Specialized Mechanization: Machinery for Olive Growing and Oil Extraction

by Xun L. (Session Rapporteur, CHI) and Leone A. (Session Chairman, ITA)

Introduction

This session, chaired by Professor Alessandro Leone from the University of Bari, focuses on machinery for olive growing and olive oil extraction, and aims to provide a comprehensive overview of the global olive oil supply chain. The session explores olive cultivation and production systems across different regions, from the traditional Mediterranean areas to emerging "new world" producers, highlighting how innovation and mechanization are reshaping the sector while preserving oil quality and quantity. There are four invited speakers in this session, and these presentations offer a global, integrated view of olive cultivation and olive oil production, highlighting how technology, mechanization, and management innovation can support a sustainable and competitive olive oil sector worldwide.

1. Global Olive Cultivation: Between Tradition and Innovation to Preserve Oil Quantity and Quality in a Changing World

by Rugini E. (Accademia Nazionale dell'Olvo e dell'Olio - Italy)

1.1. Background and Overall Perspective

- Global olive cultivation is facing a rapidly changing context driven by climate change, policy reforms, technological innovation, and evolving market and consumer trends.
- About 90% of global olive production still comes from the Mediterranean region.
- Emerging olive-producing regions include South America, Africa, Australia, China, and Argentina, where advanced agronomic techniques, intensive systems, and automation are widely adopted.
- Three main olive grove systems were identified: Traditional Groves (Less than 200 trees per hectare), Intensive Groves (300–1,000 trees per hectare), and Super-Intensive Groves (More than 1,000 trees per hectare).

1.2. Effects of Climate Change on Olive Trees and Oil Quality

- Rising temperatures are particularly severe in the Mediterranean basin.
- Key impacts include 1) Insufficient winter chilling, reducing proper flowering; 2) Earlier flowering with increased frost risk; 3) Reduced fruit set and increased fruit drop; and 4) Accelerated ripening, leading to lower oil content (up to 30% loss).
- Oil quality degradation includes: 1) Reduced polyphenols; 2) Increased acidity and oxidation; and 3) Altered fatty acid composition, especially reduced oleic acid.
- Long-term observations show a progressive decline in oleic acid content associated with increasing temperatures.

1.3. Agronomic & Cultural Practices

- Partial irrigation (40–60% of evapotranspiration) can effectively reduce water stress. Micro-irrigation systems improve efficiency but may increase disease incidence and reduce oil quality parameters. Surface irrigation may offer advantages but is not yet widely adopted.
- Sensor-based technologies optimize irrigation, fertilization, and disease detection.

- To conserve soil and reduce damage from high temperatures, no-tillage with cover cropping or mulching is adopted to increase organic matter, prevent erosion, improve soil health and ecological balance.
- Rational pruning enhances light interception, improves oil yield and quality, and reduces pest pressure. Medium pruning intensity is identified as the most effective strategy.
- Reflective materials such as kaolin and rock powders: 1) Reduce canopy temperature; 2) Improve photosynthesis under heat stress; 3) Increase oil yield; and 4) Reduce olive fly infestation by 10–40%.
- To adopt mixed farming sustainable farming such as livestock grazing, complementary crops, and agrovoltaics to lower environmental impact. Improving organic olive cultivation is another option, as it reduces environmental impact and meets the growing market demand.

1.4. Policies Supporting Sustainable Income Growth

- Sustainable income growth can be supported through: 1) Price premiums for quality and certified oils; 2) Carbon credits, as olive trees have strong carbon sequestration potential; and 3) Incentives for low-impact and sustainable production systems.

1.5. Technological & Innovative Solutions

- Micropropagation offers uniform, vigorous plants with well-developed root systems and early productivity.
- Biostimulants, including bacteria and mycorrhizae, significantly enhance plant growth.

1.6. Genetic & Breeding Approaches

- Global germplasm collections provide valuable traits such as drought tolerance, disease resistance, and high oleic acid content.
- Biotechnology achievements include: 1) Genome sequencing; 2) Development of dwarf, salt-tolerant, and drought-tolerant plants; and 3) Tetraploid olives with reduced vigor and increased oil content.

1.7. Future Outlook and Conclusions

- Future developments will focus on: 1) Automation and robotics in propagation; 2) Improved somatic embryogenesis; and 3) Advanced gene modification techniques.
- In a rapidly changing world, we can protect the olive's productivity, quality, and sustainability by pairing innovation with cultivation practices adapted to each territory, not a single olive-growing system, but more than one.
- Research is vital and must remain FREE from ideological constraints, pseudoscience, and unqualified influence, so that the olive can reach its full potential.

