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The influence of packaging on the sensorial evolution of white wine as a function of the operating conditions adopted during storage

F. VENTURI[1,2], C. SANMARTIN[1,2], I. TAGLIERI[1], Y. XIAOGUO[1], G. ANDRICH[1,2], A. ZINNAI[*,1,2]
[1]Department of Agriculture, Food and Environment, University of Pisa, Via del Borghetto 80, 56124 Pisa, Italy
[2]Interdepartmental Research Center "Nutraceuticals and Food for Health", University of Pisa, Via del Borghetto 80, 56124 Pisa, Italy

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Abbreviations: BiB, bag-in-box; k_{TSO2}*, total sulphur dioxide degradation kinetic constant;* TSO_2*, total sulphur dioxide*

Summary. – With the aim to determine the influence of packaging in preserving the quality of wine, in this research project the sensorial evolution of a white table wine stored in different packaging materials (glass bottles provided with different closures; bag-in-box (BiB) containers; tetrabricks®) and different volumes (2 volumes for each packaging) has been evaluated over a period of 12 months. For each packaging solution two different temperature levels (4° and 20°C) were also maintained throughout the storage period.
The preliminary results obtained indicate that wine evolution (characterized by both sensorial and chemical parameters) might be greatly influenced by the packaging characteristics. In particular in glass bottle, the crown cap allowed the best storage conditions for wine, closely followed by natural cork, while the wine maintained in tetrabricks® showed the worst organoleptic profile with the maximum level of oxidation and the highest evolutionary state, closely followed by the wine packaged in BiB containers.

Introduction. – As widely reported in the literature (Yam *et al.*, 2005; Vanderroost *et al.*, 2014; Wani *et al.*, 2014) it is possible to highlight four basic functions for traditional food packaging: (i) communication (Becker *et al.*, 2011; Celhay *et al.*, 2015; Van Ooijen *et al.*, 2016); (ii) protection (Robertson, 2012); (iii) convenience (Vanderroost *et al.*, 2014; Wani *et al.*, 2014); and (iv) containment (Vanderroost *et al.*, 2014; Wani *et al.*, 2014).

Glass containers are still usually preferred for bottling wine (Ghidossi *et al.*, 2012; Wani *et al.*, 2014) being the only material with a high

[*] Corresponding author: angela.zinnai@unipi.it

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impermeability to gases and vapours, stability over time, transparency and readily recyclable (Mentana *et al.*, 2009). Nevertheless, as a consequence of some objective limitations for the extensive use of glass containers in food industry (i.e. heavy weight, fragility to internal pressure, impact and thermal shock, etc.) (Wani *et al.*, 2014), nowadays there is growing worldwide demand for alternative solutions to glass also for bottling wine (Charters and Pettigrew, 2007) in order to propose inexpensive packaging resources, practical to use and often marketed as "eco-friendly," particularly in relation to their contributions to waste prevention (Aarnio and Hamalainen, 2008; Ghidossi *et al.*, 2012; Cleary, 2013).

In this context, starting from the past two decades, among all the possible packaging materials it has been possible to observe an expansive utilization of polymeric materials for wine packaging, including PET bottles, multilayer tetrabricks® and bag-in-box (BiB) type containers (Robertson, 2012; Revi *et al.*, 2014).

With the aim to determine the influence of packaging in preserving the quality of wine, in this research project the sensorial evolution of a white table wine stored in different packaging materials (glass bottles provided with different closures; BiB; tetrabrick®) and different volumes (2 volumes for each packaging) has been evaluated over a period of 12 months.

As well known, temperature influences the oxygen permeability of thermoplastic polymers (Robertson, 2012; Fu *et al.*, 2009; Hopfer *et al.*, 2012; Makhotkina *et al.*, 2012). As oxygen is one of the main factors affecting wine evolution as well as its deterioration (Moutonet and Vidal, 2006; Kwiatkowski *et al.*, 2007; Ghidossi *et al.*, 2012; Dombre *et al.*, 2015), two different temperature levels (4° and 20°C) for each packaging solution were maintained throughout the storage period (12 months).

