Authent-Net Commodity Status Report

Commodity: olive oil

State of the Art of the commodity:

1. Market Share of Commodity:

About 98.7% of olive orchards are located around the Mediterranean Sea. The rest of olive crops (1.3%) are distributed in some countries of American continent such as USA, Argentina or Chile, and Australia.

The average of the virgin olive oils worldwide production in the last six years (2009-2015) was 1,794,200 t. The production in European Union accounts for more than 72% of this world production. Spain is the first worldwide producer with at least 61% of the virgin olive oil production. The increment of production, mainly in Spain and Tunisia, and non-Mediterranean producer countries, it has been complemented with the increment of consumption (20% of increment per each decade from the 60s until now). This increment was higher in the 90s due to the demand of USA, Canada, and Australia.

2. Process Specificity of commodity (production/welfare):

Virgin olive oil (VOO) is the oil obtained from the fruit of the olive tree (*Olea europaea* L.) solely by mechanical or other physical means under conditions, particularly thermal conditions, which do not lead to alterations in the oil, and which has not undergone any treatment other than washing, decantation, centrifugation and filtration. Virgin olive oils fit for consumption are the following:

– Extra virgin olive oil (EVOO) is a VOO which has a free acidity, expressed as oleic acid, of not more than 0.8 g per 100 g and whose organoleptic characteristics correspond to those fixed for this category in the trade standard.

– Virgin olive oil is a VOO which has a free acidity, expressed as oleic acid, of not more than 2 g per 100 g and whose organoleptic characteristics correspond to those fixed for this category in the trade standard.

– Ordinary virgin olive oil is a VOO which has a free acidity, expressed as oleic acid, of not more than 3.3 g per 100 g and whose organoleptic characteristics correspond to those fixed for this category in the trade standard.

– Virgin olive oil not fit for consumption as it is, known as lampante virgin olive oil, is a VOO which has a free acidity, expressed as oleic acid, of more than 3.3 g per 100 g or whose organoleptic characteristics correspond to those fixed for this category in the trade standard. It is intended for refining or for technical purposes.

It is important to consider the classification according to European Union, in which ordinary category does not exist. In this case, the limits of free acidity are the following:

Extra virgin olive oil: ≤0.8 g per 100g.

Virgin olive oil: ≤2 g per 100g.

Lampante virgin olive oil: >2 g per 100g.

3. Trade of Commodity:

About 78% of worldwide consumption corresponds to producer countries, being Italy the first consumer country (38.5%) followed by Spain (28.4%). However, the higher increment of consumption of virgin olive oils is observed in non-producer countries. Thus, European producer countries have become importer/exporters of virgin olive oil. Further information can be obtained from Handbook on Olive Oil: Analysis and Properties (Aparicio, R., Harwood, J., Eds., 2° Edition, Springer, New York, 2013) and on the website of International Olive Council (http://www.internationaloliveoil.org).

In the non-Mediterranean zones, the imports of USA, Australia, Japan, Canada or Brazil have to be highlighted, being USA the first import country from European countries principally.

Although Southern Europe, North Africa, and the Middle East produces over 98% of the world's olive oil, recently several new producer countries outside the Mediterranean region (USA and Australia) have begun to produce olive oil for their domestic and export markets. Australia produces about 18,000 t of olive oil from 110 processing plants. Production is primarily from medium-density orchards and the cultivars Barnea, Frantoio or Picual. Expansion is limited due to the scarcity and high cost of irrigation water. Average production costs for orchard are approximately $4,500/ha or $1.92/kg of oil. In the case of USA, California produces the 99% of olive oil, producing approximately 4,000 t of oil, which represents only 2% of total USA consumption. Production has doubled in the last 2 years and will continue to increase significantly as new orchards come into full bearing. Over 70 % of the production is from the cultivar Arbequina, followed in descending order by Arbosana, Koroneiki, Frantoio, and Leccino. Production costs for the orchard are range from $3,311 to $6,020/ha, or $1.65 to $3.00/kg oil.

