

Vis/NIR spectroscopy as a green technology: quantification of environmental benefits by using LCA for the assessment of grape (*Vitis vinifera* L.) quality parameters

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INTRODUCTION

Grape quality composition at harvest is one of the most important factors that determine the future quality of the wine. By measuring certain grape quality parameters, it's possible to determine the optimum harvest timing ensuring the production of high-quality wines. These parameters are usually obtained through **wet-chem analyses** which have proved to be slow, time-consuming, destructive, and require expert qualified personnel, in addition to that they don't seem to be the greenest solution. From a perspective of precision agriculture, there are other more sustainable proposals to replace wet-chem laboratory instruments, such as **simplified portable systems** which work with **vis-NIR technology** allowing grapes quality determination.

METHODOLOGY

To determine the sustainability of wet-chem analysis and vis-NIR portable devices, a consolidated methodology is needed. **Life Cycle Assessment (LCA)** aims to assess all the environmental burdens connected with a product or a process, back to the raw materials and down to waste removal. This method is developed according to the international standards of series **ISO 14040-14044**. This methodology will lead to the impact assessment of the chemical and the optical analyses so that **the most sustainable one is to be obtained**.



BENCHTOP SPECTROSCOPY and PORTABLE DEVICE CASE STUDIES

The goal of this study is to evaluate and compare the environmental impact of two types of methods, chemical and optical, used in the wine sector to identify the quality of the grapes. Three main quality parameters were considered: **dosage of sugars**, determined by digital refractometer; **total acidity** analyzed using volumetric titration and **pH-value** measured thanks to a pH meter. The environmental impact was defined for both the chemical methods (destructive analyses) and the vis-NIR spectroscopy (non-destructive analysis). Specifically, for the non-destructive analyses, two solutions were considered: the **benchtop spectroscopy** and the **prototype** of a simplified and portable device that incorporates sensors and it's used to measure the same three quality parameters cited above.

In detail, the study was performed following these aspects:

- Functional Unit:** the pool of analyses carried out for the three different parameters
- System Boundaries:** from cradle to grave
- Geographical Field Application:** Italy
- Software Used:** SimaPro v 9.1.1.1.
- Database Used:** Ecoinvent 3.6
- Reference period:** 2021

The following methods were analyzed:

