University-industry collaboration in food engineering for food production and storage

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A specific Food Engineering Research Group of the DISTAL - Department of Agro-Food Sciences and Technologies of the University of Bologna, based in Cesena at the Campus of Food Sciences (http://www.distal.unibo.it/it/dipartimento/sedi/sede-di-cesena), develops research topics related to both the processes and the agri-food products, in collaboration with other scientific areas and, in particular, with specific local, national and international food related companies.

In the last decade, this activity has been particularly focused on the research of rapid and non-destructive techniques than the existing ones able to accurately evaluate the physical and chemical parameters that contribute to defining the quality of an agri-food product, with particular attention to the problem of authenticity and adulteration. These methods have also proved to be often suitable for both laboratory use and installation on processing lines.

In particular, the problems of assessing the degree of ripeness and the geographical origin of fruit and vegetables, the quality of extra virgin olive oil, the maturation and authenticity of cheese and salami, the freshness of eggs and fish, and the conditions optimal baking of bakery products, coffee roasting, behavior of agricultural products during post-harvest operations, exposure to shocks and vibrations during transport and in automatic selection processes were investigated.

In addition to the characterization of quality parameters, research work has also considered the issues of food safety and environmental protection. On this topic we highlight the study and the establishment of alternative physical treatments, for example based on hot air impulses or cold plasma, able to decontaminate products and packaging without the direct use of chemical sanitizers, with consequent benefits for consumers and environment. The technological improvement of food through use of innovative techniques, such as pulsed electric field, is a further topic of the research group in close collaboration with the Advanced Food Technology group.

Engineering meets with food production also in a particularly significant alliance in terms of plant design and processes, a sector in which our country occupies an important place, through the development of mathematical simulation models. With these techniques, thermal, fluid dynamic and diffusion phenomena are studied that involve the processes of transformation and conservation of food, such as frying, roasting, refrigeration, salt diffusion during the maturation of meat and cheese, as well as the diffusion of water during seasoning or drying. The reproduction of the phenomenon allows both an analytical study of

A note on the food engineer The field of food plant design reflects the same enormous heterogeneity of food materials. A quick glance at the list of the product sectors represented in exhibitions such as *Cibus Tec* in Parma or *Fruit Logistica* in Berlin is able to show a huge variety of industrial sectors, unit operations and their corresponding plant implementations (e.g. packaging, transport of liquid, solid or pasty products, heating, refrigeration, clarification, homogenisation). Therefore necessarily different professional skills converge within it. In particular, in the space between the world of biological sciences and that of engineering, operates both the plant designer and the food technologist of food engineer, as named in USA and UK. This last professional figure, perhaps less known in the engineering world, is not called to choices that directly concern the design of the machines but rather the layout of the plant in the production area, the choice between different solutions commercially available, the calibration and the drafting of maintenance plans. The strong point in the connection between the technologist and the plant designer lies in the knowledge of the food product and of the transformation processes, in relation to specific commercial, technological and hygienic requirements. In this perspective, the food technologist plays a decisive role in the machinery and plant sector, not only to verify the quality of the product under the chemical-analytical and organoleptic aspect. To such roles must be added those related to the regulation of the plants according to the characteristics of the product, to the sanitary controls and safety at work.

the process parameters and the consequent optimization of a plant prototype. Testifying the versatility of the method shows how recently the DISTAL-UniBO research group has developed numerical models in many sectors, such as the study of the coffee roasting process, the cooking phases of different bakery products such as biscuits or wafers for confectionery, diffusion of carbon dioxide in eggs preserved in a modified atmosphere, of heat treatments in conditions of natural and forced convection, for the decontamination of eggs destined for the fresh market, of the thermal transfer in refrigerated packets of frozen vegetable products and of fruit of IV gamma, as well as of the phases of seasoning and preservation of sausage products.

With similar techniques it has also been possible to develop innovative methods for the determination of the qualitative parameters (physical and chemical, with particular reference to the thermal, diffusive and rheological parameters) that contribute to the definition of food quality, faster, more efficient and cheaper than those traditional.