Key KNOWN Authenticity Issues with this commodity:

The possible authenticity issues described in olive oil can be classified into three types; (i) mixture of different categories of olive oil, (ii) mixture with other vegetable oils, (iii) problems related to mislabelling, such as virgin olive oil labelled as extra virgin olive oil, or oil labelled with an origin that does not match with its real provenance. Although olive oil authenticity is a complex topic, the main issues and subissues can be summarizes as follows:

Issue: Adulteration
Subissue:
- Addition of cheaper oil to olive oils (Detection of refined hazelnut oils in ROOs).
- Addition of refined oils to VOOs (Detection of seed oils in VOOs).
- Addition of low to high oil categories (Detection of deodorised VOOs in VOOs).

Issue: Geographical origin
Subissue:
- Inexact label (Detection of VOO from several origins).
- Traceability (Characterisation of PDOs).

Issue: Agricultural systems
Subissue: Organic vs. conventional (Addition of conventional to organic VOOs).

Issue: Cultivar.
Subissue: Varietal VOOs (e.j. Authentication of monovarietal VOOs).

To guarantee the quality and safety of olive oil and to control its authenticity, this product has been at the forefront of the implementation of multiple standard methods. Thus, olive oil has become one of the most strictly regulated food products.

Since it is a product highly regulated, in all the works related to olive oil authenticity it is relevant to consider the regulatory bodies and associations for olive oil, which present an extensive collection of analytical methods to characterize olive oils and olive-pomace oils and to avoid possible frauds. These organizations are, among others, International Olive Council (IOC), European Commission (EC), Codex Alimentarius Commission, CODEX STAN, German Society for Fat Science (DGF), Association of Official Analytical Chemistry (AOAC), American Oils Chemists' Society (AOCS), International Union of Pure and Applied Chemistry (IUPAC), and Federation of Oil Seeds and Fats Association (FOSFA). Olive oil is subjected to worldwide trade, and international regulation is provided by trade standards published and updated by these institutions. Particularly important is to consider the trade standards of IOC and EC.

There is a considerable interest in optimizing current methods and developing new ones, because it is important to keep the pace with changing technologies and sophisticated adulterations. Great part of research is focused on these activities.

The improvement of the standard methods requires time and an important and continuous funding on innovation and research activities. Since some of the current adulterations described today are more sophisticated than in the past, the strategy of some current research studies is to combine standard methods and emerging technologies, including fingerprinting approaches into a single comprehensive analytical strategy. The analytical techniques are sometimes based on spectroscopic techniques (near-infrared-NIR spectroscopy, Fourier transform mid-infrared spectroscopy-FTIR spectroscopy, etc.).

A list of authenticity issues is presented below. The importance is established in each one of them from a general point of view (e.g. frequency, difficulty in its detection), although there is not official data from an international perspective about their incidences.

1. Substitution:

- *Substitution of a high quality virgin olive oil (e.g. extra virgin) by a lower grade virgin olive oil (virgin or lampante)*

It can be determined by panel test (sensory assessment) and by volatile compounds analysis (e.g. SPME-GC). Free acidity, peroxide value and other physico-chemical parameter also help in controlling quality. They are mentioned below.

Importance: Medium-Low

- *Substitution by other vegetable oils (see following section "addition of substance x").*

2. Addition of substance X

- *Detection of vegetables oils in olive oils*

Fatty acid composition may detect the presence of high linoleic vegetable oils (soybean, rapeseed, sunflower, etc.), myristic acid indicate the presence of fractionated palm oils and lignoceric acid the presence of peanut oils. Sterols composition may detect the presence of seed oils (*Brassicace*ae oils, rapeseed oils, mustard seed oils, etc.). ΔECN42 may detect the presence of seed oils (corn oils, sunflower oils, etc.). These analytical parameters could be used alone or in combination.

