Thesis Report, in Orihuela on October the 12th, 2023.

Firmado por CALIN SANCHEZ ANGEL - ***1443** el día 12/10/2023 con un certificado emitido por AC FNMT Usuarios

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