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EFFECT OF DRYNG CONDITIONS AND STORAGE TIME ON COMPOSITIONAL AND SENSORY CHARACTERISTICS OF UNSHELLED HAZELNUTS

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Abstract
The aim of the work was to assess the effect of different drying conditions and storage time on raw unshelled Tonda Gentile Romana hazelnuts (harvest 2017). Drying was conducted with a laboratory desiccator at 20, 30, and 40 °C, applying two air circulation velocity until the moisture content of samples was lower than 6%. The oxidation state of the lipid fraction and volatile profile of hazelnuts were studied during 15 months of storage. In addition, sensory analysis was performed among samples.

Keywords*: Hazelnut, Drying, Shelf-life, Oxidation, Sensory analysis.*

1. Introduction

Hazelnut (*Corylus avellana* L.) is worldwide one of the most important nut crops and it accounts for a cultivated area of approximately 672,000 ha and a yearly production of about 1 million of tons of in-shell nuts. Over 67% of the hazelnut world production is supplied by Turkey, while Italy is the second hazelnut producer (13%) (FAOSTAT, 2017). The largest part of the production is stored and used for several food preparations or products and only about 10% is directly consumed. Quality of the final products is strongly dependent on the pre-processing treatments and the storage conditions of the seeds (Fontana *et al.*, 2014). One of the most important factors affecting hazelnut quality is moisture content, since seeds are perishable in their fresh state and may deteriorate within few days after harvest as a high-water activity promotes the development of moulds, colour changes and rancidity (Ghirardello *et al.*, 2013; Ozay *et al.*, 2016). In fact, the kernel lipid content is very high, up to 60% wt, with a considerable amount of unsaturated fatty acids (Amaral *et al.*, 2006), which makes the hazelnut easily perishable to rancidity. For these reasons, to extend the storage life as long as possible preserving the original quality, nuts must be dried immediately after harvest to reach a moisture content below 6% wt (USDA, 2016) and a water activity lower than 0.70 at 25°C (FDA, 2018).

Sun drying is a cheap method used by small producers, but it is not suitable for large productions (Lopez *et al.*, 1998). For this reason, drying is carried out using forced air circulation driers with a slow stream of warm air (40–45 °C). Even though several studies dealing with drying kinetics and moisture transfer parameters are reported in literature, the complex structure and chemical composition of hazelnuts (Lopez *et al.*, 1997, 1998) have not yet allowed to obtain a complete set of reliable information on the process. In this work, the effect of three temperatures and two air fluxes on chemical and sensory characteristics of raw Tonda Gentile Romana hazelnuts during 15 months of storage was studied. A novelty aspect of this research work, with respect to the previous ones, is the evaluation of the synergic effects of the most important parameters for drying process as temperature, air flux and storage time on chemical and sensory quality of hazelnut.

2. Material and Methods

Unshelled raw hazelnuts of Tonda Gentile Romana (TGR) variety (harvest 2017) were furnished by Soremartec Srl (Alba, CN, Italy) and dried with a pilot plant at 20, 30 and 40 °C applying two fluxes of air (7.513 m^3/min and 13.15 m^3/min) until the moisture content was about 6%. After the drying process, hazelnuts were deshelled and stored for 15 months at 20 °C in sealed aluminium bags. Analyses were performed at 0, 6, 12 and 15 months. Two production batches were done for each condition.

Hazelnuts were milled with a laboratory mill and the obtained powders (size between 250 and 500 μm) used for the evaluation of moisture (%) with a thermobalance Eurotherm (Gibertini, Milano, Italy), water activity (a_w) with an Aqualab Pre (METTLER Group, USA) and volatile components with a gas chromatograph/mass spectrometer working in SPME extraction mode. An oxidation test was performed with an Oxitest (Velp Scientific, Usmate Velate, MB, Italy) while the volatile profile was defined with an electronic E-nose Pen 3 (Airsens Analytics, Schwerin, Germany). Hazelnut oil was extracted with a cold-press system. Peroxide value (mEq O_2/kg) and total acidity (% of oleic acid) of oils were determined with a FoodLab system (CDR srl, Firenze, Italy). External and internal colour of kernels was evaluated with a CM-5 spectrophotometer (Konica Minolta, Milano, Italy) and reported as CIELab values. A descriptive sensory analysis was performed with a group of 20 trained panellists (8 male, twelve females, 25–35 years old). Sixteen descriptors were used and quantified with a five-point scale (1-very low; 5-very intense).