Importance: Low

- *Detection of pomace oil in olive oils*

The determination of erythrodiol+uvaol (E+U) may indicate the presence of pomace oil. The presence of waxes may also indicate the presence of pomace oil when the concentration of E+U is within (2%-4.5%).

Importance: Medium-Low

- *Detection of crude and/or refined corn oil in olive oil*

Detection of crude and/or refined corn oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols (apparent β-sitosterol -beta-sitosterol + delta-5-avenasterol + delta-5-23-stigmastadienol + clerosterol + sitostanol + delta 5-24-stigmastadienol-, campesterol, stigmasterol) and determination of ΔECN42.

Importance: Low

- *Detection of refined corn oil in virgin olive oil*

The quantification of stigmastadienes may detect the refined corn in virgin olive oil (stigma-3,5 diene).

Importance: Low

- *Detection of cotton oil in virgin olive oil*

Detection of crude and/or refined cotton oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols and determination of ΔECN42.

Importance: Low

- *Detection of refined cotton oil in virgin olive oil*

The quantification of stigmastadienes may detect the refined cotton in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *Detection of palm oil in virgin olive oil*

Detection of crude and/or refined palm oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols and fatty acid.

Importance: Medium-Low

- *Detection of refined palm oil in virgin olive oil*

The quantification of stigmastadienes may detect the refined palm in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *Detection of peanut oil in virgin olive oil*

Detection of crude and/or refined peanut oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols and fatty acid.

Importance: Low

- *Detection of refined peanut oil in virgin olive oil*

The quantification of stigmastadienes may detect the refined peanut in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *Detection of soybean oil in virgin olive oil*

Detection of crude and/or refined soybean oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols and fatty acid.

- *Detection of refined soybean oil in virgin olive oil*

The quantification of stigmastadienes may detect the refined soybean in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *Detection of rapeseed oil in virgin olive oil*

Detection of crude and/or refined rapeseed oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols and ΔECN42.

Importance: Low

- *Detection of refined rapeseed oil in virgin olive oil*

The quantification of stigmastadienes may detect refined rapeseed oil in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *Detection of mustardseed oil in virgin olive oil*

Detection of crude and/or refined mustardseed oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols.

Importance: Low

- *Detection of refined mustardseed oil in virgin olive oil*

The quantification of stigmastadienes may detect the refined mustardseed oil in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *Detection of hazelnut oil in virgin olive oil*

Detection of crude and/or refined hazelnut oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols and Global method (triacylglycerols).

Importance: Medium-Low

- *<u>Detection of refined hazelnut oil in virgin olive oil</u>*

The quantification of stigmastadienes may detect the refined halzenut in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *<u>Detection of safflower oil in virgin olive oil</u>*

Detection of crude and/or refined safflower oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols and fatty acid.

Importance: Low

- *<u>Detection of refined safflower oil in virgin olive oil</u>*

The quantification of stigmastadienes may detect the refined safflower in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *<u>Detection of sesame oil in virgin olive oil</u>*

Detection of crude and/or refined sesame oil in olive oil (mixture of refined olive oil and virgin olive oil) and/or refined olive oil by quantification of sterols and fatty acid.

Importance: Low

- *<u>Detection of refined sesame oil in virgin olive oil</u>*

The quantification of stigmastadienes may detect the refined sesame in virgin olive oil (stigma-3,5-diene).

Importance: Low

- *<u>Detection of the presence of any edible oil (crude or refined) in virgin or refined olive oil</u>*

Selected ^{13}C and ^{1}H NRM spectroscopies may detect the adulteration with hazelnut.

Infrared or Raman bands may detect some kinds of adulteration.

Importance: Medium-Low

- *<u>Detection of the presence of any refined edible oil in virgin or refined olive oil</u>*

Spectroscopy by FTIR or FT-Raman may detect *cis/trans* bands to determine the presence of any refined edible oils.

Importance: Low (medium low for refined edible oil in refined olive oil).