Among the elements of plant engineering innovation now launched towards industrial production, visible / near infrared spectroscopy is undoubtedly the most used non-destructive method in post-harvest processing for the estimation of qualitative parameters of fresh fruit and vegetable products. The spectroscopic techniques operating from the visible to the infrared are currently implemented both in portable systems and on the processing lines and the most promising applications in the food field currently concern the characterization of surface or sub-surface damages, as well as the quantification of maturation indices based on contained in soluble solids.

The radiation in the near infrared, in fact, once crossed a certain thickness of biological material, contain information about the chemical composition of the same. Similarly, surface characteristics (such as defects related to color, shape, rot and damage) can be detected by optical sensors and image analysis. The comparison of the images of the product, obtained with radiations at different frequencies (at the limit only one visible and one infrared) can provide a method of great power and effectiveness for the non-destructive characterization. It is a technique, called hyperspectral, of which there are now many positive testimonies in the research literature concerning the possibility of highlighting problems both on the surface and within the fruits.

The acquisition of images in several contiguous spectral bands integrates the spectroscopic analysis with that of the image and can also provide a direct identification of the different components of the product and their spatial distribution. The measuring systems currently available on the market allow spectroscopic analysis in the frequency ranges UV, VIS-NIR, NIR, SWIR (Short Wavelength Infrared) and LWIR (Long Wavelength Infrared), corresponding roughly to the wavelength range between 10^{-5} and 10^{-8} m.

At the same time, a research activity aimed at exploiting the interaction of electromagnetic waves in the radio spectrum has also been carried out to develop non-destructive systems for the determination of the quality of agri-food products. Both for optical and RF techniques, multivariate analysis, such as PLS regression and artificial neural network, were often used to develop models to predict quality attributes of agri-food products.

For fresh fruit there are also solutions on the market such as those based on piezoelectric elements, positioned inside bellows structures that allow the sensor to be combined with each fruit on the line, capable of measuring the response to a small impulsive stress, providing a mechanical evaluation in terms of texture. The-

Shelf-life evaluation topics and analytical methodologies

- study and assessment of degradation phenomena limiting food shelf-life;
- application and development of accelerated storage test;
- study of products/packaging interactions in different storage conditions (RH, time, temperature);
- implementation and optimization of stabilizing treatments for shelf-life and safety improvement of food products;
- study of material characteristics for food packaging after accelerated photo-oxidative and thermal-oxidative accelerated aging in order to simulate real processing and storage conditions;
- evaluation of the environmental sustainability of materials, product and processing environmental sustainability through the life cycle assessment analysis (LCA);
- physico-chemical and sensorial characterization of food products quality;
- non-destructive techniques for food quality assessment (elctronic nose, NIR, radio frequencies, image analysis by computer vision system etc.);
- study of water state and mobility in food through the use of multi-analytical approach (sorption analysis, Differential scanning calorimetry, LR-NMR etc.);
- Innovation and development of macro- and micro-structural, rheological (fundamental and empirical), and calorimetric (DSC, TAM-Air) analytical techniques for the study and characterization of different types of foods;
- metabolic approach for the study of tissue stress promoted by fruit and vegetable minimal processing through the use of calo-respirometric and metabonomic (HR-NMR) techniques.

refore, these solutions allow to express a maturity index that is well correlated with the classic penetrometric flesh firmness.

The Advanced Food Technology Unit of the Department of Agriculture and Food Sciences, located at the Campus of Food Science in Cesena, deals with the study on quality characterization, stability, shelf-life, processing and packaging of fresh and frozen fruit and vegetable, minimally processed products, dried and semi-dried fruit, coffee, and bakery products, combining a technological, quali-quantitative and engineering approach also in collaboration with the plant engineering group described above.

On Animal products the research activities are looking to the quality characterization, stability, shelf-life, processing and packaging of seasoned, fermented, emulsified and ready-to-eat meat products, fish and seafood products, egg products.

From raw materials to the final product, research on processing technology has been established on fruit, vegetables, cereals, meat products, bakery, pasta, virgin olive oil and beverages. Minimally processing of fruit, osmotic dehydration, air-drying, freeze-drying, deep fat-frying, baking and roasting are studied to keep good quality during processing.

