Evaluation of olive oil quality grade using a portable battery operated sensor system

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Olive oil quality is normally assessed by chemical analysis as well as sensory analysis to detect the presence of organoleptic defects. Two of the most important parameters that define the quality of olive oil are the free acidity and the peroxide index. These chemical parameters are usually determined by manual titration procedures that must be carried out in a laboratory by trained personnel.
In the case of small industrial environments, such as olive oil mills and small packaging centers, that can not afford an internal laboratory for quality analysis, the olive oil samples to be tested must be shipped to an external laboratory and this results in high costs for the analysis and long response times.
A portable sensor system to evaluate the quality grade of olive oil is presented. The system is battery operated and is characterized by small dimensions, light weight and quick measurement response. The working principle is based on the measurement of the electrical conductance of an emulsion between an hydro-alcoholic solution and the olive oil sample.
Tests have been carried out on a set of 17 olive oil samples. The results have shown how for fresh olive oil samples, the olive oil free acidity can be estimated from the electrical conductance of the emulsion. In the case of oxidized olive oil, the measured electrical conductance is also function of the oxidation level and a conductance threshold can be set to discriminate extra virgin olive oils from lower quality grade oils. The proposed system can be a low-cost alternative to standard laboratory analysis to evaluate the quality grade of olive oil.

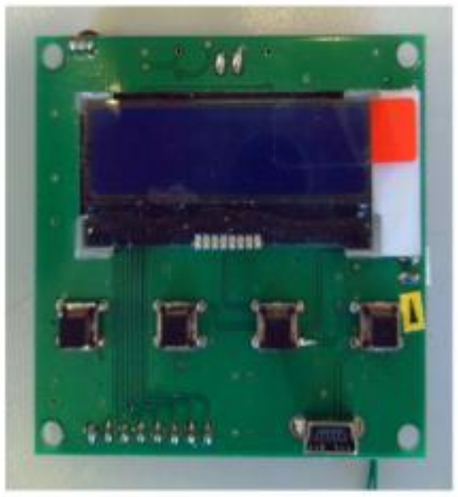
Portable sensor system

The system is characterized by small size (11 x 15 x 5 cm), light weight (350g), quick measurement response (30 seconds) and can be powered by a USB port or batteries (3 AAA alkaline batteries). The system working principle is based on the electrical characterization of an emulsion between an hydro-alcoholic solution (60% ethanol, 40% distilled water) and the olive oil under test. The emulsion electrical conductance is measured using a 50 mL Falcon vial modified with a couple of cap-shaped stainless steel electrodes.
The system primary function is the measurement of the olive oil free acidity. In fact, in presence of the hydro-alcoholic solution, the free fatty acid molecules dissociate and generate ions that contribute to the increase of the emulsion electrical conductance. In presence of oxidized olive oil samples, characterized by peroxide index > 20 meq O_2 / kg of oil, the presence of non-volatile compounds (such as aldehydes, ketones and hydrocarbons) also contributes to the increase of the emulsion electrical conductance.

The measurement process follows these steps:

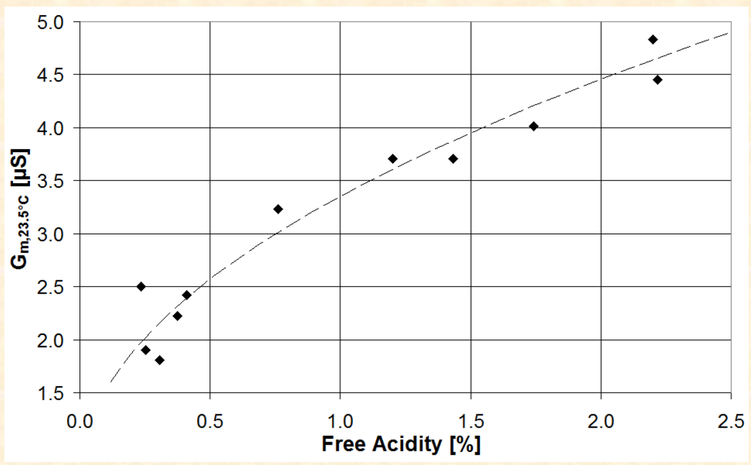
- The reagent (15 mL), an hydro-alcoholic solution of 60% ethanol and 40% distilled water, is added to the sensor vial.
- The reagent electrical conductance is measured using the portable system to check if it is suitable for the measurement (i.e. it is not degraded).
- The olive oil under test (1 mL) is added to the sensor vial.
- The sensor vial is vigorously stirred for about 15 seconds to create the emulsion.
- The emulsion electrical conductance and the environmental temperature are measured using the portable system and these values are used to estimate the olive oil quality grade.

