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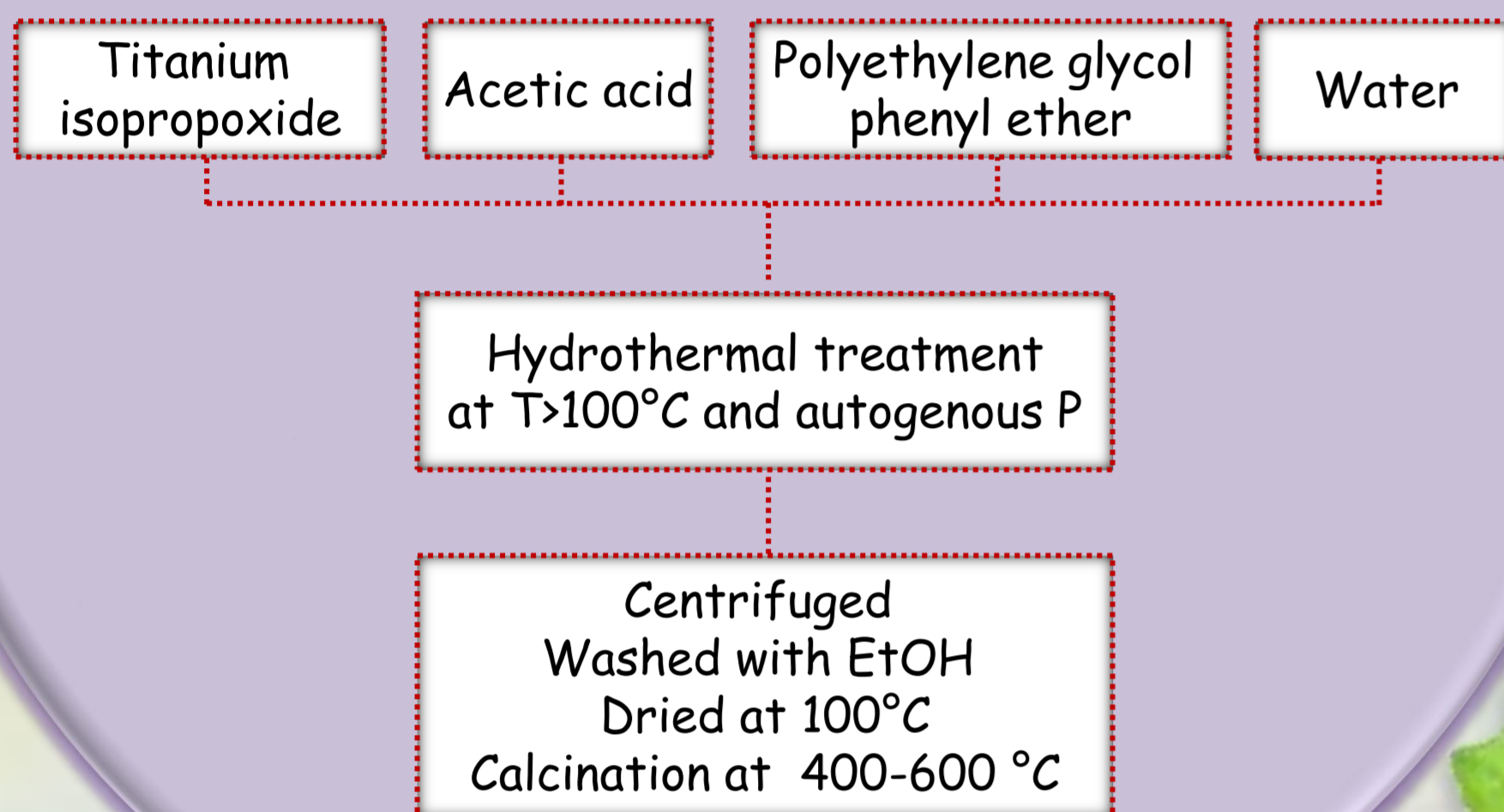
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Global energy consumption is currently based on fossil fuels (oil, natural gas and coal) but, in the last decades, the scientific community has pushed the research on renewable resources¹. In 1991 a new type of photovoltaic device was introduced to the world: the Dye Sensitized Solar Cell (DSSC), a sandwich structure system based on nanocrystalline titanium dioxide (TiO₂) and organic dyes. The current work aims to develop a methodology to recover the main waste product of a venetian winery, located in the heart of DOCG Prosecco hills, by extracting the organic dyes contained in winemaking by-product called "lees" for the realization of a DSSC device, transforming an agrifood waste into a resource, to produce renewable and sustainable electricity from photovoltaic solar cells.