Lab equipment has been set up to investigate fundamental rheological and textural parameters with a rheometer and a fully equipped texture analyser to characterize physical food properties related to sensorial profile. Moreover a special apparatus has been set up for digital image processing to quantify mainly size, shape, surface and colour distribution in foodstuff. Concerning beverages technological improvement and applications for wines, vinegar, beer and fruit juices, the opportunity to give consumers new and more nutritive beverages have pushed the research towards some substances because of their specific properties: antioxidants in wine (polyphenols, anthocyanins and mainly resveratrol); aminoacids in fruit juices, polysaccharides in beer, new sweeteners in vegetal juices. New formulations for food and beverages, with a high antioxidants content, have been studying involving sensorial and analytical destructive techniques but also some multi-parametric non-destructive techniques: the “electronic nose”, the near (NIR) and medium (FTIR) infrared spectroscopy.

In this context, to improve the organoleptic properties of foods, selection of yeast and lactic acid bacteria are used as starters or adjuncts. The application of engineering methods to the plants and processes of the agro-food industry completes the research work carried out in Cesena. The main topics of this work are: physical and mechanical characterization of the biomaterials and agro-food products; quality improvement oriented study of systems for transport, sorting, packing, storage and distribution of the agricultural products; numerical simulations of plants and processes; orchard and vineyard mechanization.

The group is also involved in product innovation actions, to study of new formulation and packaging methods for tailor-made vegetable and animal products for the improvement of the sta-

bility during the shelf-life and of quality characteristics including functional, rheological and structural properties.

The Interdepartmental Centre of Industrial Agrifood Research - CIRI

Placed into the Forlì–Cesena Technopole, in the frame of the Emilia-Romagna Technological Platform system, belonging to the Interdepartmental Center of Agrifood Industrial Research, Unit operations and innovative processing procedures are developed on pilot scale studies and optimization of different traditional and innovative processing steps (unit operations, dehydration, thermal stabilization, vacuum, marination, vacuum impregnation, drying, ultrasound, pulsed electric fields (PEF), ozone and other innovative non-thermal treatments). Furthermore, studies and minimization of food toxicants as a consequence of heat treatments, processing and storage conditions are carried out (http://www.agroalimentare.unibo.it).

Regarding the technological aspects on food processing, the activities are addressing the study and optimization of thermal processing for food preparation and stabilization as a function of the technology and the type of final product (e.g. pasta, bakery products, juices and vegetable products, probiotic and symbiotic etc.).

Hot topics: packaging, preservation, analytical techniques

The research group on Advanced Food Technology is studying some aspects on the optimization of food packaging: migration tests, physico-chemical characterization (thermal, mechanical, barrier properties etc.) of conventional synthetic polymers and innovative biodegradable and compostable packaging materials; test and developments of smart and active packaging; development and optimization of modified atmosphere packaging.

Moreover experimental approaches and analytical techniques for the study of food quality and stability during storage are dealing with food shelf-life study and modelling of food products and evaluation of packaging modifications. In Table 1 selected topics on shelf-life evaluation are reported.

DI COSA PARLIAMO?

Il “Made in Italy” è il brand per cui il nostro paese è riconosciuto a livello internazionale e nel quale il settore agro-alimentare gioca un ruolo cruciale. Proprio per questo la filiera alimentare deve garantire il miglior livello di controllo della qualità in tutte le sue fasi.

La crescente attenzione dei consumatori alla sicurezza dei prodotti sta, infatti, indirizzando l’industria e la ricerca verso uno sviluppo, stabile e continuativo, di sistemi più veloci, affidabili e meno invasivi. Nello specifico, in merito ai prodotti freschi, l’integrazione dei metodi tradizionali con le tecnologie spettroscopiche e analisi dell’immagine permette di ottenere una migliore definizione qualitativa interna ed esterna dei prodotti.

Dal punto di vista del design, gli strumenti ingegneristici utilizzati dal sistema alimentare devono essere confacenti alle peculiarità chimico-fisiche dei prodotti, per garantire flessibilità ed affidabilità senza dimenticare le necessità contingenti della realtà produttiva ed i vincoli igenico-sanitari.