- *Detection of the presence of VOOs deodorized at low temperature in EVOOs.*

The determination of ethyl esters may detect the presence of deodorized at low temperature in EVOOs, although it is not effective enough, and there is not an efficient method for detecting this kind of adulteration.

Importance: Medium-low

3. Process/production/welfare deception

- *Determination of the geographical provenance (country, region, PDO) of VOO*

The determination of some compounds present in olive oil may detect the geographical provenance of oils such as:

1. Fatty acids

2. Sterols

3. Hydrocarbons

4. Other minor compounds.

Some strategies include:

- Chemical profiling of the oil (SEXIA project: Aparicio R, Alonso V. Characterization of virgin olive oils by sexia expert system. Progress in Lipid Research. 1994;33(1-2):29-38.).

- EA-IRMS or NMR may determine the provenance of VOOs.

- ICP-MS or ICP-AES may detect the geographical provenance of VOOs.

Importance: Medium

In addition to this authenticity issues, it is important to note that there are standard methods and parameters described by International Olive Council (COI) to determine olive oils **quality** characteristics:

- Free acidity.

The higher the value correspond to the worse the olive quality because the processing of unhealthy olives increases free acidity.

- Organoleptic assessment: median of fruity attribute and median of defect (Panel Test)

- Fatty acid methyl esters and fatty acid ethyl esters.

EVOOs should have no ethyl esters or at trace level. High values characterize lampante olive oils.

- Peroxide value.

After extraction from olives, oil undergoes oxidation depending on several external variables.

- Absorbency in ultraviolet at K_{232} and absorbency in ultraviolet at K_{270}

Oxidation products absorbs at this wavelength. The higher values correspond to the oxidative status.

There are also standards methods described by International Olive Council (COI) to determine olive oil **purity** characteristics.

- 2-glyceryl monopalmitate (%)

A higher value is related to presence of esterified oils whose triacylglycerol are obtained by chemical synthesis.

- Absorbency in ultraviolet at K_{232} and absorbency in ultraviolet at K_{270}

A higher value is related to presence of refined oil.

- Myristic acid (%)

A higher value is related to presence of seed oil, mainly fractionated palm oil.

- Linolenic acid (%)

A higher value is related to presence of seed oils such as soybean oil and low erucic rapeseed oil.

- Eicosecoic acid (%)

- Behenic acid (%)

- Lignoceric acid (%)

A higher value is related to presence of seed oils such as peanut oils.

- ∑C18:1 *trans* isomers (%) and ∑C18:2 + C18:3 *trans* isomers (%)

A higher value is related to presence of refined oils, even if UV absorption is inside the limits.

- Cholesterol (%)

A higher value is related of presence of animal fats or of fractionated palm oil.

- Brassicasterol (%)

A higher value is related to presence of *Brassicaceae* oils even if with “zero” erucic acid content.

- Campesterol (%)

A higher value is related to presence of seed oils.

(Possibly listed in most common to least common type of known fraud with regards to this commodity) – Needs to link to FI terms?

Existing relevant information on methods:

The following standard methods are described by International Olive Council or can be found in scientific research papers:

1. Fatty acids
http://www.internationaloliveoil.org/documents/viewfile/4137-met28eng

2. Sterols
http://www.internationaloliveoil.org/documents/viewfile/4145-met30eng
García-González, D. L., Viera, M., Tena, N., Aparicio, R. (2007). ISSN: 0017-3495

3. ΔECN42
http://www.internationaloliveoil.org/documents/viewfile/3884-testing7

4. Erythrodiol+uvaol
http://www.internationaloliveoil.org/documents/viewfile/4145-met30eng

5. Waxes
http://www.internationaloliveoil.org/documents/viewfile/7717-met-31-alkylester-waxes

6. Stigmastadienes
http://www.internationaloliveoil.org/documents/viewfile/3863-testing2

7. Ethyl esters
http://www.internationaloliveoil.org/documents/viewfile/4137-met28eng

8. Global Method (triacylglycerol composition) used to determine hazelnut oils in olive oil
http://www.internationaloliveoil.org/documents/viewfile/4092-metodo-global-english