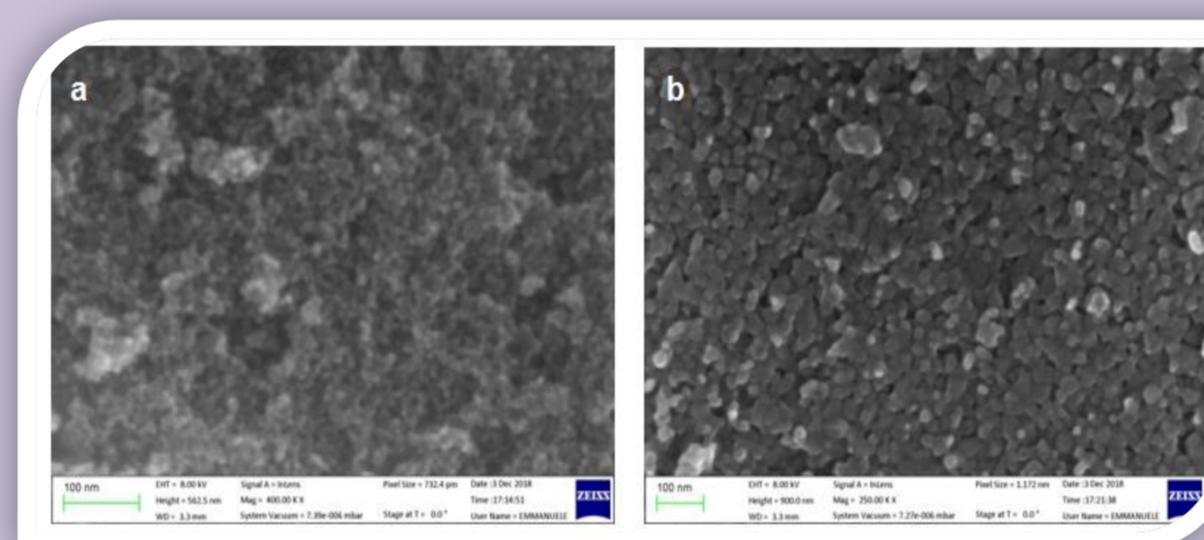
Synthesis of nanostructured titania



Microscopy FEG-SEM

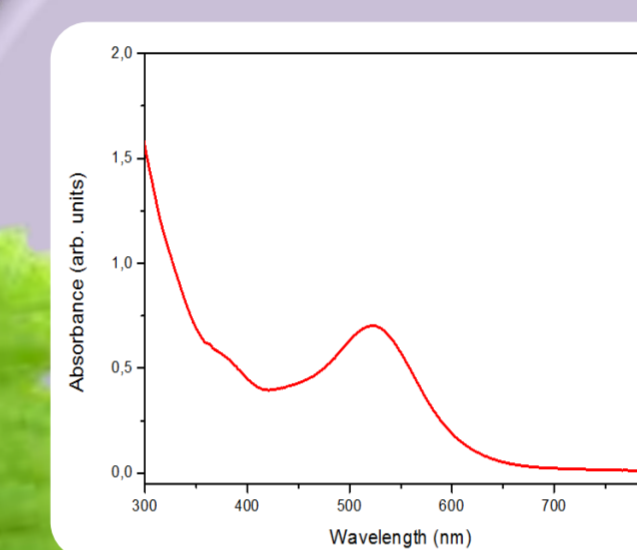
The morphology of the synthesized TiO₂ was evaluated by with FEG-SEM:

- ✓ Presence of nanoparticles with a size < than 80 nm.
- ✓ Increasing in size, as well as in aggregation of the nanoparticles, by increasing the calcination T.