Factorial analysis of variance with Duncan test ($p<0.05$) and a Principal Component Analysis (PCA) was performed with Statistica ver.13 software (StatSoft Inc, USA). A Kruskall-Wallis test was applied for sensory attributes.

3. Results and discussion

The factorial analysis carried out using the three process parameters (drying temperature, air flux and storage time) highlights that air flux has a significant effect for all the chemical parameters examined while storage time and drying temperature have significant effects only for compositional variables (Table 1). Interactions are mainly influenced by storage time and air flux showing significant differences for all the compositional variables.

Table 1. Results of factorial analysis performed for each chemical parameter evaluated on dried hazelnuts during the storage time.

Parameter	M (month)	C (°C)	F (m^3/min)	M*C	M*F	C*F	M*C*F
Humidity	***	***	***	***	***	***	***
A_w	***	***	***	***	***	***	***
Peroxide value	***	***	**	***	***	***	***
Oil acidity	***	ns	***	***	***	***	***
Induction Period	***	***	ns	***	*	*	ns
L* (E)	***	***	***	***	***	***	***
a* (E)	***	ns	*	*	*	ns	ns
b* (E)	ns	***	***	***	***	*	***
L* (I)	*	ns	***	ns	ns	*	**
a* (I)	ns	ns	*	ns	ns	ns	*
b* (I)	ns	ns	*	ns	ns	ns	ns

*M-storage time; C-drying temperature; F-air flux; E-external kernel; I-internal kernel; ***p<0.001; **p<0.01; *p<0.05; ns-not significant*

The moisture has decreased in all samples above all during the first six months of shelf-life and a similar trend was showed by a_w. Generally, lower values were observed in samples dried at low air fluxes (Figure 1).

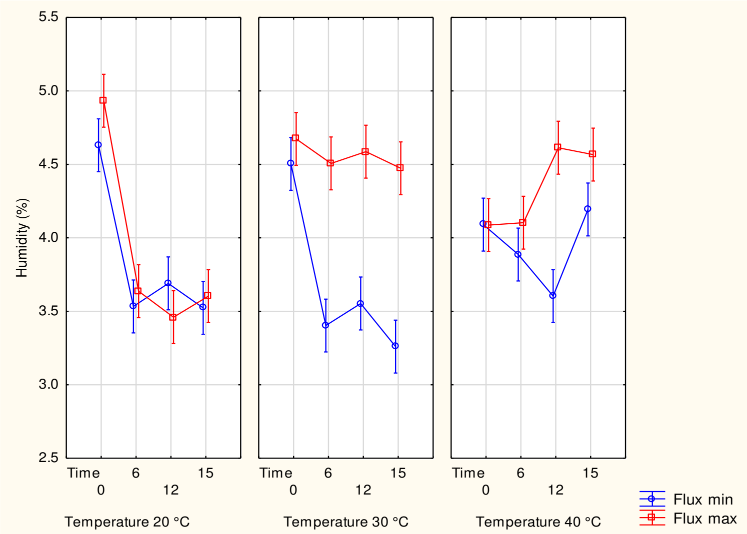

Fig. 1. Humidity values (%) of hazelnuts during storage for each drying treatment.

Moreover, the acidity showed a significant increase (*$p \leq 0.001$*) during the storage with differences only due to air flux (Figure 2), while the peroxides reached the maximum value at 12 months then a decrease has been highlighted due to the secondary oxidation (Figure 3).
The lower values for peroxides were generally obtained for the hazelnuts dried with the maximum flux of air.

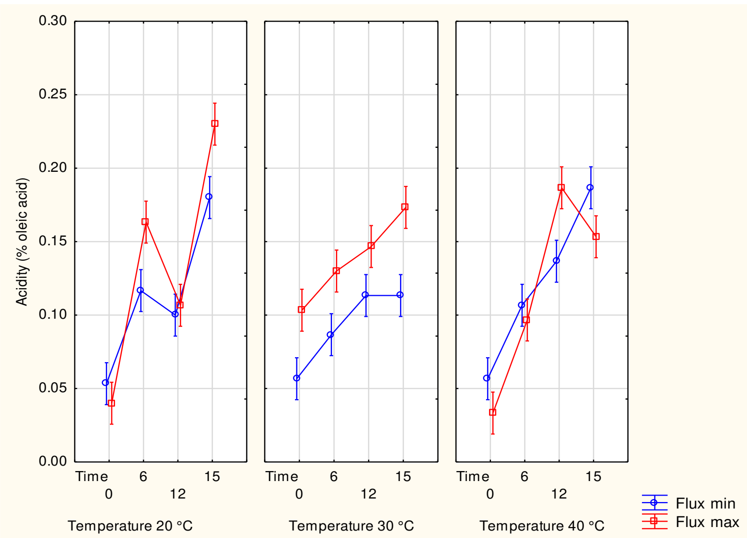

Fig. 2. Values of acidity (% oleic acid) of hazelnuts during storage for each drying treatment.