All electrical measurements, data processing and data filing are carried out using an ad-hoc designed electronic board. The electronic board integrates a LCD screen to display the measurement results, four buttons for user interaction, a USB port used to power the sensor system and to transfer the measured data to a PC, a temperature sensor to compensate the variation of the emulsion electrical conductance due to temperature.



Analysis of olive oil samples

The portable sensor system has been used to evaluate the quality grade of a set of 17 olive oil samples (11 fresh olive oil samples characterized by a peroxide index < 20 meq O_2 / kg of oil and 6 oxidized olive oil samples characterized by a peroxide index > 20 meq O_2 / kg of oil). All samples have been tested with the portable sensor system and the quality parameters (free acidity and peroxide index) determined using the reference manual titration techniques.

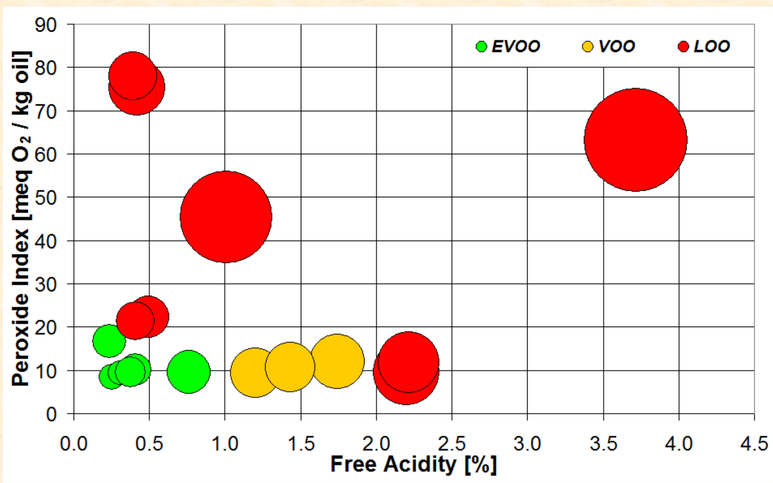


The subset of 11 olive oil samples characterized by a peroxide index < 20 meq O_2 / kg of oil has been tested with the portable sensor system. In the figure, the emulsion electrical conductance at 23.5 °C ($G_{m,23.5°C}$) is plotted vs. the free acidity determined by the reference titration technique. A correlation exists between $G_{m,23.5°C}$ and the olive oil free acidity. The best-fit curve that correlates the two parameters is defined by the following equation:

$$FA = \left(\frac{G_{m,23.5°C} - 0.6856}{2.6662} \right)^2$$

The equation has been used to estimate the free acidity for all tested olive oil samples. The free acidity estimated with the portable sensor system is very close with the value obtained with the reference titration technique and the error in the estimated free acidity is never higher than 0.23%.

The full set of 17 olive oil samples (6 EVOOs, 3 VOOs and 8 LOOs) have been tested with the portable sensor system. In the case of oxidized samples, characterized by a peroxide index > 20 meq O_2 / kg of oil, the presence of non-volatile compounds contributes to the increase of the emulsion electrical conductance.
The results on the full set of samples is presented in the figure, where each sample is represented by a circle of different colors depending on the quality grade (EVOO, VOO and LOO), while the circle diameter represents the emulsion electrical conductance at 23.5°C. In general, samples of lower quality grades are characterized by higher values of the circle diameter. The results show that setting a suitable threshold value for the emulsion electrical conductance at 23.5 °C ($G_{m,23.5°C,TH}$ = 2.7 µS) EVOOs can be discriminated from lower quality oils (VOOs and LOOs) with good accuracy. In particular, all 11 samples of lower quality grades are correctly classified. In the case of EVOOs, 5 samples out of 6 are correctly classified and the only misclassified sample is characterized by a free acidity value (0.76%) that is close to the threshold between EVOO and VOO (0.8%).



CONCLUSIONS: A portable battery-operated sensor system for the evaluation of olive oil quality grade has been presented. The system is characterized by small size, light weight and quick time response. It can be used for in-situ evaluation of olive oil quality grade in small industrial environments.
The system working principle is based on the measurement of the electrical conductance of an emulsion between an hydro-alcoholic solution and the olive oil sample. The emulsion electrical conductance is mainly affected by the free acidity as well as the oxidation level of the sample. Tests on a set of 17 olive oil samples have shown how EVOO samples can be discriminated from lower quality oils with good accuracy.