As SO_2 plays an important protective role against oxidation in wine, the chemical evolution of this compound during storage may represent a good index of oxidative degradation of the product as a function of the packaging used (Fu *et al.*, 2009).

Materials and Methods. – *Experimental protocol adopted*. - The white table wine (pH 3.35 ± 0.01; titratable acidity 4.96 ± 0.20 g/L as tartaric acid; net volatile acidity 0.30 ± 0.02 g/L as acetic acid; total phenols 0.32 ± 0.01 g/L as gallic acid; non-flavonoids phenols 0.26 ± 0.03

as gallic acid; proanthocyanidins 0.05 ± 0.01 g/L as catechins; total SO_2 0.117 ± 0.008 g/L) was packed in different packaging materials at the same time in a commercial winery bottling line, using a fully automated bottling/filling station as reported below:

Glass bottles (different volumes) + different closures:

- Crown cap (0.5 and 1 L)
- Screw cap (0.375 and 0.750 L)
- Cork (0.375 and 0.750 L)
- Polymeric (0.375 and 0.750 L)

Tetrabrick® (0.250 and 1 L)

BiB (3 and 20 L)

For each packaging, container volumes were chosen based on the most frequent use specific for each of them. In order to reduce the bias deriving from the utilisation of different volumes for different packaging, the volume effect was studied by comparing each other the values obtained for each couple (large volume vs small volume) of packaging solution.

Packaged wine was shipped by air-conditioned truck (T = 20 ± 1°C) from the bottling/filling facility located at Castellina Marittima (PI) to the Food Technology Laboratory of the DAFE (University of Pisa) after 1 day from bottling/packaging. Sampling of wine was carried out at 3 days, 6 months and 12 months of storage. During the whole observation period all samples were stored in a controlled temperature cabinet at two different temperature levels: 4 ± 1°C and 20 ± 1°C.

As glass is characterized by a high impermeability to gases and vapours (MENTANA *et al.*, 2009), when wine is stored in a glass bottle, the barrier against the external atmosphere is provided by the closure. In order to highlight the real influence of the different closures on the evolution of the stored wine, all bottles were maintained without the capsules throughout the storage time.

Chemical evolution. – In order to evaluate the statistical significance of the experimental data, all chemical determinations were run in triplicate. The reliability of data sets was evaluated by One Way Completely Randomized ANOVA (CoStat, Cohort 6 software). Comparisons among means were performed by Bartlett's X2 corrected test ($P < 0.05$). Tukey's HSD multiple mean comparison test ($P < 0.05$) was used to state the differences among variables.

Total SO_2. – Time evolution of total SO_2 (TSO_2) concentration was determined by the Ripper titrimetric method (ZOECKLEIN *et al.*, 1999).

The identification of the best values to be assigned to the model parameters was carried out by the specific statistical programme BURENL (Buzzi Ferraris and Manca, 1996) able to identify the minimum value of the F function, which is given by the sum of squares of differences occurring among experimental ($Y_{i,\,exper.}$) and calculated ($Y_{i,calc.}$) data in a space of j-dimensions (where j is equal to the number of model parameters):

$$F = \sum_{i=1}^{N} (Y_{i,calc.} - Y_{i,exper.})^2 \qquad (1)$$

where N represents the total number of experimental determinations. The values assumed by the model parameters at the minimum of the F function represent the best values.