L’implementazione dei processi è, infine, chiamata in causa anche per la realizzazione di funzioni accessorie come la preservazione dei valori nutrizionali del cibo, l’incremento della digeribilità, la data di scadenza e la biodisponibilità dei vari componenti.

A bibliographic review

In the depicted frame, a brief review of the scientific results achieved, as evidenced by the publication of research activity through the main scientific journals, is here reported.

Journal of Food Engineering 2019 - **Evaluation of drying of edible coating on bread using NIR spectroscopy.** Chakravartula, S., Cevoli, C., Balestra, F., Fabbri, A., Dalla Rosa, M.“[…] utilize near infrared (NIR) spectroscopy as a tool to rapidly monitor and develop predictive model for the drying of edible coating on bread (mini-burger buns) surfaces. The procedure proposed could be used for faster quantification of moisture during drying process.”

Food Research International 2013 - **FT-NIR and FT-MIR spectroscopy to discriminate competitors, non compliance and compliance grated Parmigiano Reggiano cheese.** Cevoli, C., Gori, Nocetti, Cuibus, Caboni, M. Fabbri, A.“[…] infrared spectroscopy, coupled to different statistical methods, were used to estimate the authenticity of grated Protected Denomination of Origin Parmigiano Reggiano cheese. […]The results showed that NIR and MIR combined with different statistical approaches can be suitable for a sensitive, non-destructive, rapid and inexpensive screening of grated P-R cheese authenticity.”

Biosystems Engineering 2018 - **Finite element model to study the thawing of packed frozen vegetables as influenced by working environment temperature.** Cevoli, C., Fabbri, A., Tylewicz, U., Rocculi, P.“[…] To study the effect of environment temperature on heat transfer inside frozen foods a parametric finite element model was developed and validated for three products (peas, spinach cubes and grilled aubergines). The relation between calculated product temperatures, environment temperature and time was investigated and a good fit was obtained (R2 > 0.97)”.

Biosystems Engineering 2017 - **Heat transfer finite element model of fresh fruit salad insulating packages in non-refrigerated conditions.** Cevoli, C., Fabbri, A.“[…] A parametric analysis using a finite element model able to describe the heat transfer inside the containers, on varying packaging material (expanded polystyrene: EPS, and air), geometry, dimension, insulation layer thikness and boundary conditions, was developed and validated”.

Journal of Food Engineering 2016 - **Rheological parameters estimation of non-Newtonian food fluids by finite elements model inversion.** Fabbri, A., Cevoli, C.“[…] it was set up a method, based on the inversion of a simple finite element model, simple laboratory measurements and a more simple apparatus respect classic capillary tube”.

Journal of Food Engineering 2015 - **2D water transfer finite elements model of salami drying, based on real slice image and simplified geometry.** Fabbri, A., Cevoli, C.“[…] It were developed two finite element models of water diffusion inside a salami, taking account of the vapour exchange phenomena at the surface. One based on the real fat and meat distribution, as acquired by image analysis and a second considering the salami material as homogeneous”.

Journal of Food Engineering 2014 - **Finite element model of salami ripening process and successive storage in package.** Cevoli, C., Fabbri, A., Tabanelli, G., Montanari, C., Gardini, F., Lanciotti, R., Guarnieri, A.“[…] Two parametric numerical models were developed to study the moisture diffusion physics, during ripening and storage in package inside dry fermented sausages”.

Journal of Food Engineering 2017 - **Assessment of food compositional parameters by means of a Waveguide Vector Spectrometer.** Ragni, L., Berardinelli, A., Cevoli, C., Filippi, M., Iaccheri, E., Romani, S.“[…] An instrumental prototype operating in the frequency range from 1.6 to 2.7 GHz was designed, set up and tested with several substances and food products. High correlations were found between spectral data and compositional parameters by means of partial least-squares (PLS) multivariate regression. The technique appeared suitable as a rapid method for qualitative characterization both for simple and complex matrices”.

