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ABSTRACT

Considering the global practices promoting sustainable agriculture, as well as in line with the latest trends in the food industry responding to consumer needs, the production of plant-based powders offers a strong potential in this context. The quality of such products is a resultant of initial plant matrix composition subjected to multi-step processing, which in turn can trigger formation of hazardous process contaminants. Thus, moderation of their quality in terms of the presence of native bioactives and minimized process contaminants formation is of great importance.

The study aimed at the benefit-risk evaluation of the processing conditions for plant-based powders obtainment depending on the matrix composition using holistic approach including physico-chemical and biological characterization, and to provide the recommendations for their production. The research was structured in three main stages designed to investigate: (**I**) processing-induced changes towards improved properties of plant powder products; (**II**) plant-based matrix complexity vs. bioactive response and process contaminants drivers; and (**III**) cross-factors influencing the biological properties of powdered plant products.

In the first phase, a multidirectional approach was adopted to recover bioactive components from botanical by-products into ready-to-use powders. For powdered preparations from chokeberry pomace, the inclusion of selected carrier(s) during particular drying techniques provided the highest retention of (poly)phenolics and the lowest hydroxymethyl-*L*-furfural (HMF) content. The formation of the latest was attributed to the inulin application for powder production. Cranberry preparations showed substantial differences in (poly)phenolics and HMF presence and content depending on solvent used for pomace extraction, with the indication of acidified 50% ethanol as the preferred extraction medium, while using acetone favored the formation of this undesirable compound in powders. Suitably adjusted processing was proved to be an effective strategy in minimizing the content of process contaminants in the final product. Overall, the findings confirmed the feasibility of converting chokeberry and cranberry pomace into high quality powders as well as their extraction-dependent and thermo-modulated quality modification.

The second stage was designed to recognize the effectiveness of selected components of different fruit matrices in shaping the bioactive potential of the powders obtained from them. The heterogeneity of the matrix in which the bioactives were present conditioned their anti-diabetic ability, while flavonols affected antiglycation potential of freeze-dried fruit products according to the reaction stage. In order to explore the matrix-originated drivers that influence the formation of process contaminants, model systems resembling simplified composition of selected fruit juices were adopted by including major organic acid, sugar, and ascorbic acid. Furfural (FF) was formed when drying at

90 °C, while HMF was formed even at 60 °C and above and in considerably lower quantities under spray drying conditions. No process contaminants were detected in lyophilized powders, proving that their formation in real matrix depends on other components. Freeze- and spray drying ensured comparable retention of vitamin C, and no linkage was found between this compound and process contaminants presence. Finally, based on compositional differences between models applied and resulting FF and HMF contents it was possible to surmised, that the organic acids may also take part in the process contaminants formation under specific processing conditions in plant-based matrix. Consistently, matrix complexity was presented as a critical differentiating factor determining the properties of plant powders, which should be carefully considered when designing their powdering technology.

The final stage included examination of biological potential of powders obtained from plant-based matrices that were diversified in terms of cultivar (blueberry matrix) as well as its pretreatment (beetroot matrix) and subjected to different processing conditions. The cultivar differentiation resulted in substantial antioxidant capacity differences pointing at blueberry powders from Bluecrop and Bluejay displaying the most desired potential. The higher antibacterial activity against *Helicobacter pylori* when compared to *Campylobacter jejuni* was presented for all blueberry products, however carrier application significantly weakened this effect. Treating at relatively high temperatures during vacuum drying tended to improve the anti-inflammatory properties of such products, depending on the cultivar used. In case of beetroot powders, juice pretreatment reduced betalains content in final products, while inulin was the most effective in protection of syringic acid derivatives. Products with oligofructose and inulin exhibited stronger antioxidant capacity than those with Nutriose® and maltodextrin. Nutriose®-added products showed selective antiproliferative activity toward leukemia cell lines, while oligofructose-based stimulated the *in vitro* proliferation of cancer cells. Moreover, oligofructose induced HMF formation, regardless processing applied. Finally, it was proven that the specific biological response of plant-based powders was dependent on joint matrix-processing interrelation.

Conclusively, in the study the comprehensive overview about relationship between plant-based matrix, applied processing and resulting properties was presented. The potential of processing to produce powders with the best possible properties has been demonstrated, depending on the botanical material used. The complexity of the constantly changing matrix has been identified as a major challenge in the design of high-quality powder products, as even small variations can alter their properties. Therefore, the development of plant powders with targeted health-related properties should be preceded by preliminary studies dedicated to the specific material to be processed.