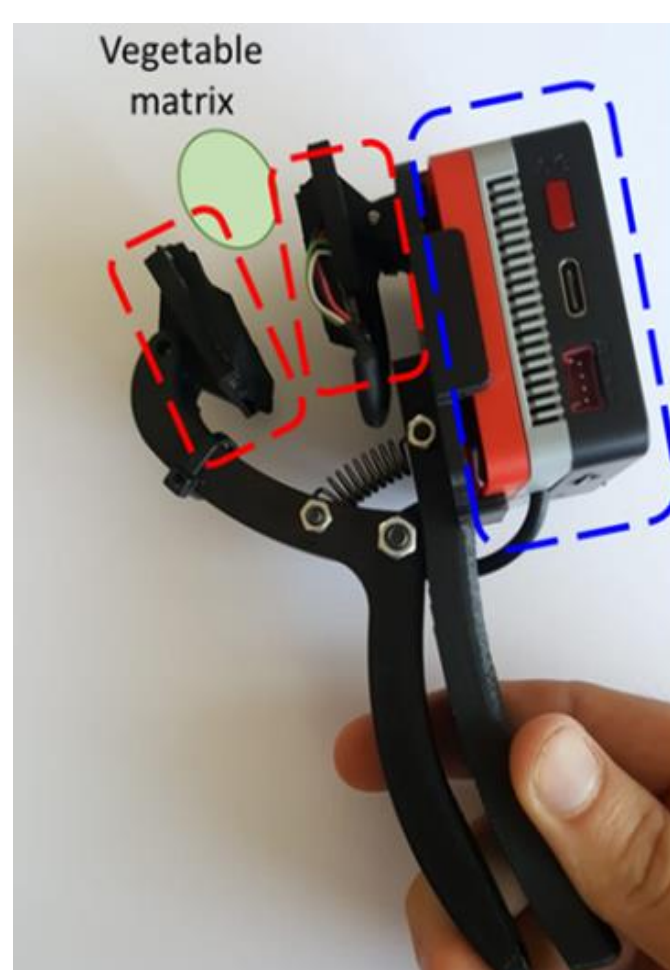
1. WET-CHEM ANALYSES

Automatic titrator
TSS analyser
pH meter



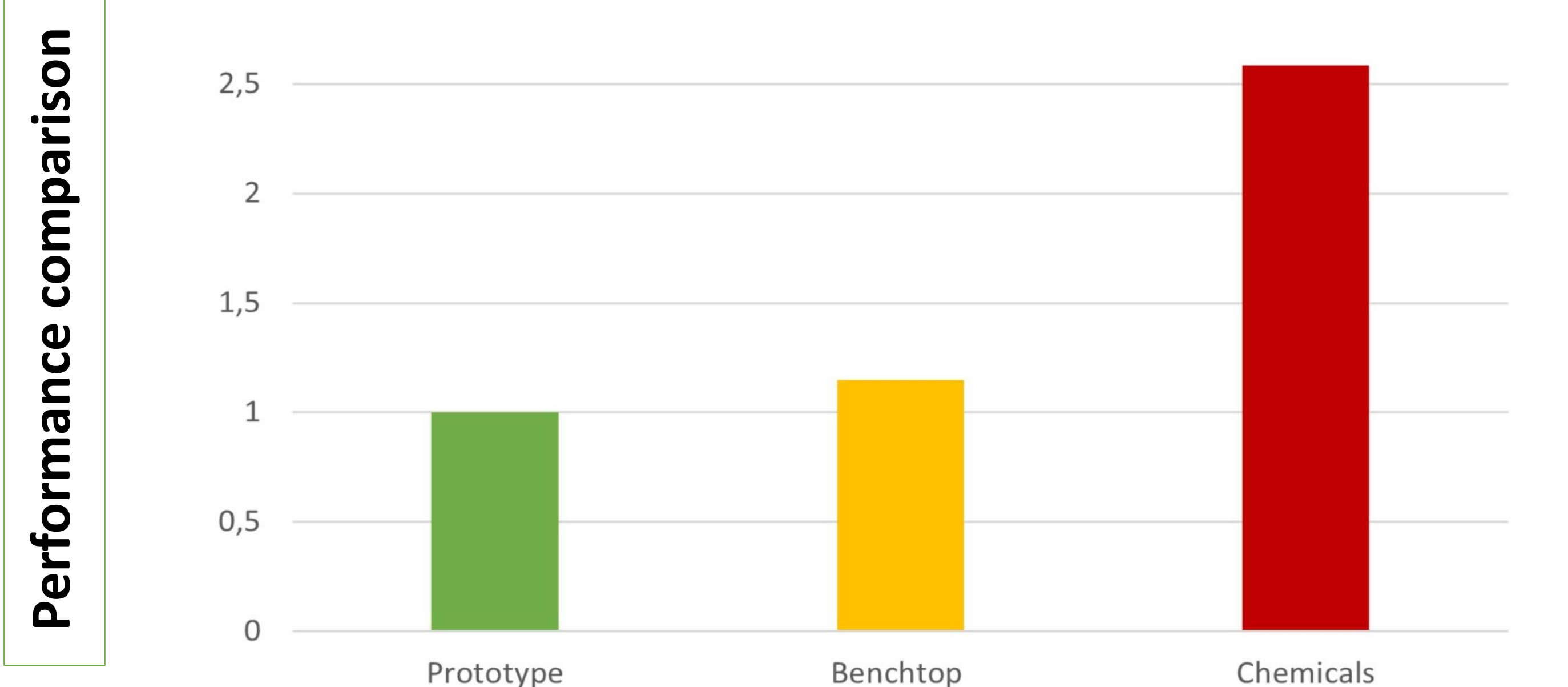
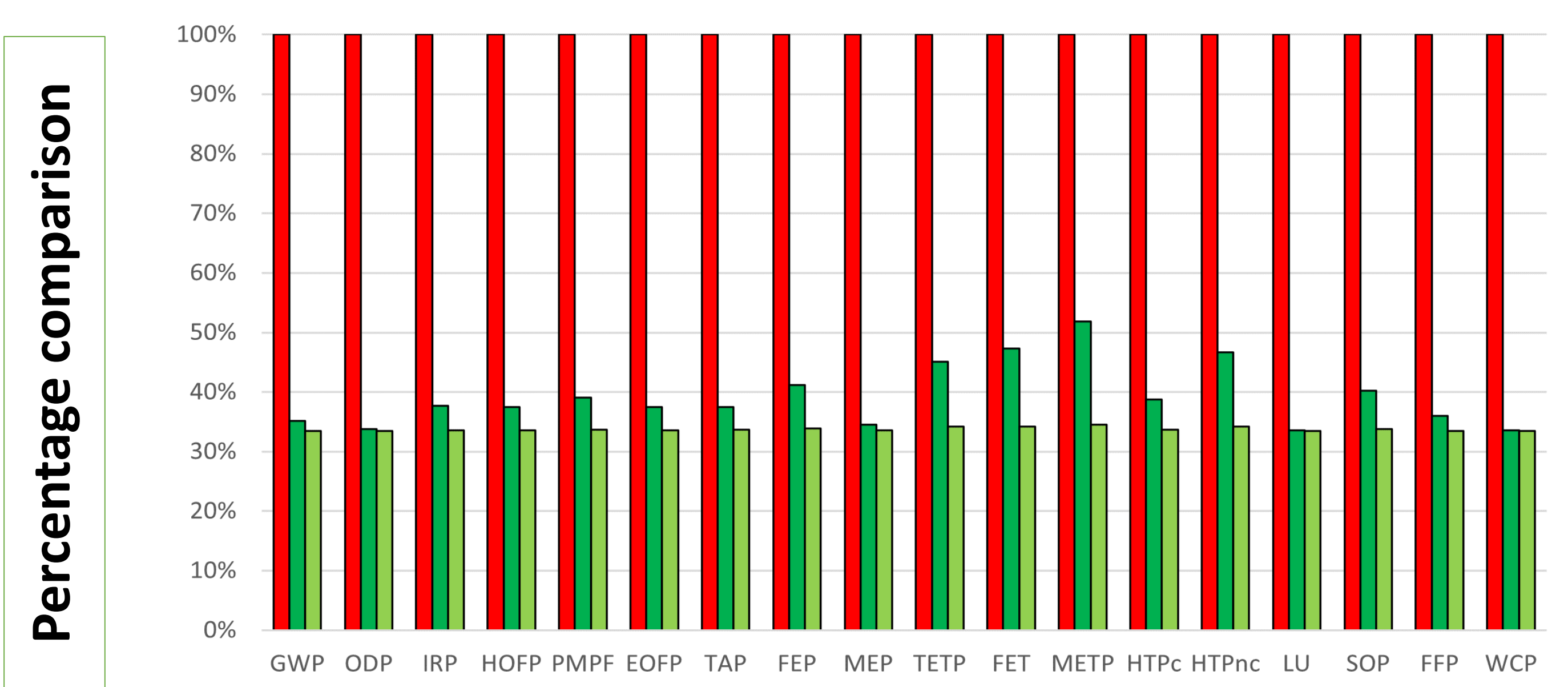
2. OPTICAL ANALYSES

Benchtop NIR instrument
Prototype cost-effective vis/NIR device



RESULTS

The results obtained from the study highlight that the use of **chemicals** during the procedures of the wet-chem analyses is the main driver of the environmental impact, while for what concerns the optical analyses with the two different instruments, the **calibration phase** is the most impactful factor. At the end of the study, it was possible to define the optical analysis with the **prototype as the most suitable and greenest solution** to obtain the three quality parameters. Nevertheless, the study did not consider the variability of results due to the performance of the two optical devices, therefore an additional observation was made normalizing the results obtained concerning a **performance factor**.



After this further evaluation, results showed how the optical analysis with the **portable device is once again the best solution** to obtain much more reliable measurements compared to the benchtop instrument.