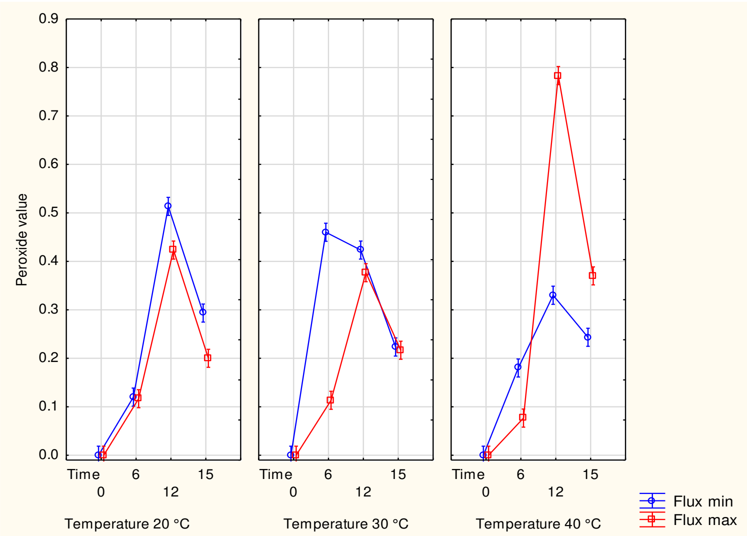

Fig. 3. Values of peroxide (mEq O_2/kg) of hazelnuts during storage for each drying treatment.

Induction periods of oxidation, evaluated with the Oxitest, were influenced by all the processing parameters applied but were significantly higher ($p \leq 0.01$) when a medium temperature (30 °C) was used for drying (Figure 4).

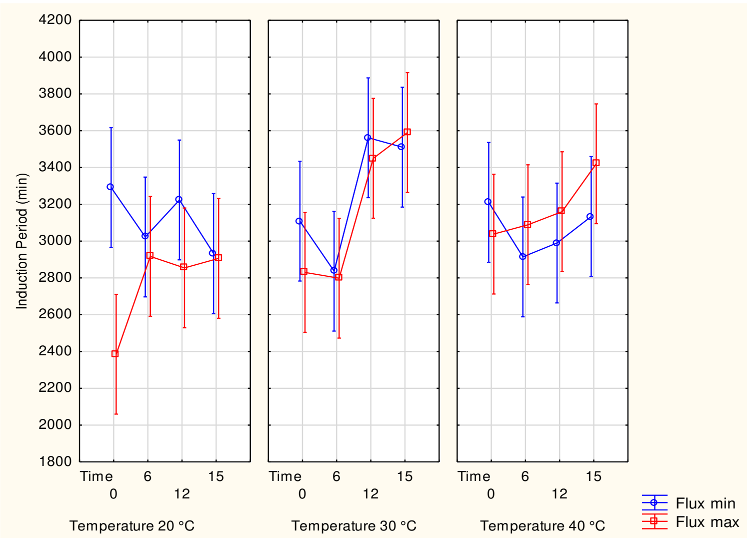

Fig. 4. Values of Induction Period (min) of hazelnuts during storage for each drying treatment.

While colour of the internal kernel was not strongly influenced by storage times and drying methods (as shown in Table 1), the colour of the external kernel changed during the storage time. In particular for all the drying methods, there was an increment of L^* and a* and a decrement for b* values during the storage then a darkening colour with more red tone.

More than fifty volatile metabolite compounds were identified with SPME-GC/MS during the storage. They were assorted into seven groups according to their structure (alcohols, terpenes, ketones, aldehydes, acids, esters and miscellaneous). Generally, factorial analysis carried out for these groups showed that the drying temperature has no significant effects, while storage time has significant effects for all the compounds examined (Table 2). Finally, the effect of air flux was significant for all groups, except for acids and miscellaneous. Interactions were generally significant but for terpenes only interaction between storage time and drying temperature highlighted a significant value.

Table 2. Results of factorial analysis performed for the sums of volatile compounds determined on dried hazelnuts during the storage time.