2. Advanced Field and Mechanical Milling Technologies to Enhance the Olive Oil Supply Chain and Sustainability: towards AI

by Leone A. (University Bari - Italy)

2.1. Olive Oil Quality: Consumer Perception and Evolution

- Olive oil quality can be viewed at four levels: Legal quality, safety, Healthy, Sensory.

- Modern consumers associate olive oil with high quality, which goes beyond legal and safety standards.
- Although bioactive and volatile compounds represent only 1–2% of olive oil, they determine most of its perceived value.
- Technological paradigms have evolved: quantity (Until the 1980s), quality (1990s onward), sustainability (today).

2.2. Key Steps to Achieve Quality and Sustainability

- High-quality and sustainable olive oil production depends on three main stages: olive production in the field, olive oil extraction in the mill and oil storage and bottling.
- Agricultural engineering plays a crucial role, particularly in reducing production costs.
- Cost distribution in olive cultivation: Harvesting (42%), Pruning (35%), Other operations (23%).
- Improving harvesting efficiency has the greatest economic impact.

2.3. Mechanical Innovation in Olive Harvesting

- Harvesting must be fast and efficient due to the narrow optimal harvest window, during which oil quality rapidly changes.
- For discontinuous canopies, the hand-held machines and trunk shakers are used to harvest. Hand-held machines have low capacity and are suitable for use in marginal areas and developing regions. Trunk shakers, which are used for approximately 60% of global olive harvesting, offer high efficiency and cause minimal damage when correctly operated.
- Over-the-row harvesters (self-propelled or trailed) are used for continuous canopy with high work capacity (0.5–0.6 ha/hour), and they also enables full mechanization of pruning, soil, and weed management.

2.4. Harvest Planning Using Digital Technologies

- Poor harvest planning can overload mills during peak periods.
- It's possible to plan olive harvest one week in advance with image analysis by knowing two parameters: the maturity index and the quantity of olives per hectare.

2.5. Innovations in Olive Oil Processing

- Traditional cleaning includes dry and water washing.
- Optical sorting systems (RGB and near-infrared cameras) can separate damaged or low-quality olives to greatly improve the sorting process.
- Conventional hammer crushers rely on pressure and friction, causing paste overheating. When knife crushers are used, there is no difference in quantity, but the health value of the oil increases (polyphenols content by about 34%), and the sensory profile improves.
- Traditional malaxers mix can olive pastes, but lead to uneven thermal treatment. The use of heat exchangers between crusher and malaxer can effectively solve this problem while maintaining the same extraction efficiency but increasing the health value by 30%.
- Horizontal centrifuges separate oil from pomace. New sensor technologies are developed to enable real-time monitoring: Near-infrared sensors measure oil loss in pomace and Turbidity sensors prevent clogging in vertical separator.

2.6. Future Directions in the Olive Oil Supply Chain

- In the field: improving data collection (using DSS, image analysis, other sensors), processing data, and making decisions and make the field operations in an automated way.
- In the mill: circular economy solutions (stone recovery, anaerobic digestion, biogas production), full process monitoring with energy and quality sensors, and continuous processing systems (reducing energy consumption by up to 50%).
- Long-term vision: Integration of sensors, actuators, and machine learning to automate the entire system, ensuring high yield and high quality while meeting all sustainability goals.

3. Technologies and Mechanization to Enhance Value Chain in Developing Countries

by Di Terlizzi B. (CIHEAM - Italy)

3.1. Mission and Structure of the CIHEAM BARI

- Headquarters in Paris, with institutes in Italy (Bari and Trieste), France, Spain (Zaragoza), and Greece.
- Focus areas: Agriculture, Economy, and Local development.
- Main mandate: training, research, and international cooperation for third countries.
- Activities aim to improve farmers' income and living conditions, not just generate academic knowledge.

3.2. Education, Training, and Social Impact

- The institute runs master's programs, vocational and technical training, advanced courses for decision-makers, and open innovation programs for farmers and entrepreneurs.
- Trainees become "ambassadors" in their home countries, linking local administrations, universities, and institutions.
- Network spans over 100 countries, with thousands of trained professionals.
- A measured social impact index of 3.92, based on tracking alumni careers and improvements in living standards.

3.3. Network-Based Cooperation Approach

- The institute emphasizes working through networks, not acting alone.
- Cooperation model includes capacity building and institutional strengthening, field implementation and partnerships with local universities and administrations.

3.4. Advance Specialized Course

- Precision agriculture is a key focus, especially for Mediterranean and developing countries.
- A 10-week international course on precision agriculture was launched for high-level decision-makers from 16 countries, supported by Italy's Ministry of Foreign Affairs.
- Participants visit Italian companies to understand modern mechanization and technologies.