Journal of Food Engineering 2016. **Multi-analytical approach for monitoring the freezing process of a milkshake based product.** Ragni, L., Berardinelli, A., Cevoli, C., Iaccheri, E., Valli, E., Zuffi, E., Lazzarini, R., Gallina Toschi, T.“[…] An optical device, assisted by image analysis, was set up to characterized and monitor crystals growth and air bubble forming during freezing of milkshake product. A strong correlation was obtained between image data and rheological and electrical parameters, measured with simple prototypes. These latter techniques can take the place of more complex and expensive optical methods to monitor the freezing process of this product”.

Journal of Agricultural and Food Chemistry 2013. **Rapid screening of fatty acid alkyl esters in olive oils by time domain reflectometry.** Berardinelli, A., Ragni, L., Bendini, A., Valli, E., Conte, L., Guarnieri, A., Gallina Toschi, T.“[…] Time domain reflectometry (TDR) and partial least-squares (PLS) multivariate statistical analysis was used to determine the fatty acid alkyl esters content in olive oils. TDR technique seems potentially suitable for monitoring this important quality parameter of the olive oil during the extraction process”.

Journal of Food Engineering 2010. **Non-thermal atmospheric gas plasma device for surface decontamination of shell eggs.** Ragni, L., Berardinelli, A., Vannini, L., Montanari, C., Sirri, F., Guerzoni, M.E., Guarnieri, A.“[…] A 15 kV gas plasma generator, equipped with a treatment chamber, was set up and used to reduce microbial contamination of shell eggs. After 90 min of plasma exposure, a reductions up to 4.5 Log CFU/eggshell were observed for S. enteritidis. Reactive species generated by the discharge was characterized by optical spectral emission”.

Journal of Food Engineering 2010. **Impact device for measuring the flesh firmness of kiwifruits.** Ragni, L., Berardinelli, A., Guarnieri, A.“[…] A device consisting of a conveyer belt that drive the fruits onto a horizontal plate, mounted on a load cell, was used to measure the impact force. This force resulted correlated (R2 = 0.823) with the Magness-Taylor flesh firmness of the fruit, so the technique could be developed for on-line selection of the kiwifruits”.

Biosystems Engineering 2008. **A dielectric technique based on a one-chip network analyser to predict the quality indices of shell eggs.** Ragni, L., Berardinelli, A., Guarnieri, A.“[…] A prototype based on a capacitor probe and a phase and gain comparator was assembled and used to assess some main freshness indices of eggs. From tests conducted in the frequency range 50–500 MHz after 1, 2, 4, 8, and 15 days of storage at room temperature, PLS R2 values up

to 0.996, 0.876, and 0.678 were obtained for the time of storage, the air cell height, and the thick albumen height, respectively".

Journal of Food Engineering 2005. **Damage to pears caused by simulated transport.** Berardinelli, A., Donati, V., Giunchi, A., Guarnieri, A., Ragni, L.“[...] Packaged pears of different cultivars were submitted to vibration simulating a medium-long transportation by an electro-dynamic shaker. Mechanical damage due to vibro-pressure stresses occurred in 25%, 36%, and 28% of fruits of Abate, Conference and Decana, respectively".

Journal of Agricultural Engineering Research 2001. **Mechanical behaviour of apples, and damage during sorting and packaging.** Ragni, L., Berardinelli, A.“[...] Mechanical impacts were measured in sorting and packing lines by an "instrumental sphere". The data describing the impacts were used to stress, by a lab device, apples of different cultivars simulating the stress conditions in the lines. Because of the most severe process handlings, damage can occur, consisting of darkening and fractures of the flesh with a depth of 4-5 mm and a diameter of 12-15 mm".

Journal of Food Engineering 2006. **Use of a simple mathematical model to evaluate dipping and MAP effects on aerobic respiration of minimally processed apples.** Rocculi, R., Del Nobile, M., Romani, S., Baiano, A., Dalla Rosa, M.“[...] A new general respiratory model based on the Michaelis–Menten type enzyme kinetics was tested to describe changes in aerobic respiration of minimally processed apple".