	M (month)	C (°C)	F (m^3/min)	M*C	M*F	C*F	M*C*F
Alcohols	***	*	***	*	***	***	***
Terpenes	***	ns	***	ns	**	ns	ns
Ketones	***	ns	*	*	***	***	***
Aldehydes	***	ns	*	*	**	***	***
Acids	***	ns	ns	***	***	***	***
Esters	***	***	***	***	***	***	***
Miscellaneous	***	ns	ns	ns	ns	ns	ns

M-storage time; C-drying temperature; F-air flux;
****p<0.001; **p<0.01; *p<0.05; ns-not significant*

Among the volatile compounds, the linear C_6 aldehyde, hexanal and the linear C_6 1-hexanol play an important role. These compounds are known as markers of lipid oxidation that determine green, vegetable and fatty odours. During the storage, their concentration increase and the highest concentration for hexanal was observed at 15 month in samples dried at 20°C with a low flux (Figure 5) while the highest value for 1-hexanol was detected at 12 month in samples dried at 40°C with a low flux (Figure 6). At low temperature of drying the higher concentration of aldehydes was produced by hazelnut dried with the low flux of air.

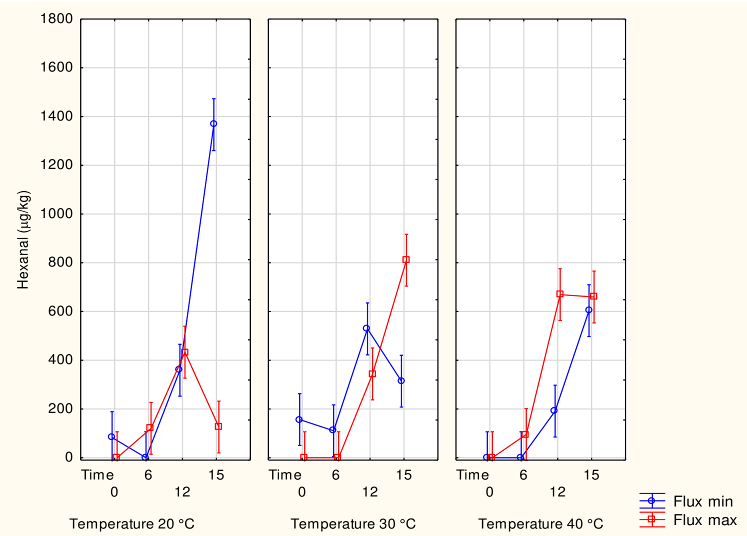

Fig. 5. Values of hexanal (µg/kg) during storage for each drying treatment.

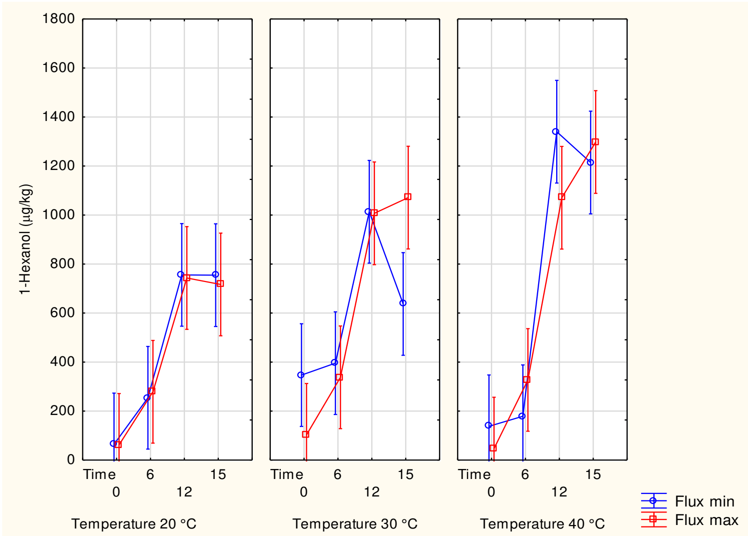

Fig. 6. Values of 1-hexanol (µg/kg) during storage for each drying treatment.

The PCA analysis of E-nose data obtained at the start of the storage and after 15 months of storage (Figure 7 and 8) showed a good discrimination of hazelnut samples. In particular at the start of the storage, there are two groups subdivided by PC1. In positive values of PC1, which explains the 82% of variance, there are all samples dried at 20 °C (P1 and P4) and 30 °C with a low air flux (P5) while, for negative values of PC1, there are all samples dried at 40 °C (P9 and P12) and samples dried at 30 °C with high air flux (P11) underlining how the temperature of 30 °C is an intermediate condition compared to those of 20 °C and 40 °C (Figure 7). At the end of the storage, it is possible to observe three groups. The first is constituted by samples dried at 40 °C with a high flux of air (P9) while the second is constituted by samples dried at 20 °C with a high flux of air (P4) and at 30 °C with a low flux of air (P5). Finally, the third is constituted by samples dried at 20 °C with a low flux of air (P1) and samples dried at 30 °C with a high flux of air (P11) (Figure 8).