3.5. Challenges of Agricultural Mechanization in Developing Countries

- Pakistan case: The national goal to cultivate olives for oil faces the challenge of transforming wild mountain trees into a productive resource. The core hurdle is ensuring community adoption of new grafting and cultivation techniques to create local livelihoods and prevent rural migration, requiring a slow, participatory approach rather than a simple technology handover.

- Egypt case: A formal tender for tractors failed because their catalytic converters were incompatible with the quality of local agricultural fuel. This exposed a deeper systemic issue: government procurement focuses on buying new machinery but neglects spare parts, leading to a cycle of cannibalizing new machines and leaving advanced technology useless.
- General Challenge: Both cases illustrate the "vicious circle" of cooperation. Success requires changing institutional mentalities to move beyond simple hardware procurement. The key is to support laws and business models that enable farmer groups, associations, or cooperatives to access, maintain, and sustainably benefit from technology.

3.6. Major Cooperation Project: TANIT (Tandem Italie Tunisie)

- Largest cooperation project ever undertaken by Italy.
- Objectives are to treat wastewater and transport it to long-desertified areas and recreate conditions similar to Roman-era water systems, but in reverse.
- Requires the careful planning of irrigation, mechanization, crop systems, and farmer settlement.

3.7. Long-Term Engagement in Olive Cultivation & Development

- Olive production is seen as a key entry point for technology transfer and cooperation. Italian olive and mechanization technology is highly valued and in demand.
- Examples: 1) Kurdistan (Iraq): shift from olive planting for greening to productive olive farming. 2) Syria: Technical Assistance for the Improvement of Olive Oil Quality in Syria In the period 2005-2006.

4. The Challenges of EVOO Production in New Regions: the Australian and Californian Experience

by Canamasas P. (Cobram Estate Olives Consultant - Argentina)

4.1. Strategic Position of the Southern Hemisphere

- An early harvesting (low-maturity fruit) strategy is adopted to maximize oil quality, as Southern Hemisphere produces less than 5% of global olive oil.
- Early harvest also helps reduce alternate bearing by protecting flower differentiation for the following season.
- Main drawback: low-maturity fruit is harder to harvest and process and yields less oil.

4.2. Key Production Challenges

- Green, low-maturity olives are harder to detach, pose more difficulty in oil extraction, and have higher paste viscosity.
- Irrigation is essential for economic viability but Leads to high-moisture fruit, which negatively affects oil extraction and quality.
- Severe labor shortages, especially in Australia. Full mechanical harvesting is necessary for large-scale operations (6,000 ha in Australia).

4.3. Olive Orchard Management

- The Water Stress Index is measured by airplane with camera to identify under-irrigated areas, clogged drip lines, lack of pressure, and determine the best irrigation schedule for different areas.

- Leaf analysis in mid-summer and Soil analysis in winter are applied to create fertilization programs. The nutrients supply is achieved through driplines fertilization (for major elements like nitrogen, potassium, phosphorus), and low-volume spraying (for minor elements).
- Pruning is one of the highest production costs. Predominantly mechanical pruning (topping and hedging), supplemented with manual pruning, is applied to get the potent best canopy shape for maximum light interception with maximum oil accumulation. The maximum tree height is limited to 80% of row spacing to avoid shading.
- Index evaluation (like NDVI) is employed to indicate photosynthesis activity and to identify underperforming areas.
- Canopy volume model combined with flower and fruit counts is used to estimate crop yield.

4.4. Mechanical Harvesting Technologies

- Harvesting is the largest cost in the production chain. Different types of machines are used according to the height and planting mode of olive trees.
- All machines use GPS tracking to monitor trees picked per day and manage resource.

4.5. Processing Plant Technologies

- Fruit characterization is the key to do a proper industrial job, such as oil content, moisture content, maturity index, and fruit size. In California, small fruit (due to super high-density groves) leads to high-viscosity paste (harder to extract oil); in Australia, high moisture (due to irrigation) is the main challenge.
- Color sorter technology is used to remove diseased fruit, frost-damaged fruit and mummified fruit (major issue in mechanized harvesting). It is very important to remove mummified fruit, as it dramatically increases free fatty acids (FFA).
- Crusher speed adjusted based on fruit condition (2,400–3,600 RPM).
- Enzymes, which are permitted for use in both Australia and California, serve two primary functions: they reduce the required malaxation time and improve oil extraction efficiency from low-maturity fruit. Meanwhile, talc is used as an emulsion breaker, specifically to process paste with high moisture content.
- As there is a negative correlation between paste viscosity and industrial efficiency, paste preparation evaluation is applied to predict efficiency.
- Heat exchange systems is very simple and useful to Reduce malaxation time and Improve extraction efficiency. This system is adopted for all processing lines in Australia and California.
- Online moisture & FFA measurements are employed, and also online pomace analysis is used to track oil losses and adjust processes immediately.

