Valorisation of Berry Pomace: From Waste to Bioactive Compounds

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1 Introduction

Fruits and berries are amongst the essential food components and their processing is a major direction of food industry. At the same time processing of fruits and berries produces a huge amount of wastes—one of the major waste streams globally. Significant amounts of berries are processed into juices as a by-product leaving large quantities of berry press residues—pomace. Considering its low calorific value, in some cases high acidity, the berry pomace is considered as a waste product or used inefficiently mainly due to a lack of valorisation of their processing methods. However, the berry pomace contains high amounts of valuable phytochemicals—polyphenolics, lipids, carbohydrates, vitamins and others, and the development of new waste valorisation methods can help to convert the berry pomace into high value products using environmentally friendly approaches.

The aim of the present study was to develop possibilities of converting the berry pomace into high value ingredients using different environmentally friendly extraction and fractionation methods and to test properties of the obtained products as well as evaluate their application potential.

2 Materials and Methods

As a study object, wild and industrially cultivated berries were used: blackcurrant, bilberry, raspberry, highbush blueberry, lingonberry, cranberry and American cranberry. Dried berry press residues obtained after juice extraction were used for the experiments. For the extraction of biologically active compounds different extraction methods were tested (treatment with ultrasound, conventional extraction, Soxlet extraction, treatment with microwaves, and extraction with supercritical CO_2). During extraction, the extrahents polarity influence, extraction procedure and kinetics, solid-liquid ratio and other parameters were studied. The total yield of extracted substances, their radical scavenging activity as well as a group of parameters (total carbohydrates, total lipids and other) were determined. The composition of the obtained extracts was characterised using GC-MS, UPLC as well as HPLC-MS/MS. For the optimization of the polyphenolic extraction efficiency response surface methodology (RSM) was used.

3 Results and Discussion

Studied berries contain a high number of different groups of substances, however taking into account the application potential in functional food, cosmetics and biopharmacy as well as market value, polyphenolics and lipids were considered as substances of priority interest. Thus the berry pomace processing strategy was developed based on the extraction of corresponding groups of substances starting with polyphenolics or lipids.

For the lipids extraction, conventional solvent extraction can be applied but we preferred to use the supercritical carbon dioxide extraction as a “green” extraction method. At optimal conditions the yields of berry waxes/oils are from 12 to 18%. In total, 111 different substances were identified by comparing their mass spectra and retention index with the reference mass spectra and reference retention index. The highest numbers of substances were found in the cloudberry (86), lingonberry (79) and crowberry (78) extracts. The lipid

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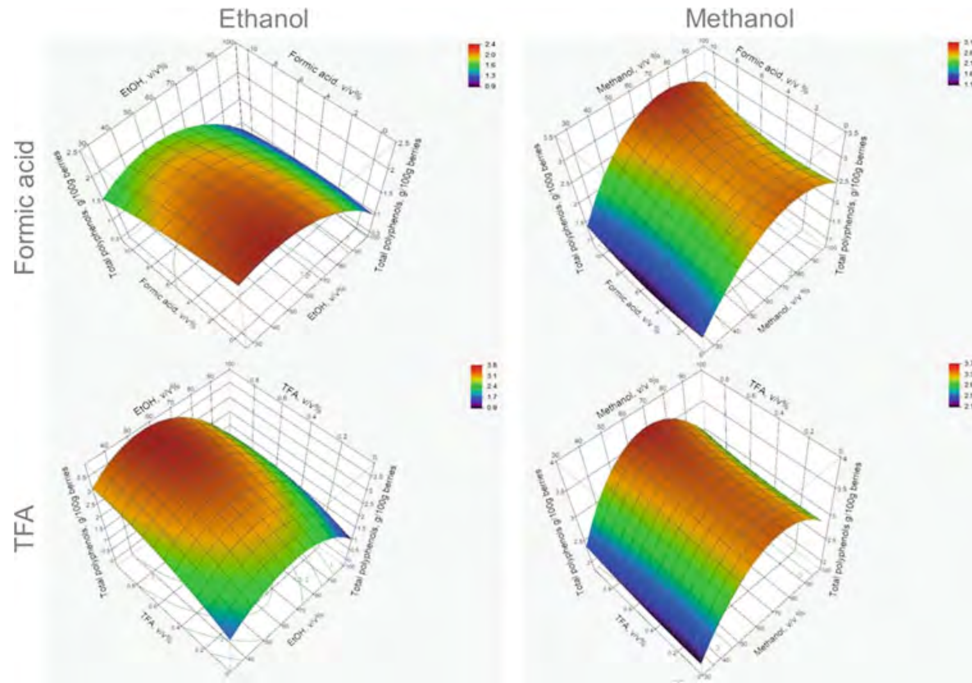

Fig. 1 Response surface plots for total polyphenolics in function of solvent composition and acid concentration

fraction contained compound classes like triacylglycerols, fatty acids, sterols, triterpenoids, alkanes, phenolic and carboxylic acids and carotenoids. All berry pomace extracts contained high amounts of C18 unsaturated fatty acids (for example, up to 102 µg/g of blueberries) and phytosterols (86 µg/g of β-sitosterol of blueberries), and high amounts of benzoic acid were found in lingonberries (164 µg/g).

After the removal of lipids the berry pomaces might be subjected for extraction of more polar groups of substances. Amongst these interesting groups we may cite the polyphenolics which are strong antioxidants but some of them, for example anthocyanines are berry pigments and might be valorised as food colorants. To select the best polyphenolic, specifically, anthocyanin, extraction method different approaches were tested (treatment with ultrasound, conventional extraction, Soxlet extraction, treatment with microwaves) and it was found that the highest yields were provided by the treatment with ultrasound-depending on its power. The study of the extraction kinetics shows that the process is fast (<30 min). The optimisation of the solvent composition from berry press residues of American cranberry was achieved using the RSM approach. Total polyphenols were extracted with different solvent mixtures according to the RSM experimental design and different surface response profiles, with plateau surface (Fig. 1) indicating optimal extraction conditions and optimal extrahent composition—aqueous ethanol (40–70%) in presence of an acidifying agent (formic acid).

Moreover, to validate the optimal polyphenol/anthocyanin extraction solvent mixtures, extraction from two different types of samples, berry press residues and whole, dried berries were carried out. Comparing whole berry extracts with berry press residue extracts, it is possible to conclude which type of sample contains more polyphenols and anthocyanins, thus pointing out the potential sources of the berry materials for further processing of berry pomace. To show and compare the composition of anthocyanins from whole berries and their pomace the extraction conditions found as optimal for American cranberries were tested on of 5 different berries and anthocyanin and polyphenolic analysis using UPLC and HPLC-MS/MS were carried out. The lowest market value and potential biological activity have carbohydrates and to obtain stable polyphenolic concentrates in solid form, carbohydrates were removed using column chromatography.

Consequently, the concept of biorefining may be successfully applied to berry pomaces for the development of high added value functional ingredients and this aim might be achieved using "green" technologies.

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