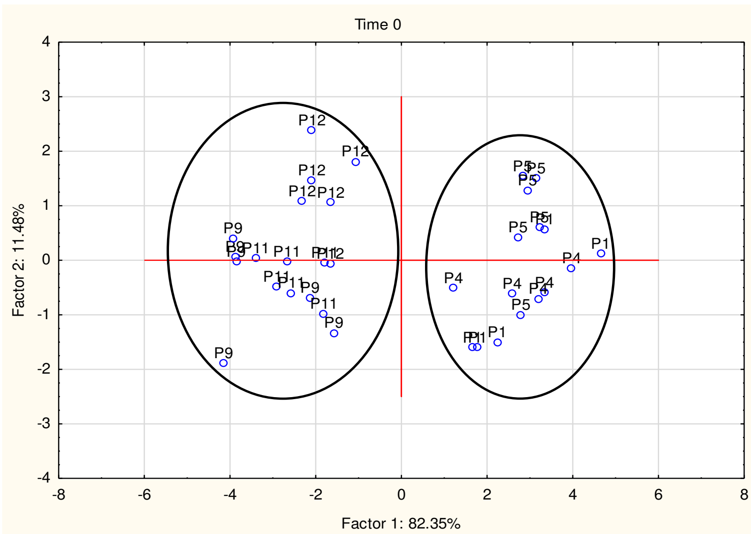

Fig. 7. Score plot obtained with a PCA for the E-nose data measured on hazelnuts at the start of the storage for each drying treatment.

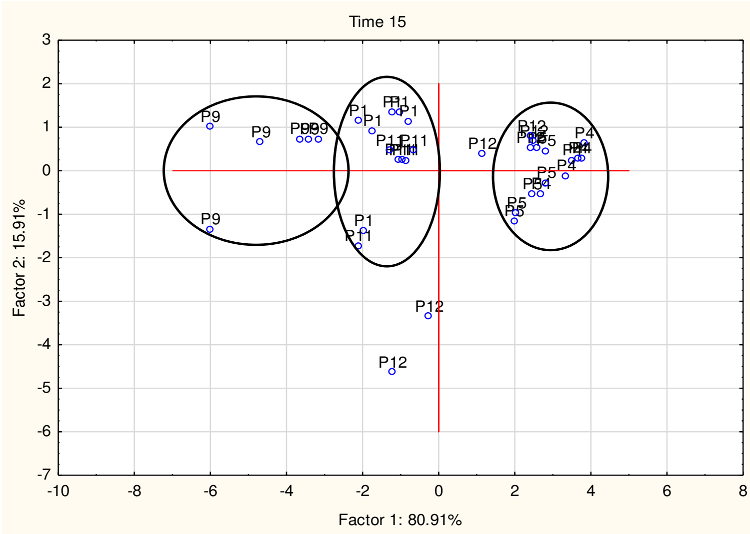

Fig. 8. Score plot obtained with a PCA for the E-nose data measured on hazelnuts after 15 months of storage for each drying treatment.

Among the sensory attributes the odour intensity generally increases during the storage with a maximum at 15 months, due to an increment of the rancidity, woody and vegetable odour/aroma.

4. Conclusions

Results obtained in this work are very important for the drying process since they showed that hazelnuts dried with a low flux of air and intermediate temperature (30 °C) have the better stability to the oxidation also with a storage time of 15 months. Using a 20°C drying temperature in combination with a minimum air velocity, the drying treatment to obtain the initial moisture was significantly longer respect to the others. This treatment determined a higher hazelnut lipid oxidation during the storage period. In fact, by findings, a higher formation of hexanal, a lower induction time (oxitest data), a higher peroxides (except for the treatment at 40°C) were observed. In addition, the initial higher humidity at the start of the storage probably influenced the hydrolytic parameters such as the acidity that is higher in comparison to the other drying test. Moreover, hazelnuts even dried at higher drying temperature, independently by air flux, showed even a lower sensorial stability during storage due to a high formation of 1-hexanol.

Further studies are necessary in order to evaluate if other process parameters as the air humidity or the change of the temperature during the drying could influence the quality of the hazelnut and the stability during the storage.

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