Sensorial evaluation. – The sensorial profiles of wine as a function of the storage packaging were evaluated by a trained panel (10 assessors, 7 males and 3 females, aged between 30 and 65 years). All the involved assessors were included in the "expert panel" of the Department of Agriculture, Food and Environment (DAFE) of University of Pisa; all assessors had previous experience in sensory descriptive analysis, mainly in wine evaluation. According to the DAFE internal procedure for assessor selection and training, based on a normalized technical procedure reported in the literature (Pérez Elortondo *et al.*, 2007), expert assessors must repeat and pass re-qualification tests at least once a year to demonstrate that they are satisfactorily still capable of evaluating the samples. As tests and criteria for re-qualification are the same as those for qualification, both qualification for new assessors and periodic re-qualification for expert assessors can be carried out at the same time. If an expert assessor does not pass one or more tests, she/he will repeat the failed tests up to two times. If tests are not passed, the assessor is removed from the panel. In addition to providing information about assessor suitability, re-qualification tests help to keep the assessors alert, avoiding relaxation and undervaluation of training.

The assessors were provided with a specifically developed sensorial sheet consisting of a not structured, parametric, descriptive wine scoring chart. The synthetic definitions (Jackson, 2009) of each descriptor present in the sensorial sheet are shown to the assessors before starting the sensorial evaluations, with the aim to clearly define the meaning of the terms proposed in the sensorial sheet.

The panellists ranked the wine stored in each packaging solution on a scale from 0 to 10, made comments on the quality, and evaluated the intensity of each parameter, including visual, aroma, and taste attributes, as well as an hedonic parameter such as the overall appreciation (Martin and Rasmussen, 2011).

Tasting was carried out in the morning, in a well-ventilated quiet room and in a relaxed atmosphere. Before evaluation, samples were left for 2 h at room temperature in order to serve all samples at the same temperature, avoiding any indication about the storage temperature of each sample. The wine was then presented to assessors at the same time, regardless of the packaging conditions utilized for storage; a randomized serving order was proposed. All assessments were repeated in duplicate in two different days by the same group of panellists.

The reliability of the assessments was evaluated by One-Way Completely Randomized ANOVA (CoStat, Cohort 6 software) by Bartlett's test ($P < 0.05$). Tukey's HSD multiple mean comparison test ($P < 0.05$) was used to state the differences among variables.

Pearson's correlation coefficient test was also carried out to measure the strength of the association among TSO_2 degradation kinetic constant (k_{TSO2}) and the main wine attributes that are generally associated with oxidation.

Results and Discussion. – *Chemical evolution of stored wine*. – *Kinetics of TSO_2 degradation.* – The time evolution of TSO_2 concentration could be described by a first order kinetic equation:

$$-d[TSO_2]_{t=t}/dt = k_{TSO2} \cdot [TSO_2]_{t=t} \quad (2)$$

where k_{TSO2} is the kinetic constant and $[TSO_2]_{t=t}$ is the concentration of total SO_2 at the reaction time t=t.

After integration, the following equation can be obtained:

$$[TSO_2]_{t=t} = [TSO_2]_{t=0} \cdot e^{-k_{TSO2} \cdot t} \quad (3)$$

As reported in Table 1, the influence of packaging on the oxidation of white wine appeared evident when the wine was stored in little volume containers maintained at 20°C. In these working conditions, the differences in total SO_2 degradation rate, as a function of packaging, are statistically significant. In particular, the reduction of the concentration of TSO_2 was faster when the white wine was stored in Tetrabrick® and BiB packages. This result could indicate that the glass bottles preserve wine from oxidation better than multilayer materials, regardless of the material used for the closure. Among the four different closures, the lowest total SO_2 degradation rate was detected when the crown cap was utilized, closely followed by the polymeric one.

TABLE 1. – *First order kinetic constant describing the time evolution of total sulphur dioxide concentration as a function of the packaging used during storage (small volume packages, 20°C, storage time 12 months).*

Packaging	k_{TSO2} (days^{-1})	Confidence Interval (CI, $\alpha < 0.05$)	r^2
Glass bottle + Cork	0.041	0.00013	0.77
Glass bottle + Polymeric	0.029	0.00012	0.99
Glass bottle + Crown cap	0.021	0.00011	0.74
Glass bottle + Screw cap	0.039	0.00016	0.95
Tetrabrick®	0.045	0.00015	0.93
BiB	0.049	0.00012	0.91

k_{TSO2}, total sulphur dioxide degradation kinetic constant; BiB, bag-in-box.