5. Panel Discussion and Q&A Session - Key Sentences

- The apparent contradiction between the high price of olives and the profitability of olive oil production is explained by strong regional differences in market prices, demand, and production costs. In importing countries such as Australia and the United States, limited domestic production combined with high consumption allows olive oil to be sold at relatively high prices, making the economic balance sustainable despite the high olive-to-oil conversion ratio. Overall profitability depends more on oil yield per hectare, market price, and production costs than on the price of olives alone. Global olive oil prices are largely determined by Spain, which produces more than half of the world's olive oil and therefore plays a central role in price stabilization.

- Oil quality is not determined solely by the type of grove, as the same variety can produce oils of similar quality under different training systems when management is appropriate. Variety, environmental conditions, tree density, harvest timing, and fruit health play a more decisive role in determining oil quality, and the same cultivar may express different sensory profiles depending on soil, climate, and year. For table olives, market preferences have expanded over time, but the most important characteristics remain large fruit size, a small stone, and soft pulp.
- The goal of zero-waste olive oil production can be achieved by converting olive mill byproducts into biogas and reusing the resulting digestate, which is mostly water with low solid content, as an irrigation resource. Storing byproducts during the milling season and applying digestate gradually throughout the year through drip irrigation creates an effective circular system, and research results show that digestate performs better than direct application of olive mill wastewater.
- Canopy volume measurement is not only useful for estimating production but is also applied to calculate accurate spray volumes for crop protection, allowing better coverage and reduced waste. While canopy analysis tools are already effective for spray management, the use of aerial imaging to detect early pest stages remains technically challenging with current technology.
- The quality and sustainability of oil and olive productivity depend on olive variety and type of cultivation (traditional, intensive, super-intensive). The right balance between these things must be found in order to enhance oil quality. The importance of table olives production and quality also needs to be considered.
- Increased automation in field operations and the use of anaerobic digestion of destoned pomace to produce energy, will improve the sustainability of olive oil production.
- Olive oil is food. Climatic changes in the form of an increase in average annual temperatures negatively affect the production of olive oil and its quality.
- For the successful production of quality olive oil, all technologies provided by Industry 4.0 should be used.
- Olive production is shaped by culture in terms of sustainability. Similar to the rubber tree, it represents the expansion of the concept of "sustainability" defined in Rio to include economic, ecological, and social aspects.
- Tomorrow's sustainability must therefore be complemented by cultural aspects, as this is the only way to preserve and guarantee global diversity.
- In addition to the new possibilities in sensor technology, actuator technology, and process control, it should not be forgotten that the countless small-scale olive groves must also be preserved and cultivated. The use of autonomous field robotics is expected to play a special role in this regard and will be able to reduce the inevitable peaks in workload in a socially acceptable manner.
- The vast majority of olive oil production is via traditional tree planting and provides much employment for local people, the development of modern plantations is still a minority area.
- Whilst many modern technologies exist for improving olive tree production, GMO, sensors, mechanisation etc. there remains a need for technology that fits within the traditional harvesting methods developed over centuries. Climate change will have major consequences on olive oil production and may offer an opportunity for a greater understanding of production.
- Olive growing plantations come in many different layouts and also ages of the cultivations. And preserving or producing the top oil quality is a challenge. It may be that mechanization can even contribute to have oil quality that is 'better' than the that based on the traditional methods. At what point is there a trade-off between increasing mechanization and the oil quality?
- Enhancing the value chain in developing countries requires an integrated approach education, farm advisory services, and a clear path for technological developments. It is not clear if slow evolutions or rapid introduction of new technologies carry a more lasting benefit.

- Future mechanization in olive cultivation must move beyond incremental efficiency toward fully integrated systems that connect field operations, processing, and data intelligence—linking canopy sensing, harvest automation, and milling optimization within a circular and traceable supply chain.
- By combining AI-enabled monitoring, adaptive harvesting technologies, and energy-efficient milling, the olive sector can transform from a resource-intensive value chain into a regenerative one—preserving oil quality, reducing waste, and extending mechanization benefits to small and emerging producers across Mediterranean and developing regions.
- It is important in areas with a lot of olive trees to operate, where possible, with the mechanization of tree pruning, in order to adapt the plants to mechanical harvesting.
- Increase the diffusion of umbrella-type shaking machines (for medium-sized trees) and increase the diffusion of new continuous systems suitable for continuous mechanical harvesting (with machines derived from those used for grape harvesting) with cooperative management (considering the high costs of the machines themselves).