Exploitation of technological innovations along the olive oil milling process for an optimization of the plant performance

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Summary
This work aims to evaluate the production process of olive oil in terms of production yield and reducing waste of by-products with a view to enhancing the economic savings without leaving out the quality aspects. Some solutions in different critical points of the process were evaluated to optimize the oil extraction procedure.
The study focused on: (i) the use of a olive tree leaves conditioner to reduce the leaves volumes deriving from the cleaning machine of the mill and to facilitate the humification process in order to obtain a by-product rich in nitrogen, a crucial lacking element in composting processes; (ii) the conditioning of paste temperature using a continuous malaxer machine to increase, in a short time, the temperature of paste during processing, and to limit the oxygen exposure thanks to the controlled conditions and no water addition; (iii) the application of vis/NIR spectroscopy in order to correlate spectral data, acquired on intact olives and pastes, to the crucial parameters.

1. Introduction
The aspect of enhancing the quality and of recycling in the olive oil productions chain waste is a topic of relevance. Moreover, many farmers burn olive tree pruning materials with high CO_2 emission, olive pomace and wastewater are often spread directly in field, with consequent environmental impact (Cini & Regis, 2000; Altieri & Esposito, 2008). By the other hand these problems involve the olive oil chain, for little and medium companies. The solution here proposed consists of composting waste and residuals, directly in farm with the aim of closing the organic matter circle directly in the farm. The need to improve better performances in composting could be of interest to adopt the prototype performed by the authors, considering two aspects: minimize the waste costs and increase the process performances. Moreover, the actual frontier of olive oil quality enhancement is focused on the flavour's maximization. Since 2009 the authors performed a prototype of malaxer machine to increase, in a short time, the temperature of paste during processing.
The selection of olive fruit with defined properties that ensure positive attributes in olive oil is foreseeable using vis/NIR and NIR spectroscopy in olive oil production (Armenta et al., 2010). However, limited work has been undertaken about the implementation of vis/NIR and NIR spectroscopy directly in the mill.

2. Materials and methods
(i) Prototype of a leaves conditioner: considering the composting need and knowing the volume of leaves outbound the blowing in the olive mill, the study was carried out in Montepaldi (farm of the University of Florence) exactly in the specific area of the company, where it is situated the rectangular section cemented tank surrounded by a 1 meter wall. Moreover, a simple machine was used to reduce the leaves volume. The operative principle of this prototype consists in the use of the air vortex of the mill plant to allow the entrance of olive leaves in the opening placed at the top of the machine. On the bottom of the machine is positioned a set of

equidistant blades, which assures the partial or complete cutting and allow to obtain a final product with the volume reduced of about 1/3. The prototype of the chopper machine has been built entirely in stainless steel. The accumulation of residual waste has been realized by the union of: 400 kg of green stalk, 400 kg of walnut shredded, 400 kg of white marc unfermented, 1400 kg of olive wet pomace, 300 kg of olive leaves and 400 kg of grapevine shredded.
The mass was turned over every 2 weeks, to support aerobic fermentation and metabolic activity of microorganisms. The dimensions were 9,10 m x 2,20 m x 0,20 m (4.004 m^3).
(ii) The prototype of the continuous malaxing machine (Figure 2.1) consists of:
a knife crusher from which the olive pomace goes into the malaxer consisting of four tubes (each one of the length of 1 m), with internal cochlea, horizontally disposed in a vertical plane. The pomace velocity can be regulated, but in this study was fixed at 4 m min^{-1}.

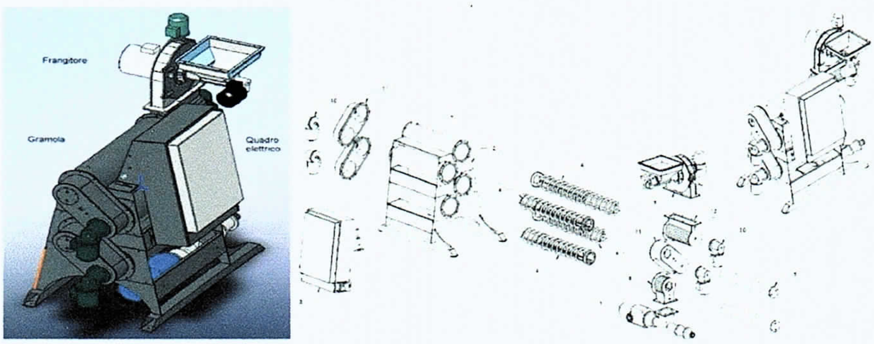

Figure 2.1: Prototype of the continuous malaxing machine

(iii) Testing of a vis/NIR device: a total of 54 olive samples (400-500 g), which presented no infection or physical damage, were quickly transported to the laboratory to be analysed, and for each sample a homogeneous batch of olives (i.e. approx. 300 g) was selected. For each sample, 30 olive fruit vis/NIR spectra were acquired, for a total of 1620 optical measurements. For each olive, using a portable spectrophotometer (Jaz, OceanOptics, USA), two spectral measurements were taken in reflectance mode and averaged. Physical measurements (i.e. yield point force and total deformation energy) were carried out on the olive samples and the maturity index (MI) was calculated; after, the fruit were crushed for olive paste production, and chemical analyses (moisture, oil and sugars content) were performed and correlated to the spectral data.