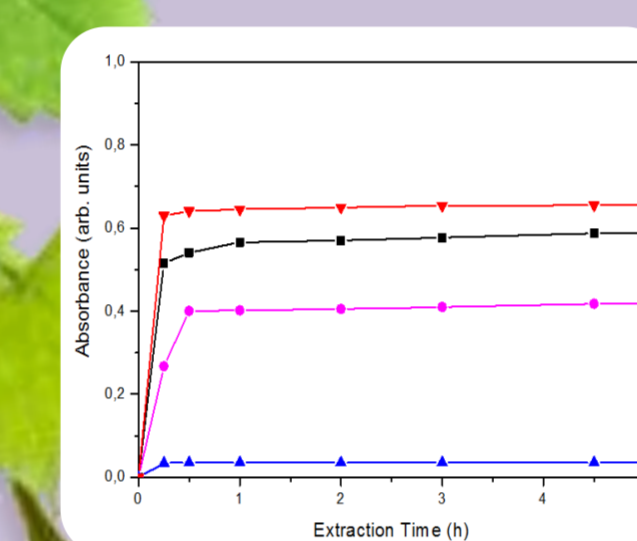


a) Calcination at 400°C ;
b) Calcination at 600°C.

Extraction process

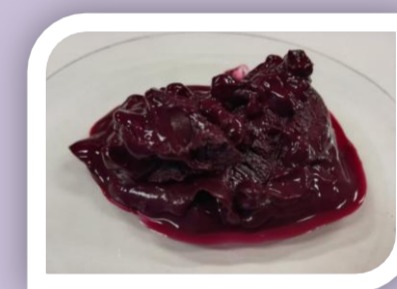


- ✓ Winemaking lees were collected in the first period of 2019 from Vinicola Serena srl.
- ✓ The extraction process was monitored by UV-Vis spectrophotometry.



- ✓ Kinetics of the dye extraction process proved that extraction can occur in few hours.
- ✓ For all solvents employed, absorbance increased rapidly in the first hour.

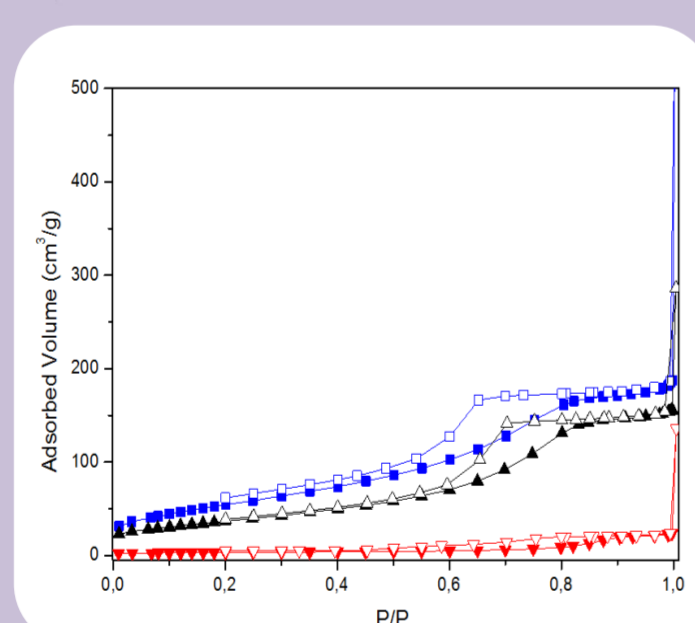
Winemaking lees used to extract a dye solution.



N₂ physisorption at -196°C

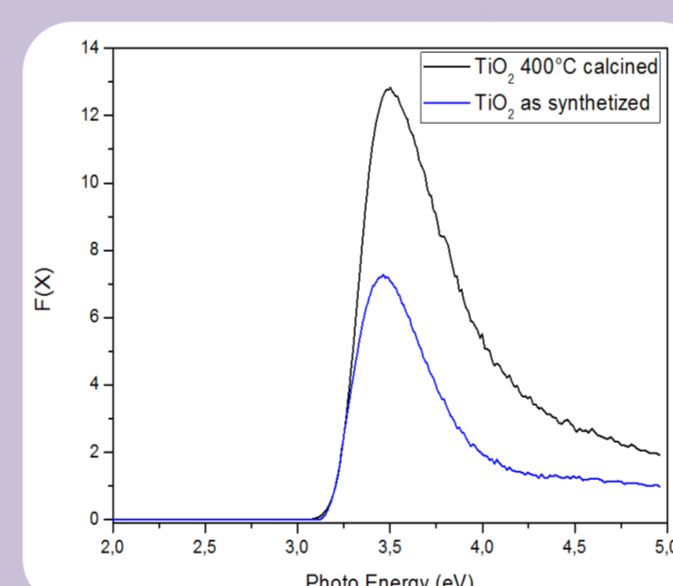
The textural properties of TiO₂ samples were determined by N₂ physisorption.