9. Method of ^{13}C and ^{1}H RMN used to determine edible oils in virgin olive oil
http://dx.doi.org/10.1016/j.aca.2012.12.003

10. Method of FTIR or FT-Raman spectroscopy to determine edible oils in virgin olive oil
http://dx.doi.org/10.1016/j.foodres.2013.07.039

11. Method FTIR or FT-Raman spectroscopy to determine refined edible oils in virgin olive oil
http://pubs.acs.org/doi/abs/10.1021/jf050595n

12. Method sterols and fatty acids to determine geographical provenance of olive oils –
http://dx.doi.org/10.1016/j.foodchem.2015.04.139

13. Method sterol, fatty acids and hydrocarbons to determine geographical provenance of olive oils
http://dx.doi.org/10.1002/ejlt.200900015

14. Method for determining volatile compounds and phenolic to detect substitution with low grade virgin olive oils
http://dx.doi.org/10.1021/jf101316d

15. Method of EA-IRMS to determine geographical provenance in virgin olive oils
http://doi:10.1016/j.foodchem.2008.04.059

16. Method of ICP-MS to determine geographical provenance in virgin olive oils
http://dx.doi.org/10.1016/j.foodchem.2011.01.064

17. Free fatty acids used to determine the quality of olive oils - According to ISO 660, "Determination of acid value and acidity".

18. Method for organoleptic assessment used to determine the quality of olive oils http://www.internationaloliveoil.org/documents/viewfile/3685-orga6

20. Peroxide value used to determine the oxidation of olive oils - According to ISO 3960, "Determination of the peroxide value"

21. Method of absorbency in ultraviolet to determine the oxidation of olive oils
http://www.internationaloliveoil.org/documents/viewfile/4101-dec-20ecn42-eng

22. Method for determining the content 2-glyceryl monopalmitate to determine esterified oils –
http://www.internationaloliveoil.org/documents/viewfile/3325-23-apalmeng

(Many of these would link to WP2 - Knowledgebase in FoodIntegrity)

Official Bodies/Countries involved in controlling this commodity and funding research associated to their authenticity:

eg: Oils and Fats

International:

- International Olive Council, IOC. (http://www.internationaloliveoil.org/)

- European Community (http://ec.europa.eu/agriculture/olive-oil/legislation/index_en.htm).

Other professional associations are directly involved in discussion about authenticity of olive oil, and they sometimes fund some research projects on fraud control.

a.) **Italy**: (list of organisations that are involved in funding authenticity research for this commodity.)

- Associazione italiana industria olearia, ASSITOL (Italian Association of Olive Oil Industry)

- Società Italiana per le Studio delle Sostanze Grasse, SISSG (Italian Society of Olive Oil Study)

- AGER (agrofood and research)

- Ministry of Agricultural, Food and Forestry Policies

b.) **Spain:** (list of organisations that are involved in funding authenticity research for this commodity.)

- Interprofesional del Aceite de Oliva (Interprofessional of Olive Oil).

- Ministerio de Agricultura, Alimentación y Medio Ambiente (Ministry of Agriculture, Food and Environment).

- Asociación Española de la Industria y Comercio Exportador de Aceites de Oliva y Aceites de Orujo, ASOLIVA (Spanish Association of Industry and Exported Trade of Olive Oils and Pomace-Oil)

- Asociación Nacional de Industriales Envasadores y Refinadores de Aceites Comestibles, ANIERAC (Spanish Association of Packing Industrial and Refining of Edible Oils).

c.) **Greece:** (list of organisations that are involved in funding authenticity research for this commodity.)

- Panhellenic Confederation of Unions of Agricultural Cooperatives (PASEGES).

- Greek Association of Industries and Processors of Olive Oil (SEVITEL).

- Hellenic Association of Industries and Packers of Olive Oil (ESVITE).