3. Results and discussion

(i) The use of olive tree leaves conditioner reduces the leaves volume deriving from the cleaning section by 30-40%, producing a good composting element (the chemical parameters are reported in Table 3.1).

Table 3.1: Chemical parameters results for 3 company's compost samples and 1 repetition respectively for each sample

Parameters	Sample 1	Rep. 1	Sample 2	Rep. 2	Sample 3	Rep. 3
pH	4.64	4.78	7.35	6.57	9.51	9.86
Residual after drying at 105°C (%)	41.30	41.70	42.90	48.20	40.80	47.10
Ashes (%)	2.40	2.10	2.50	2.60	4.30	5.40
Organic Carbon	26.40	32.90	28.60	33.60	30.44	33.20
Total Nitrogen	10.40	10.40	10.70	11.20	4.60	4.70
Total Phosphorus	3.30	4.04	3.70	4.25	3.70	4.15
Pb (mg/kg)	9.70	7.20	5.50	6.20	8.50	6.60
Total Cu (mg/kg)	9.70	14.40	10.30	10.40	8.90	18.60
Cd (mg/kg)	< 1	< 1	< 1	< 1	< 1	< 1
Hg (mg/kg)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ni (mg/kg)	9.70	14.40	6.30	8.60	6.30	8.60

Zn (mg/kg)	14.50	14.40	10.80	10.40	11.40	20.70
Inferior calorific power	-	-	-	-	3966.00	4047.40
Humification index	-	-	-	-	0.50	0.49

The humidity of 50% could be considered very good, pH tends to acidity in first sampling for CO_2 and organic acid formation, while successively it tends to neutrality thanks to aeration that induce CO_2 expulsion, and to ammonia production from corroded proteins. Finally, it tends to alkalinity with pH value around 9,5, while for high quality compost the expected result is at least 8,5 (D.lgs n 152 2006; D.M. n 21 2000). Organic carbon results are in accordance to the size of 30%. The results in terms of heavy metals content can be considered as good.
(ii) In Table 3.2 are reported the results of the test concerning the different temperatures of the interspace conditioning water in the four tubes of the malaxing machine prototype:

Table 3.2: Interspace conditioning water temperature (°C) in the experimental test

Tube	Test 1	Test 2	Test 3	Test 4
1	17.4	18.0	21.6	22.0
2	18.4	19.0	18.4	22.5
3	19.0	15.4	20.9	22.6
4	18.2	16.4	15.4	16.6
Pomace temperature	18.8	23.7	23.4	26.3
Final oil temperature	23.0	26.0	26.0	25.7

The presented results regard the physical performance of the machine. The chemical and sensorial analysis were also performed, showing a very good quality of the obtained oils (data not shown).
(iii) PLS regression models were built for each parameter measured (Table 3.3). Regarding textural parameters, the possibility to use the reference data on a single berry allowed to obtain acceptable results for the prediction of indices usually difficult to be predicted in an optical non-destructive way. Interesting results were obtained for the prediction of the yield point force. Slightly better results were obtained from spectra on olive pastes compared to those arising from the models calculated using spectra on intact olives. Also in this case, better results were achieved for the prediction of MI. This result may have interesting applicative implications, since the MI requires time for measuring and sample preparation.

Table 3.3: Descriptive statistics and statistics of the PLS models elaborated on vis/NIR spectra of intact olives for the prediction of chemical, maturity and textural parameters (Giovenzana et al., 2017)

					Calibration		Cross-Validation		
Parameters	**n**	**Mean**	**DS**	**LVs**	**R^2_{cal}**	**RMSEC**	**R^2_{cv}**	**RMSECV**	**RPD**
Moisture (%)	48	53.32	3.97	8	0.87	1.39	0.57	1.89	2.10
Oil content (g kg $^{-1}$)	44	371.11	49.93	9	0.85	18.67	0.74	25.85	1.93
Sugar content (g kg $^{-1}$)	46	38.87	5.69	7	0.65	3.31	0.42	4.35	1.31
Maturity Index	47	0.85	1.02	3	0.93	0.24	0.92	0.26	3.92
Yield point force (N)	14.10	41.26	17.26	9	0.63	12.32	0.62	12.44	1.39
Total deformation energy (N mm)	1373	450.35	103.69	10	0.42	78.83	0.4	79.96	1.30

SD standard deviation; LV latent variables

4. Conclusions

(i) The composting approach and the use of the presented prototype gained could be of interest in small farms and could be extended in different contexts of the agro-food industry.

(ii) The experimental plan aimed to provide a thermal stress to the pomace, before the extraction of the oil. This approach is performed to enhance the oil fragrancy, and the first tests were encouraging.

(iii) Regarding vis/NIR spectroscopy, the obtained results were encouraging for chemical analyses (moisture, oil and sugars content), physical measurements (yield point force and total deformation energy) and maturity index prediction, demonstrating the feasibility of real-time estimation of crucial indices for the milling plant settings.

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