Sensorial evolution of stored wine. – To verify whether and how the sensory properties of wine changed qualitatively and quantitatively as a function of the packaging as well as of the operating conditions adopted during storage (HIRSON *et al*., 2012), an analysis of variance was carried out on the experimental data related to the sensory attributes deriving from different packaging materials, volumes of packaging and storage temperatures. The results of the ANOVA applied to the main attributes utilized to describe view, smell and taste as well as the overall appreciation are reported in Tables 2-4. Among all the descriptors ranked by the panel components, only the parameters that showed statistically significant differences in one or more storage conditions are reported and discussed.

Effect of packaging material on the sensorial evolution of stored wine. – In Table 2 are reported the mean values of the main sensorial parameters in order to follow the organoleptic evolution of the white wine as a function of the different packaging conditions during the storage period. Regardless of the closure, after 12 months of storage the wine maintained in glass bottles showed the highest values for the positive attributes frankness, harmony of odour and overall appreciation. In particular, among the different closures, the crown cap resulted in the best storage conditions for wine, closely followed by natural cork.

On the contrary, after 12 months of storage, the wine maintained in tetrabricks® showed the worst organoleptic profile with the maximum level of oxidation and the highest evolutionary state, closely followed by the wine packaged in BiB containers.

Effect of volume of packaging on the sensorial evolution of stored wine. – In Table 3 are reported the mean values of the main sensorial

TABLE 2. – *Sensorial evolution of wine stored in large volumes at 20°C (storage time 12 months).*

Packaging	Oxidation	Frankness	Harmony of odour	Degree of aging	Overall appreciation
Natural Cork	3.8 [b]	2.6 [ab]	3.6 [a]	6.6 [ab]	2.2 [b]
Polimeric Cap	4.2 [ab]	3.5 [a]	3.6 [a]	6.4 [ab]	1.8 [b]
Crown Cap	3.9 [b]	3.4 [a]	3.5 [a]	5.7 [b]	3.7 [a]
Screw Cap	4.5 [ab]	1.7 [b]	1.7 [b]	7.4 [a]	1.9 [b]
Tetrabrick®	6.9 [a]	1.2 [b]	1.5 [b]	7.9 [a]	1.6 [b]
BiB	6.5 [a]	1.7 [b]	1.4 [b]	8.3 [a]	1.2 [b]

Within the same column parameters not sharing the same letter have a significantly different mean concentration ($\alpha < 0.05$). BiB, bag-in-box.

TABLE 3. – *Sensorial evolution of wine stored in different volumes at 20°C (storage time 12 months).*

Packaging	Frankness	Harmony of odour	Balance	Degree of aging	Overall appreciation
NATURAL CORK	2.6 [ab]	3.6 [a]	2.2 [ab]	6.6 [ab]	2.2 [b]
Natural cork	2.5 [ab]	2.8 [ab]	1.8 [ab]	7.0 [ab]	2.4 [b]
POLIMERIC CAP	3.5 [a]	3.6 [a]	2.2 [ab]	6.4 [ab]	1.8 [b]
Polimeric cap	2.3 [ab]	3.0 [a]	1.8 [ab]	7.1 [ab]	1.8 [b]
CROWN CAP	3.4 [a]	3.5 [a]	3.1 [a]	5.7 [ab]	3.7 [a]
Crown cap	2.7 [ab]	2.6 [ab]	2.2 [ab]	7.1 [ab]	1.8 [b]
SCREW CAP	1.7 [ab]	1.7 [ab]	2.0 [ab]	7.4 [ab]	1.9 [b]
Screw cap	1.6 [ab]	1.7 [ab]	2.3 [ab]	7.2 [ab]	2.1 [b]
TETRABRICK®	1.2 [ab]	1.5 [ab]	1.7 [ab]	7.9 [ab]	1.6 [b]
Tetrabrick®	0.5 [b]	0.6 [b]	0.9 [b]	9.3 [a]	0.9 [b]
BIB	2.4 [ab]	2.1 [ab]	2.5 [ab]	6.9 [ab]	2.3 [b]
BiB	1.7 [ab]	1.4 [ab]	1.4 [ab]	8.3 [ab]	2.2 [b]