- National Interprofessional Organization of Olive Oil and Table Olives (EDOEE). The three associations mentioned above are members of this interprofessional association.

Gaps:

It is necessary to reinforce the funding and research organization for a better coordination of the research activities on traceability and fraud control across the food supply chain**.** Specific gaps are:

- Harmonization of the olive oil categories between regulations.

- Reducing the number of trade standards (IOC, EU, Codex Alimentarius, USA and Australia) by their harmonisation and an active collaboration between regulatory bodies.

- Development, validation and pre-normative activities followed by the standardization of a method for the assessment of the organoleptic characteristics. For this purpose, it is necessary to analyse the existing methods, and to promote the design of reference materials to improve sensory assessment and the development of methods based on the determination of flavour compounds. Other challenges are the determination of thresholds and ratios among volatiles and to evaluate the aroma impact of these compounds. Other objective is the development of fMRI methods to measure the hemodynamic response of the brain during the smelling and testing olive oils to understand better the olive oil quality.

- Identification of research needs for robust methods to replace or complement standard methods, in particular to simplify laboratory work and improve efficiency in authenticity control.

- Determination of the blend of extra virgin olive oil (EVOO) or virgin olive oil (VOO) with soft deodorized olive oil with different strategies such as:

1. Collect reliable information on the soft deodorisation process to understand better what are the conditions that are used today and how they affect olive oil composition.

2. Study in a systematic way the changes in oil composition due to soft deodorisation and to identify potential markers of this kind of adulteration.

- Harmonization of methods described to research on altered pigments, mainly chlorophyll and carotenoids, which are sensitive to light exposure, temperature or oil ageing. It is required to understand better the role of pyropheophytins in freshness control. The evaluation of other quality parameters related to freshness is also required.

- Detection of other adulterant oils (vegetable/edible oil or low quality olive oil) blended into edible VOO.

- Development of new techniques (non-targeted approaches) to improve the detection of adulterants in edible VOO. Thus, it is necessary to develop new methods based on near infra-red spectroscopy (NIR), FTIR, NMR, Raman spectroscopy, etc. to determine the standard parameters used for describing the quality and authenticity of olive oil.

- Development of genomic methods to discriminate vegetable oils and quantify the relative addition of seed oils to VOO, and to verify other features (e.g. cultivar).

- Development of "omic" procedures for a better characterization of virgin olive oil, particularly geographical traceability.

- Development of an "olive oil map" to improve the geographical traceability characterized by chromatographic, spectroscopic, and isotopic techniques.

- Improvement of chemometric tools for perfecting the analytical methods.

- To obtain a database to adjust the legal limits of some chemical compounds to the new situation of the world market, in particular in relation to the development of new cultivars, new agricultural practices and new producing countries.

Some of these gaps and challenges are extensively described in:

1. Handbook of Olive Oil. Analysis and Properties, 2nd ed; Aparicio, R., Harwood, J. Eds.; Springer: New York, 2013; pp. 261-309.

2. García-González DL, Aparicio R. Research in olive oil: Challenges for the near future. J Agric Food Chem. 2010;58(24):12569-77.

3. Valli E, Bendini A, Berardinelli A, Ragni R, Riccò B, Grossi M, Gallina Toschi T Rapid and innovative instrumental approaches for quality and authenticity of olive oils, Eur. J. Lipid Sci. Technol. 2016; 118(11), 1601-19.

4. Call on olive oil authenticity: https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/762-sfs-14a-2014.html

5. Scientific workshop on olive oil authentication (Madrid, 10-11 June 2013): http://ec.europa.eu/agriculture/events/olive-oil-workshop-2013_en.htm

6. H2020 EU Project OLEUM - Advanced solutions for assuring the overall authenticity and quality of olive oil – from 09/2016 to 08/2020. Project description: http://cordis.europa.eu/project/rcn/204671_en.html

List of known gaps in Food Authenticity Research in this commodity.