- ✓ The isotherms of all the prepared samples, both before and after calcination (from 400°C to 600°C), are of **type IV** according to the IUPAC classification.
- ✓ The presence of hysteresis loop indicates an **ordered pore size distribution in the mesoporous region**.
- ✓ The **specific surface area** of all titania samples, calculated by BET method, was > 100 m²g⁻¹.



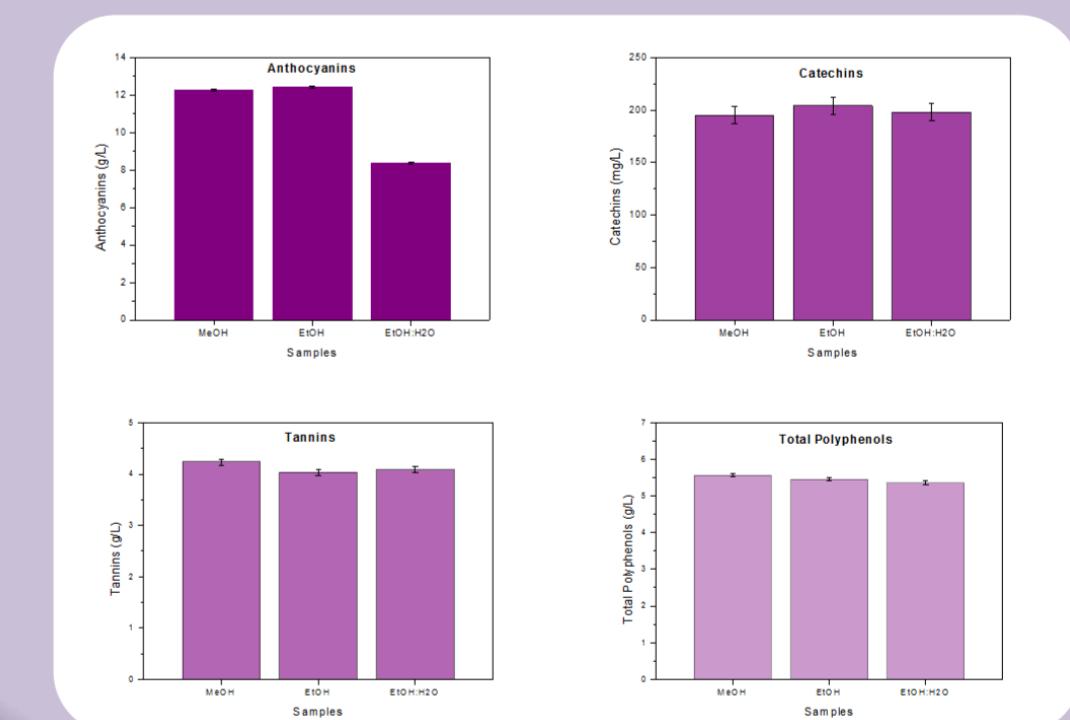
Diffuse Reflectance UV-Vis Spectroscopy

- ✓ Absorption peak in the UV region (below 400 nm), due to intrinsic absorption of titanium dioxide.
- ✓ **Band gap of titanium dioxide samples**, both as-prepared and calcined, was about the theoretical value of 3.2 eV, as expected for the anatase phase.



Dyes characterization

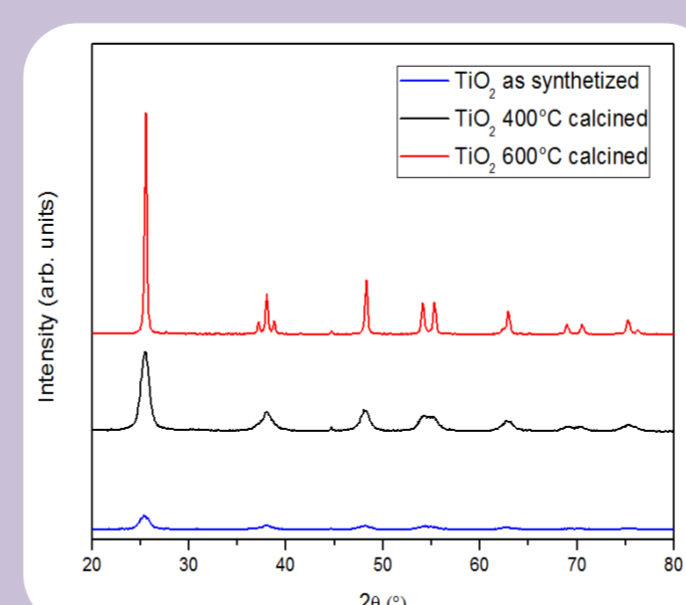
- ✓ Anthocyanins were very concentrated (10 g/L), compared to the typical values of anthocyanins content in red wine, like 109 mg/L for Merlot and 125 mg/L for Cabernet wine².
- ✓ The presence of water in the dye extraction step is responsible of the dye concentration decreasing, attributed due to the different solubility of in organic and aqueous solutions.