Capital letters indicate large volumes. Within the same column parameters not sharing the same letter have a significantly different mean concentration ($\alpha < 0.05$).

parameters in order to follow the organoleptic evolution of the white wine as a function of the different volume of packaging during storage (T = 20 ± 1°C). After 12 months of storage at room temperature, it is possible to observe a significant effect of the variation of package volume on the sensorial evolution of wine stored in tetrabricks® as well as in glass bottles with crown caps, closely followed by glass bottles with polymeric caps. In all these cases, the largest volumes preserved wine by slowing down its deterioration rate during storage. Among all the adopted operating conditions, the wine maintained in glass bottles with crown caps (vol. 1 L) showed the best sensorial profile, whereas the fastest deterioration of wine was observed when tetrabricks® at reduced volume (0.25 L) were used.

Effect of storage temperature on the sensorial evolution of stored wine. – As the deterioration of wine was faster when small volume packages were used, in order to evidence the possible effect of the storage temperature (4 and 20°C) on the organoleptic deterioration of wine, the mean values of the main sensorial parameters reported in Table 4 are referred to the smaller volume package. After 12 months of storage, it is possible to observe that the aging of white wine was significantly delayed at the lowest temperature. In this condition the wine maintained at 4°C in glass bottles with natural corks showed the best sensorial profile, while the fastest deterioration of wine was observed when it was stored in tetrabricks® at the same temperature. As the wine stored at 4°C in the smaller BiB (vol. 3 L) was defined "undrinkable" by most of the assessors, the data related to this sample are not reported in Table 4.

TABLE 4. – *Sensorial evolution of wine stored at different temperatures (4°C and 20°C) (storage time 12 months).*

Packaging	Frankness	Harmony of odour	Balance	Aftertaste	Degree of aging
Natural cork 4°C	4.6 ^{a}	3.9 ^{a}	2.9 ^{a}	3.0 ^{ab}	6.0 ^{b}
Natural cork 20°C	2.5 ^{abc}	2.8 ^{ab}	1.8 ^{ab}	6.0 ^{a}	7.0 ^{ab}
Polimeric cap 4°C	3.9 ^{ab}	3.6 ^{a}	3.1 ^{a}	3.2 ^{ab}	6.0 ^{b}
Polimeric cap 20°C	2.3 ^{abc}	3.0 ^{ab}	1.8 ^{ab}	4.7 ^{ab}	7.1 ^{ab}
Crown cap 4°C	3.5 ^{ab}	3.0 ^{ab}	2.8 ^{ab}	3.1 ^{ab}	6.4 ^{b}
Crown cap 20°C	2.7 ^{abc}	2.6 ^{ab}	2.2 ^{ab}	5.2 ^{ab}	7.1 ^{ab}
Screw cap 4°C	2.4 ^{abc}	1.6 ^{ab}	2.7 ^{ab}	2.7 ^{b}	7.3 ^{ab}
Screw cap 20°C	1.6 ^{bc}	1.7 ^{ab}	2.3 ^{ab}	4.2 ^{ab}	7.2 ^{ab}
Tetrabrick® 4°C	2.3 ^{abc}	1.7 ^{ab}	2.5 ^{ab}	3.1 ^{ab}	6.6 ^{ab}
Tetrabrick® 20°C	0.5 ^{c}	0.6 ^{b}	0.9 ^{b}	6.0 ^{a}	9.3 ^{a}
Bib 4°C	NA	NA	NA	NA	NA
Bib 20°C	NA	NA	NA	NA	NA

In grey rows values related to wines stored at the lower temperature are reported. Within the same column parameters not sharing the same letter have a significantly different mean concentration ($\alpha < 0.05$).