Food Control 2008. **Safe cooking optimisation by F-value computation in a semi-automatic oven.** Pittia, P., Furlanetto, R., Maifreni, M., Tassan Mangina, F., Dalla Rosa, M. “[...] Aim of this study was to optimise the cooking cycles of a semi-automatic oven by definition and settling of minimum thermal conditions to guarantee safety while keeping sensorial quality of cooked foods. The heat penetration curves and the correspondent thermal lethality effect (FT) of cooking cycles conventionally adopted to prepare some foods and dishes characterised by different microbial risk (high: lasagne pie, meat minced roll, meat filled peppers; standard: spinach and salmon), were determined".

J. Agric. Food Chem. 2007. **Water Absorption of Freeze-Dried Meat at Different Water Activities: a Multianalytical Approach Using Sorption Isotherm, Differential Scanning Calorimetry, and Nuclear Magnetic Resonance.** Venturi, L., Rocculi, P., Cavani, C., Placucci, G., Dalla Rosa, M., Cremonini, M.A.“[...] The amount of frozen water and the shape of the T2-relaxogram were evaluated at each water content by DSC and NMR, respectively in poultry meat. Data revealed an agreement between sorption isotherm and DSC experiments about the onset of bulk water (aw = 0.83-0.86), while NMR detected mobile water starting at aw=0.75".

Analytica Chimica 2008. **Near Infrared Spectroscopy: An analytical tool to predict coffee roasting degree.** Alessandrini, L., Romani, S., Pinnavaia, G.G., Dalla Rosa, M.The relationship between some coffee roasting variables (weight loss, density and moisture) with near infrared (NIR) spectra of original green (i.e. raw) and differently roasted coffee samples, in order to test the availability of non-destructive NIR technique to predict coffee roasting degree.

Trends in Food Science and Technology 2008. **Biodegradable polymer for Food Packaging: a review.** Siracusa, V., Rocculi, P., Romani, S., Dalla Rosa, M.“[...] The increased use of synthetic packaging films has led to a serious ecological problems due to their total non-biodegradability. Although their complete replacement with eco-friendly packaging films is just impossible to achieve, at least for specific applications like food packaging the use of bioplastics should be the future".

Journal of Food Engineering Volume 2008. **Small and large deformation tests for the evaluation of frozen dough viscoelastic behaviour.** Angioloni, A., Balestra, F., Pinnavaia, G.G., Dalla Rosa, M.“[...] by using Texture Profile Analysis (TPA), Kieffer method and rheometer measurements, the influence of freezing and storage time on dough viscoelastic performance were assessed".

Journal of Food Engineering 2009. **Effect of extrusion process on properties of cooked, fresh egg pasta.** Dalla Rosa, M., Zardetto, S.“[...] The chemical and physical characteristics of cooked fresh egg pasta samples obtained using two different production technologies were determined: extrusion and lamination".

Journal of Food Engineering 2009. **Image characterization of potato chip appearance during frying.** Romani, S., Rocculi, P., Mendoza, F., Dalla Rosa, M.“[...] The suitability of a computerized image analysis technique (with a flatbed scanner for image acquisition) in order to measure the amount and distribution of the most important visual aspects of potato chips was evaluated".

Innovative Food Science & Emerging Technologies 2011. **Modeling mass transfer during osmotic dehydration of strawberries under high hydrostatic pressure conditions.** Castro-Giráldez, M., Fito, P.J., Dalla Rosa, M., Fito, P.“[...] Simultaneous application of high hydrostatic pressure (200–400 MPa) during osmotic dehydration of strawberries was studied in this investigation. The high hydrostatic pressure treatment improved the diffusion coefficients of water and soluble solids compared to atmospheric pressure operation".

Innovative Food Science and Emerging Technologies 2011. **Application of microwaves dielectric spectroscopy for controlling osmotic dehydration of kiwifruit (Actinidia deliciosa cv Hayward).** Castro-Giraldez, M., Fito, P., Dalla Rosa, M., Fito P.J.“[...] Dielectric spectra were measured in the frequency range from 500 MHz to 20 GHz by an Agilent 85070E Open-ended Coaxial Probe connected to an Agilent E8362B Vector Network Analyzer in the fresh, treated and reposed samples. It has been demonstrated that the dielectric technique is a good method to control the osmotic treatment in kiwifruit".Ital.