X-Ray Powder Diffraction (XRPD)

XRPD analyses of TiO₂ samples calcined at different temperatures were performed.

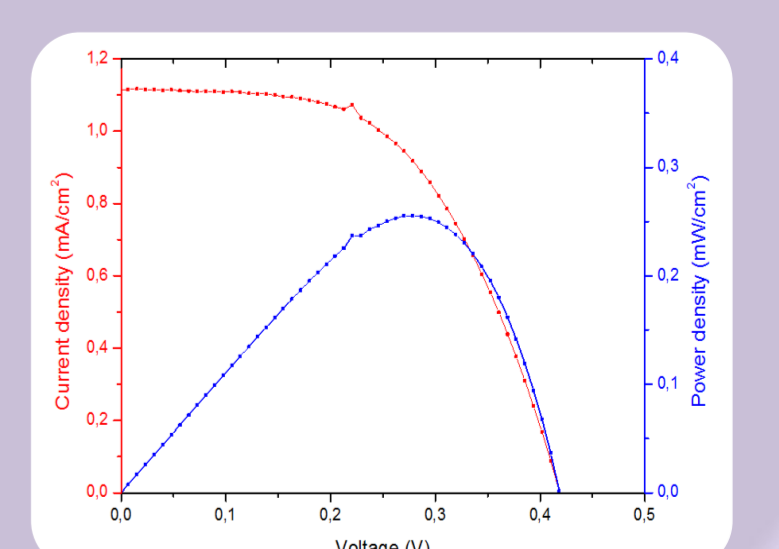
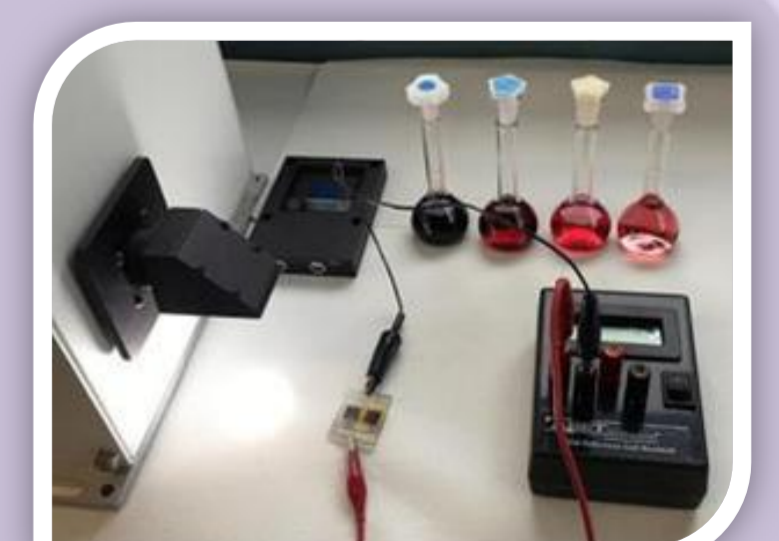
- ✓ Peaks attributable to **anatase tetragonal phase**.
- ✓ When calcination temperature increases to 600 °C, the typical rutile (110) reflections become noticeable.
- ✓ As a consequence of thermal treatment, the intensity of anatase and rutile reflections become sharper and more intense, due to growth of larger crystal domains from 6.0 to 30 nm.



DSSC photocurrent

The performance of DSSC prototypes were evaluated by measuring the open circuit voltage (V_{OC}) and the short circuit current density (J_{SC}).

- ✓ Prototypes can generate measurable **electric current**.
- ✓ Performances are comparable with the typical values of an organic dye sensitized solar cell³.
- ✓ Optimization of several parameters, both concerning the TiO₂ semiconductor and the organic dyes, is in progress.



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