Indeed, in these experimental conditions the aging of wine was strongly accelerated.

Conclusions. – The results show how the characteristics of packaging could affect wine bouquet and flavour as a function of the storage conditions used, and suggest that their rational optimization, based on experimental data, could improve the shelf life of wine and enhance the consumer's enjoyment during tasting.

Among all the adopted experimental conditions, the rate of wine aging was higher when the volume of the containers decreased and storage temperature increased. Furthermore, after 12 months of storage, the glass bottles generally better preserved wine from oxidation than multilayer materials, regardless of the closure.

In order to evidence whether the rate of total SO_2 degradation could represent a chemical index of the aging degree of the white wine during storage, the total SO_2 degradation kinetic constant (Table 1) was correlated for all packaging with the sensory attributes reported in Tables 2-4. The correlation coefficients are reported in Table 5. According to Paula and Conti-Silva (2014) a correlation coefficient of about 0.70 indicates a fairly strong correlation. Thus, it is possible to evidence that the total SO_2 degradation rate (k_{TSO2}) appeared strongly inversely correlated to positive sensorial attributes such as frankness and harmony of odour, closely followed by balance, while the negative attributes oxidation and degree of aging were directly correlated with k_{TSO2}.

On the basis of the experimental data, a new "integrated approach" deriving from the merging of both chemical and sensorial data, can

Table 5. – *Correlation matrix relating the kinetic constant describing SO_2 degradation to wine attributes (storage time 12 months; 20°C; small volume packages).*

Parameter	kSO_2
Frankness	**-0.7**
Balance	**-0.6**
Harmony of odour	**-0.7**
Aftertaste	<0.5
Oxidation	**0.6**
Degree of aging	**0.6**
Overall appreciation	<0.5

The correlation coefficients that indicate a fairly strong correlation (≥ 0.6) are reported in bold face.

be introduced to identify the best packaging and storage conditions to extend the shelf life of white wine. In this context, k_{TSO2} represents a useful index in order to describe the chemical evolution of white wine in combination with the main sensorial attributes generally associated with oxidative evolution.

The preliminary results obtained after 12 months of storage, indicate that the wine evolution during storage could be greatly influenced by the packaging characteristics (i.e. material and volume). Furthermore, also the temperature during the storage period plays a key role in the evolution of wine, since it can directly influence the oxygen permeability of the system "wine + package".

REFERENCES

Aarnio T., Hämäläinen A.: Challenges in packaging waste management in the fast food industry. *Resour. Conserv. Recy. 52*, 612-621 (2008).

Becker L., van Rompay T.J.L., Schifferstein H.N.J., Galetzka M.: Tough package, strong taste: The influence of packaging design on taste impressions and product evaluations. *Food Qual. Prefer. 22*, 17-23 (2011).

Buzzi Ferraris G., Manca D.: BURENL. Politecnico, Dipartimento di Ingegneria Chimica 'G. Natta', Milan (1996).

Celhay F., Boysselle J., Cohen J.: Food packages and communication through typeface design: The exoticism of exotypes. *Food Qual. Prefer. 39*, 167-175 (2015).

Charters S., Pettigrew S.: The dimensions of wine quality. *Food Qual. Prefer. 18*, 997-1007 (2007).

Cleary J.: Life cycle assessments of wine and spirits packaging at the product and the municipal scale: a Toronto, Canada, case study. *J. Clean. Prod. 44*, 143-151 (2013).