Journal of Food Science 2012. **Physico-chemical and electronic nose measurements in the study of biscuit baking kinetics.** Romani, S., Balestra, F., Angioloni, A., Rocculi, P., Dalla Rosa, M.“[...] Moisture content, surface colours and textures were measured during industrial cooking of biscuits. In addition the evolution of the flavour release was performed by means of an electronic nose equipped with 10 metal-oxide sensors. Multivariate statistical analyses were performed to distinguish samples as a function of their physico-chemical characteristics".

Food Research International 2014. **Environmental assessment of a multilayer polymer bag for food packaging and preservation: An LCA approach.** Siracusa, V., Ingrao, C., Lo Giudice, A., Mbohwa, C., Dalla Rosa, M.“[...] A screening of LCA for the evaluation of the damage arising from the life cycle of a bi-layer film

bag for food pack- aging was carried out. Such packages are made of films obtained matching a layer of PA (Polyamide) with one of LDPE (Low-Density Polyethylene".

Storage Journal of the Science of Food and Agriculture 2014. **Effect of different new packaging materials on biscuit quality during accelerated.** Romani, S., Tappi, S., Balestra, F., Rodriguez Estrada, M., Siracusa, V., Rocculi, P., Dalla Rosa, M.“[…] The effect of innovative multilayer packaging materials versus a standard one on biscuit quality was studied during accelerated storage at 25, 35, 45 C and 50% relative humidity for 92 days. Three different packaging materials were used: metalized orientated polypropylene (OPP)/paper (control); metalized polylactic acid (PLA)/paper; metalized OPP with ethylene vinyl acetate pro-oxidant additive (EVA-POA)/paper. EVA-POA additive is used to make the plastic layer biodegradable".

Journal of Food Engineering 2015. **Analysis by non-linear irreversible thermodynamics of compositional and structural changes occurred during air drying of vacuum impregnated apple (cv. Granny smith): Calcium and trehalose effects.** Betoret, E., Betoret, N., Castagnini, M., Rocculi, P., Dalla Rosa, M., Fito, P.“[…] Mass transfer has been analysed applying nonlinear irreversible thermo- dynamics. Water flux, water chemical potential and tissue shrinkage have been taken into account in order to accurately describe the mass transfer phenomena during air drying".

Trends in Food Science & Technology 2015. **Strategies to improve food functionality: Structureeproperty relationships on high pressures homogenization, vacuum impregnation and drying technologies.** Betoret, E., Betoret, N., Rocculi, P., Dalla Rosa, M.“[…] The effect of innovative processing technologies as HPH, Vacuum Impregnation and Drying Technoogies on bioactive compounds have been reviewed, focusing on the structure changes produced and its relationship on the product functionality, as well as on the parameters and the strategies used to quantify and increase the achieved functionality".

Innovative Food Science and Emerging Technologies 2016. **Effect of pulsed electric fields pre-treatment on mass transport during the osmotic dehydration of organic kiwifruit.** Traffano-Schiffo, M.V., Tylewicz, U., Castro-Giraldez, M., Fito, P.J., Ragni, L., Dalla Rosa, M.“[…] The effect of different PEF values (100, 250, 400 V/cm) as a pre-treatment of the osmotic dehydration (61.5 °Bx, up to 120 min) on mass transport mechanism of organic kiwifruit was assessed".

LWT - Food Science and Technology 2017. **Study on the efficacy of edible coatings on quality of blueberry fruits during shelf-life.** Mannozzi, C., Cecchini, J.P., Tylewicz, U., Siroli, L., Patrignani, F., Lanciotti, R., Rocculi, P., Dalla Rosa, M., Romani, S.“[…] Edible films or coatings could be used as an alternative way of conservation, because of their ability to reduce respiration and transpiration rate, maintain firmness and generally delay fruit senescence. The influence of different types of coating: sodium alginate (Al), pectin (Pe) and sodium alginate plus pectin (Al + Pe), was evaluated on some blueberries quality characteristics, cell viability and microbial growth during 14 days of storage at 4 °C".