**Intelligent sensors and laser spectroscopy for improving quality and prolonging the shelf life of food without chemical additives.**

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The shelf life of a product is defined as the duration for which a product remains safe.

Today, there are several strategies to prolong it by using alternative systems to chemistry to promote a reduction in the use of food additives.

There are also many methods to monitoring, but they are almost exclusively almost exclusively destructive.

One solution to this problem could be to use non-invasive sensors and instrumentation allowing the monitoring of the product characteristics through non-destructive analysis methods.

**Sensori intelligenti e spettroscopia laser per migliorare la qualità e prolungare la schelf-life degli alimenti senza additivi chimici.**

La shelf life di un prodotto è definita come la durata per cui un prodotto rimane sicuro.

Oggi esistono diverse strategie per prolungarla, utilizzando sistemi alternativi alla chimica per promuovere una riduzione dell'uso di additivi alimentari.

Esistono anche molti metodi di monitoraggio, ma sono quasi esclusivamente di tipo distruttivo.

Una soluzione a questo problema potrebbe essere l'utilizzo di sensori e strumentazioni non invasive che consentano il monitoraggio delle caratteristiche del prodotto attraverso metodi di analisi non distruttivi.

**1. State of the Art**

The shelf-life is usually defined as the time during which a food product remains safe, in compliance with the label declaration of nutritional data, and retains the desired sensory, chemical, physical, and microbiological characteristics when stored under the recommended conditions (Institute of Food Science and Technology (Gran Bretaña)., 1993). Extending the shelf-life of a product allows it to preserve its organoleptic and nutritional quality as long as possible for the benefit of the consumer (Giménez et al., 2012) and reduce the incidence of waste.

The shelf-life of food products and beverage estimation has become increasingly important in recent years due to technological developments and the growth in consumers’ interest in eating fresh, safe, and high-quality products. The shelf-life of the majority of food products is determined by changes in their sensory characteristics (Giménez et al., 2012; Hough, 2010).

 In this context, sensory shelf-life estimation become an issue of continuous and extensive research about both the deteriorative mechanisms occurring in food systems and the development and application of methodologies for shelf-life estimation (Manzocco & Lagazio, 2009).

One way to improve shelf life, under a circular economy perspective, could be to use food by-products and their bioactive compounds to eliminate the chemical preservatives perceived as potentially harmful to health by an increasing number of consumers (Ghanbari et al., 2013; Hassoun & Emir Çoban, 2017).

By-products such as peel, pulp, husk, seeds, bagasse, barks, oil cake, etc. are readily available and constitute about 30–50% of the total food weight. The utility of by products can be evaluated by its composition and the cost of extraction of valuable compounds. Some by-products retain a percentage of bioactive compounds like flavonols, polyphenols, and tannins that may contribute to create an innovative packaging system with antioxidant and antimicrobical compounds (Bañón et al., 2007; Jiang et al., 2020; Jönsson & Martín, 2016).

One of the principal uses of such antioxidant and antimicrobial compounds could be the encapsulation by spray-drying, a popular technique thanks to its simplicity, affordability, and easiness in transportation and use of the powder form (Assadpour & Jafari, 2019; Vinceković et al., 2017).

In addition to the phenolic compounds, edible chitosan-based protective films could be used arthropods repellents to keep food unaffected for longer (Perwita et al., 2020).

In recent years, the need to monitor the parameters that affect the production and storage of food and to improve its quality and shelf-life, with sensors and/or laser spectroscopy, is increasingly developing. In particular, manysensors are already present “in line” in the production chains, but the vast majority of them use destructive. Such methods, do not allow a second sampling of the product and determine a waste of the same, since it is impossible to sell the sampled product.

The use of spectroscopy and sensors can reduce food waste caused by destructive analysis.

Spectroscopy in particular allows, through an emitter, a receiver, and a beam working in the NIR, to analyze the concentration of a given gas inside a container without opening it.

Some sensors, as those developed by INFN in the work Manzella (2022), Mercanti (2022), Vicidomini (2022) allow the reading of certain parameters without doing destructive analysis too.

**2. PhD Thesis Objectives and Milestones**

The main objective of this PhD project is to identify optimal methods and conditions for increasing the shelf-life of products (ex: wine, oil) without the addition of chemical additives. In particular:

**A1) Sensors will be developed** ad hoc for the monitoring of some stages of production and storage of the product.

**A2) Attention will be given to the various stages of process and storage** of the various products and conservation of the various products to identify, always by means of sensors, any criticality of the same (fermentation, kneading, leavening, bottling, bag in bag...) until you come to understand what may be the best conditions of packaging and product maintenance (humidity, controlled atmosphere...) that extend the shelf life without the added chemistry.

**A3)** There will be monitoring of the environmental conditions that will allow you to continuously follow the temporal trends of the pressures, temperatures and light conditions inside the bottles being aged. By crossing analytical results it will be possible to determine any differences in wines, and to bring them back to different evolutionary mechanisms.

**A4) Writing and Editing of the PhD thesis**, scientific papers and oral and/or poster communications.

***Table 1*** *Gantt diagram for this**PhD thesis project.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity Months | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| A1) | ***Developed of TaylorMade sensors*** |   |   |   |  |  |  |  |   |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
|  | 1) Optimization of operative conditions |   |  |   |  |  |  |  |   |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
|  | 2) Chemical and sensory analysis |   |  |   |  |  |  |  |   |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
| A2) | ***Optimization of stages of process and storage*** |   |   |   |  |  |  |  |   |   |  |  |  |  |   |   |   |  |   |   |   |  |  |  |  |
|  | 1) Modification of the main chemical-physical parameters |   |   |   |  |  |  |  |   |   |  |  |  |  |   |   |  |  |  |   |   |  |  |  |  |
|  | 2) Shelf-life test |   |  |   |  |  |  |  |   |   |  |  |  |  |   |  |   |  |   |   |   |  |  |  |  |
| A3) | ***Development of new products and packaging*** |   |  |   |   |   |   |  |   |   |   |   |   |  |   |  |  |  |  |   |   |   |   |   |  |
|  | 1) Chemical-physical characterization |   |  |   |   |   |  |  |   |   |   |   |  |  |   |  |  |  |  |   |   |   |   |  |  |
|  | 2) Sensory characterization |   |  |   |  |  |   |  |   |   |  |  |   |  |   |  |  |  |  |   |   |  |  |   |  |
|  | 3) Evaluation of shelf-life of the product and of the optimum storage conditions |   |  |   |  |  |   |   |   |   |  |  |   |   |   |  |  |  |  |   |   |  |  |   |   |
| A4) | ***PhD thesis editing***  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |  |   |   |   |   |   |   |   |

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