Dombre C., Rigou P., Wirth J., Chalier P.: Aromatic evolution of wine packed in virgin and recycled PET bottles. *Food Chem. 176*, 376-387 (2015).

Fu Y., Lim L.T., McNicholas P.D.: Changes on enological parameters of white wine packaged in bag in box during secondary shelf life. *J. Food Sci. 74*, 608-618 (2009).

Ghidossi R., Poupot C., Thibon C., Mietton-Peuchot M.: The influence of packaging on wine conservation. *Food Control 23*, 302-311 (2012).

Hirson G.D., Heymann H., Ebeler S.E.: Equilibration time and glass shape effects on chemical and sensory properties of wine. *Am. J. Enol. Vitic. 63*, 515-521 (2012).

Hopfer H., Ebeler S.E., Heymann H.: The combined effects of storage temperature and packaging type on the sensory and chemical properties of Chardonnay. *J. Agric. Food Chem. 60*, 10743-10754 (2012).

Jackson R.S.: *Wine Tasting: A Professional Handbook.* Academic Press (2009).

Kwiatkowski M.J., Skouroumounis G.K., Lattey K.A., Waters E.: The impact of closures, including screw cap with three different headspace volumes, on the composition, colour and sensory properties of a Cabernet Sauvignon wine during two years' storage. *Aust. J. Grape Wine R. 13*, 81-94 (2007).

Makhotkina O., Pineau B., Kilmartin P.A.: Effect of storage temperature on the chemical composition and sensory profile of Sauvignon Blanc wines. *Aust. J. Grape Wine R. 18*, 91-99 (2012).

Martin K.R., Rasmussen K.K.: Comparison of sensory qualities of geographically paired organic and conventional red wines from the South-Western US with differing total polyphenol concentrations: a randomized pilot study. *Food Nutr. Sci. 2*, 1150-1159 (2011).

Mentana A., Pati S., La Notte E., Del Nobile M.A.: Chemical changes in Apulia table wines as affected by plastic packages. *Food Sci. Technol. 42*, 1360-1366 (2009).

Moutounet M., Vidal J.C.: Monitoring of oxygen in the gas and liquid phases of bottles of wine at bottling and during storage. *J. Int. Sci. Vigne Vin 40*, 35-45 (2006).

Paula A.M., Conti-Silva A.C.: Texture profile and correlation between sensory and instrumental analyses of extruded snacks. *J. Food Eng. 121*, 9-14 (2014).

Pérez Elortondo F.J., Ojeda M., Albisu M., Salmerón J., Etayo I., Molina M.: Food quality certification: an approach for the development of accredited sensory evaluation methods. *Food Qual. Prefer. 18*, 425-439 (2007).

Revi M., Badeka A., Kontakos S., Kontominas M.G.: Effect of packaging material on enological parameters and volatile compounds of dry white wine. *Food Chem. 152*, 331-339 (2014).

Robertson G.L.: *Food Packaging Principles and Practices*. Taylor and Francis, Boca Raton, FL, 2nd ed. (2012).

Vanderroost M., Ragaert P., Devlieghere F., Meulenaer B.: Intelligent food packaging: The next generation. *Trends Food Sci. Technol. 39*, 47-62 (2014).

Van Ooijen I., Fransen M.L., Verlegh P.W.J., Smit E.G.: Atypical food packaging affects the persuasive impact of product claims. *Food Qual. Prefer. 48*, 33-40 (2016).

Wani A.A., Singh P., Langowski H-C.: Food Technologies: Packaging. Encyclopedia of Food Safety. *Food Mat. Technol. Risks 3*, 211-218 (2014).

Yam K.L., Takhistov P.T., Miltz J.: Intelligent packaging: concepts and applications. *J. Food Sci. 70*, R1-R10 (2005).

Zoecklein B.W., Fugelsang K.C., Gump B.H., Nuri F.: *Wine Analysis and Production.* Kluwer Academic/Plenum Publishers, New York, USA (1999).