Electrostatic separation of grape stalk powder obtained from grape-wine chain waste

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Grape stalk: a first attempt to disentangle its fibres via electrostatic separation

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Introduction

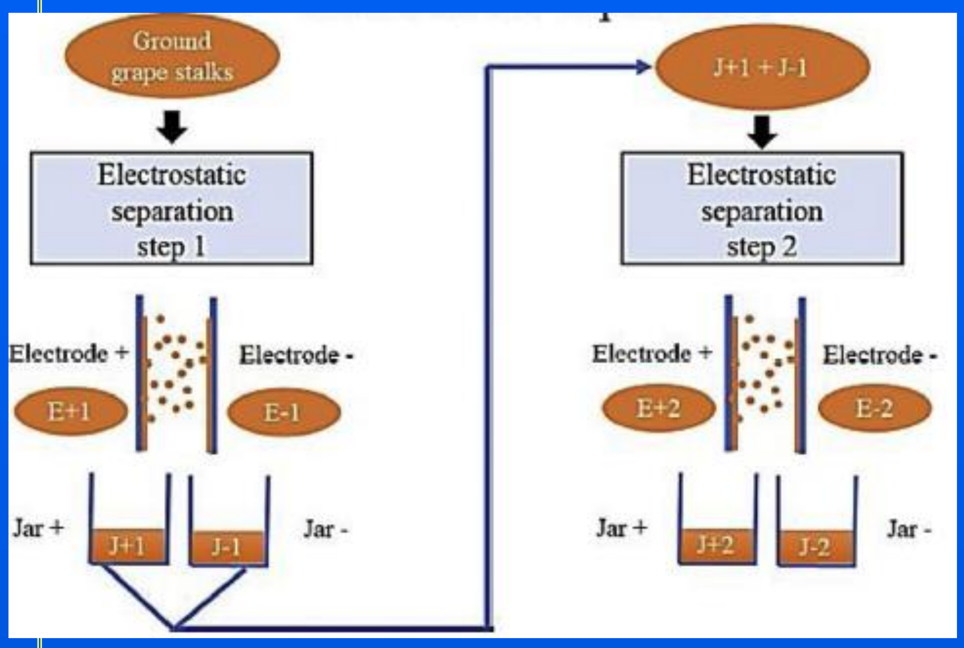

Figure 1: Experimental scheme

Grape stalks are made of lignocellulosic biomass, which represents a source of biopolymers, rich in simple sugars and phenolic compounds (Brandt et al, 2013; Guerriero et al, 2016). Since lignocellulose is a very complex material, a fractionation of its components that leads to the breakdown of their interactions is required. Pretreatment methods allow the lignocellulose to be broken down into its basic units, thus increasing accessibility for subsequent treatments on these biopolymers.

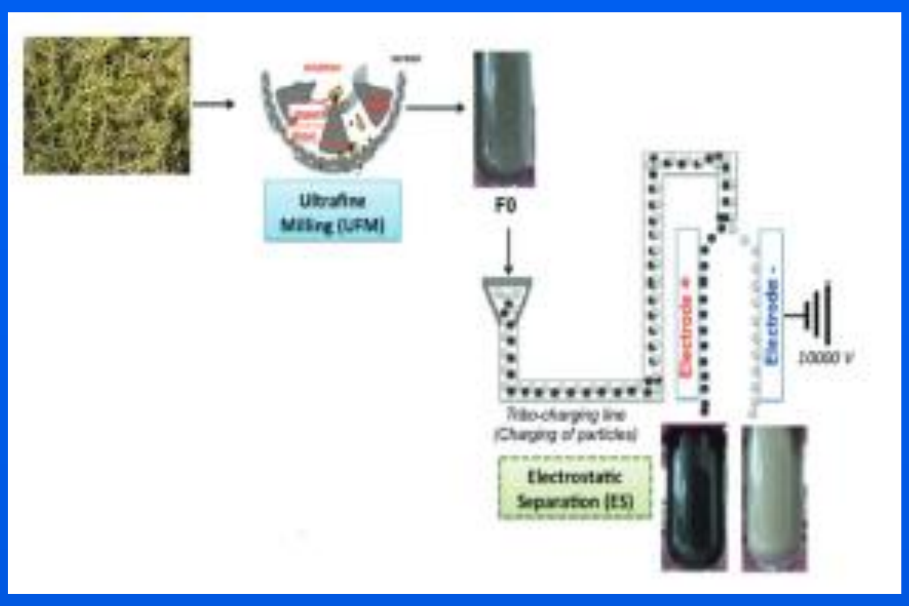

Figure 2: Electrostatic separation scheme of the grape stalk fine powder

Grape stalks were subjected to drying, grinding, and electrostatic separation, a cutting-edge technique already successfully applied to separate proteins from polysaccharides, lignin, and polyphenol. In electrostatic separation (Fig. 1), grape stalk fine particles were conveyed, through a jet of compressed air, towards a device called "tribo-charging line" where they were charged through the triboelectric effect (Mayer-Laigle et al., 2018). The charged particles were then let run through a line equipped that ended with two high voltage electrodes and during this run the positively charged particles were separated from the negatively charged ones.

