Valorization unused chokeberries: encapsulation and storage stability of their phenolic extract

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Aronia melanocarpa berries are one of the richest plant sources of phenolic compounds. Different beneficial effects on health have been reported for black chokeberries and their extracts, such as prevention and treatment of cardiovascular diseases and colon cancer, antidiabetes, and antimutagenic effects. This may principally be due to the antioxidant activity exhibited by phenolic species in these berries and their extracts (Galvan D'Alessandro *et al*, 2014).

Many berry species may be consumed fresh, but the fruits of some berry plants are not suitable for eating because their flavor is less favorable or even unacceptable by the consumers. Consequently, all harvests of such berries have to be processed into other products. Chokeberries are used for making fruit wine; they are also dried for herbal teas, used for flavoring and coloring beverages or yoghurts, and added to juice blends for color and for strengthening antioxidant properties. However, biorefining of unused chokeberry into higher added value ingredients is an important task.

Extraction is the first and important step in isolation and purification of bioactive components from plant material. Various extraction techniques can be applied for polyphenol recovery from plants, and generally these techniques can be divided into traditional and modern ones. According to a previous comparative study on different extraction techniques to recover polyphenols from chokeberries, microwave assisted extraction exhibited the highest yield in total phenolic content. In this work, the extraction conditions used were based on a previous study on optimization of phenolic compounds extraction.

However, the effectiveness of polyphenols depends on preserving the stability, bioactivity, and bioavailability of the active ingredients (Fang & Bhandari, 2010). According to Cilek *et al* (82), there are unsaturated bonds in the molecular structure of polyphenols, which makes them susceptible to oxidants, light, heat, pH, water, and enzymatic activities. Munin and Edwards-Lévy (83) reported that the instability of phenolic compounds, during food processing, distribution or storage, or in the gastrointestinal tract (pH, enzymes, presence of other nutrients), limits the activity and the potential health benefits of polyphenols. Unfortunately, they oxidize very quickly, leading to the progressive appearance of a brown color and/or unwanted odors with a considerable loss in activity. In addition, many phenolic compounds show limited water solubility and have an unpleasant taste, which must be masked before their incorporation in foodstuffs or oral medicines. Therefore, the administration of phenolic compounds requires the formulation of a finished protecting product able to maintain the structural integrity of the polyphenol until the consumption or the administration, mask its taste, increase its water solubility and bioavailability, and convey it precisely towards a physiological target. Microencapsulation is one of the techniques that is used for enhancing the shelf life and stability of phenolics.

Chokeberry phenolic extract was encapsulated by spray drying, extrusion, and co-crystallization. Extrusion was applied for encapsulation of chokeberry extract in calcium-alginate gel beads. Alginic acid sodium salt was dissolved in the prepared extract. Chokeberry extract containing calcium chloride was used as a collecting solution. For the co-crystallization process, sucrose and water were used each time to prepare syrup. Sugar and water were mixed and then heated and stirred to make syrup. The temperature of the syrup was monitored continuously and once it reached 128 °C, the syrup was removed from the heating and a known quantity of extract was rapidly added. The mixture was vigorously agitated for a short time and was then placed in a water bath at room temperature until the dry agglomerates were obtained and the temperature of the co-crystals decreased to below 60 °C. For the spray drying process, mixtures of maltodextrin and milk proteins were used as wall materials and an experimental design was applied to determine the effects of inlet air temperature, ratio of core to wall material, and drying air flow rate on encapsulation efficiency and yield. In each process, the optimum values of encapsulation efficiency and yield were predicted.

The antioxidant capacity and stability of the crude and the encapsulated at the optimum for each process conditions extract were evaluated during storage. The nonencapsulated and encapsulated extracts were evaluated with regard to total phenolic content, antioxidant activity, and color during storage at 60 ^{o}C, which is one of the temperatures recommended for accelerated shelf life studies. Samples of the extracts were placed in ambar vials and stored in a forced-air oven with controlled temperature and in absence of light for 45 days. Duplicate samples were removed every 2-3 days.

The total phenolic content of extracts was determined according to the Folin-Ciocalteu method. Antioxidant activity was determined using DPPH. An automatic Minolta colorimeter was used to measure the extract color.

The polyphenols degradation in crude extract was faster than that in encapsulated product, showing the importance of the encapsulation in the degradation of bioactive compounds as has been also reported for other functional compounds. For the encapsulated extract, the phenolic retention increased during the storage time, possibly due to the hydrolysis of conjugated polyphenols, and then decreased and remained relatively constant. The antioxidant activities of encapsulated and unencapsulated extract remained quite unaltered during storage. The minor changes in antioxidant activities may be explained by the alteration in the phenolic profiles. Phenolic content was not correlated to antioxidant activity, whereas the crude extract was the one that presented the greatest increase in color parameters during storage.

The encapsulated phenolics from unused chokeberries could efficiently be used in food industry and replace synthetic antioxidants in the cosmetics and pharmaceuticals production. The increasing demand of consumption of natural antioxidants strengthens the importance of the research in this field.

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