Valorization of tomato pomace byproduct from agro-industrial processing through a "*one-pot*" simultaneous extraction with a biphasic system.

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Tomato [*Lycopersicon esculentum* (L.)] is one of the most cultivated horticultural species in the World, thanks to its ease of processing and storage that makes it available during the year. Italy is the leading Country in the production of canned and processed tomatoes, producing 13% of the entire world production (Anicav, 2019). At the same time, Italy is the main producer at European level with over 6 million tons, followed by Spain with 4.14 million tons, from Turkey with 2.10 million tons and Portugal with 1.56 million tons. (FAO-STAT, 2019).

On the other hand, tomato industry generates huge amount of by-products, corresponding approximately to 2-5% of the biomass entering the industrial process. The predominant part of by-products is composed of skin and seeds, also called tomato pomace (TP) (Mangut, 2006). This by-product/waste represents an intriguing substrate for further valorization process, according to the Circular Economy Action Plan (European Commission, 2020) recently adopted by EU in the context of the European Green Deal (European Commission, 2019). In fact, tomato pomace is a precious source of biomass and nutrients, being particularly rich in structural polysaccharides, such as hemicellulose and cellulose, non-structural polysaccharides (pectin) and biomolecules with antioxidant, antimicrobial, antitumor, anti-fungal, anti -neurodegenerative, etc., widely used in the food and pharmaceutical industries (Lu et al., 2019). Several studies have been reported on the valorization of TP focusing mainly on the extraction of a class of compounds at a time such as pigments (lycopene and β carotene) (Pratik, 2007), polysaccharides (pectin) (Grassino et al. 2015), fatty acids or proteins. (Boccia, 2019)

In the light of our knowledge, only few studies investigated a biorefinery model consisting of cascading extraction processes for the production of multiple compounds with high added value. Recent strategies proposed the integration of supercritical CO_2 extraction of pigments from TP with the subsequent separation of proteins from the residue (Kehili, 2016), or anaerobic digestion of residue for bioenergy production (Scaglia et al.,2019; Allison, 2017). Azobou et al. (2020) suggested a sequential extraction of polyphenols and lycopene from tomato skins, the extraction of edible oil from tomato seeds, and the solid residue valorization by producing a low-cost bio-sorbent for dye removal. Moreover, Nagarajn et al. (2020) investigated the extraction of a hydrocolloid complex composed of lipids and pectin from TP.

The aim of our work was to set up a sequential process (at lab scale) inspired by the Green Chemistry principles and using ecofriendly solvents and techniques for valorizing TP by means cascade extractions of high value compounds. The investigated biorefinery model consisted in a "*one-pot*" simultaneous extraction of lipids and pectin from TP, through a biphasic system (BPS) composed of two immiscible green and safe solvents (ethyl acetate and water), followed by a microwave assisted extraction (MAE) of cutin from the resulting solid residue (SR).

The *one-pot* extraction with BPS was tested a different temperature (25, 40 and 60 °C) and time (1, 5 and 10 minutes). It generated a three phases system (Figure 1): the Red Phase (RP, ethyl acetate), the White Phase (WP, water) and the Solid Residue (SR), corresponding to 7.5% dw, 17.8% dw and 74% dw of tomato pomace, respectively, and an extraction efficiency higher than 99%.

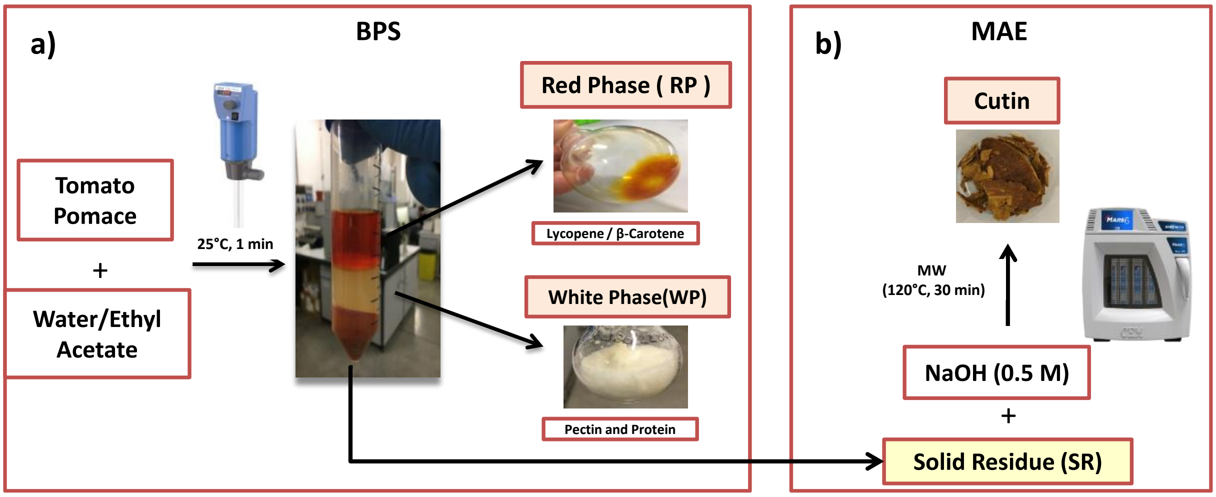

Figure 1. The integrated bio-refinery process designed for valorization of tomato pomace: **a)** *"One-pot"* simultaneous extraction of lipids, pigments (lycopene and β-carotene) and pectin with a biphasic system BPS (ethyl acetate and water); **b)** Microwave assisted extraction (MAE) of cutin from solid residue.

The RP was composed of lipids that contained also a high amount of valuable pigments such as *all-trans* lycopene (1.24 mg g^{-1} dw of tomato pomace) and *β*-carotene (0.18 mg g^{-1} dw of TP), and a minor content of polyphenols (0.25 mg GAE g^{-1} dw of TP).

The WP was composed mainly of high quality pectin (70% dw) that formed a polymeric gelatinous structure at the interface between water and ethyl acetate, making it easy to be separated by filtration. A certain amount of proteins (25% dw) was also found in the polymer.

The microwave assisted extraction (MAE) of cutin from the solid residue SR was optimized by varying extraction temperature (from 100 °C to 160 °C) and time (from 10 to 30 minutes). The highest cutin yield (~20% dw of TP) was found operating MAE with an alkaline solution (0.5M NaOH) at 120 °C for 30 minutes. Interestingly, the yield of compounds extracted with our *one-pot* simultaneous biphasic extraction process and MAE were comparable or higher than yield achieved by conventional methods of concern for the environment.

In conclusion, the preliminary results of proposed cascading process seem to demonstrate the effectiveness of green sequential extractions of high value compounds from tomato pomace, converting a by-product/waste in a multi-products source. Further investigations will aim to the production of functional feeds, biopolymers and platform compounds.