Aim

The aim of this work is to explore alternative solutions for the use of grape stalks, which are recalcitrant by-products of the wine industry, and for this reason only, still scarcely considered. The electrostatic separation was applied to finely-milled grape stalks to assess its effectiveness to disentangle, even partially, substances which are closely linked and that belong to the same tissue or structure which is the case of grape stalks. This separative technique has interesting applications as a pre-treatment to ease lignocellulosic fractionation under sub-sequent enzymatic or chemical attacks.

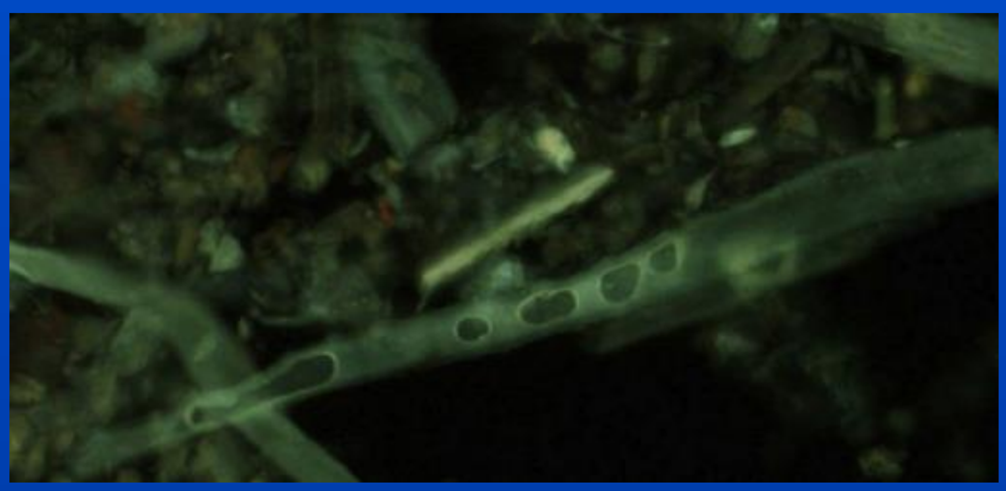

Figure 3: Fluorescence microscopy image of the grape stalk powder fraction collected at the positive electrode obtained in the first electrostatic separation (E+1). A tracheid can be noted in the foreground

Results & Discussion

All the fractions were also investigated using a fluorescence microscope to obtain information on the morphology. Microscopic analysis allowed to highlight a prevalence of fluorescent lignified structures in the samples selectively collected at the positive electrode (Fig. 2, left). As some authors had already observed (Barakat et al, 2014; Chuetor et al, 2015), it can be argued that particles with higher amount of lignin selectively moved towards the positive electrode. This phenomenon was due to a higher presence of phenolic substances, which are characterized by the presence of electronic clouds in the aromatic rings. In the control sample, the presence of these elements was fair limited (Fig. 2, right), while they were not found at all in the samples. collected at the negative electrode. A similar behavior has been already described in a study on the electrostatic separation of sunflower oil cake (Barakat et al, 2015), in which the authors showed that protein structures selectively migrated toward the positive electrode, while the lignocellulosic material was massively directed to the negative one.

The electrostatic separation allowed to obtain 9 fractions in two runs: 1 control, 4 fractions from the first separation (electrode +, electrode -, and samples collected in jars placed under the electrodes a called jar + and jar -), and 4 fractions from a second separation using the pooled samples contained in the two jars (electrode +, electrode -, jar + and jar -). All the samples were extracted with water and sulfuric acid 2% and the extracts were subjected to HPLC analyses to determine the concentration of sugars, phenolics, and possible furanic artefacts (Spigno et al, 2013; Spigno et al, 2014).
In the aqueous extracts, the concentrations of glucose and fructose were in the range of 9.4-13.5 g/100 g d.w. and 7.46-11.6 g/100 g d.w. respectively. In the acid extracts, the concentration of xylose, deriving from the cleavage of hemicellulose structures, was in the range of 8.26-17.53 g/100 g d.w., while those of furfural and HMF were 1996.19-260.24 mg/kg d.w. and 290.58-144.41 mg/kg d.w., respectively.

Figure 4: Samples of all fractions obtained with the electrostatic separation.
Ctrl, control grape stalk powder; E+: positive electrode; J+: positive jar; E-: negative electrode; J-: negative jar; 1: first electrostatic separation; 2: second electrostatic separation.

The aqueous extraction of the obtained fractions showed appreciable concentration of simple sugars that are likely lost during the grape pressing. A quite high rate of simple sugars (in particular pentoses) was also obtained through the acid hydrolysis of the residual pellet. This is a source of sugars that can find applications in the microbial fermentations for the production of various metabolites. The extraction in acid condition led to the formation of furanic compounds derived from the sugars. A proper modulation of the acid-extraction condition is necessary to lead the reaction towards either the highest yield in simple sugars or in furanic compounds. Indeed, these latter represent useful building blocks, which find employment in the fine chemistry. For this reason, other strategies, such as pyrolysis and electrochemical should be taken into account for an extensive production of these compounds.

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Conclusions

Electrostatic separation can represent an eco-friendly and sustainable pre-treatment of grape stalks to allow partial separation of both the complex and simple components without using solvents and catalysts, low energy expenditure, and limited biopolymers degradation. In this way biopolymers are better exposed and this results in a more effective enzymatic or chemical attack.

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