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Advanced technologies for cherry processing and packaging

Marco Dalla Rosa*
DISTAL Alma Mater Studiorum Università di Bologna – Campus di Cesena

Moderne tecniche di lavorazione e confezionamento delle ciliegie

Riassunto. L'evoluzione delle tecnologie alimentari, attraverso l'utilizzo delle cosiddette tecnologie emergenti, pone le basi per l'ottenimento di prodotti con un livello di stabilizzazione almeno parziale, nei confronti delle alterazioni microbiche, con modificazioni minime delle qualità intrinseche, sia sensoriali sia nutrizionali dei prodotti finiti. Alte pressioni idrostatiche, campi elettrici pulsati, plasma freddo ed osmo-disidratazione possono venire impiegati per la trasformazione di ciliegie e amarene, con ottenimento di prodotti di buona qualità e medio-lunga shelf-life. Il confezionamento del fresco e dei prodotti finiti mediante l'utilizzo di atmosfere modificate, in combinazione con la scelta dei film più adatti può essere una ulteriore soluzione per migliorare la conservabilità dei prodotti.

Parole chiave: PEF, Ultrasuoni, Vacuum Impregnation, MAP, High Pressure.

Introduction

Cherry fruits are generally considered as a highly perishable food owing to softening rate as a result of the high rate of transpiration and respiration, mechanical damages and high perishability due to microbial infections, which dramatically reduce their storability and marketing acceptability after harvest. The main postharvest treatment able to reduce the quality loss and to extend storability of sweet cherry fruit is cold storage (Petriccione *et al*., 2015). Storage of fresh cherries is generally limited by a short shelf-life of 2-4 weeks at 0°C, with 90-95% relative humidity, but the traditional cold storage method generally causes some physiological disorder, such as surface pitting and anthocyanins degradation (Handong *et al*. 2019).

Thus, both the presence of microorganisms able to spoil and the senescence progress quickly lead to the loss of the fresh product quality attributes. The occurrence and activity of those factors along the collection and distribution chain are the important keys to be considered at all steps, leading to the final product maintenance of those valuable fruits. In fact, several studies enhanced the beneficial of the cherry components, proving that their consumption can contribute to tackle several diseases, including cancer, cardiovascular, diabetes and inflammatory diseases, as a result of a decline in oxidant stress, tumor suppression, inflammation and glucose control (Mccune *et al*., 2011).

On the other hand, processing of cherries to prolong the shelf life is an important way to offer a diverse array of the products year-round. The large diversity of products requires a similar diversity in processing technology.

Evolution of traditional cherry processing

Traditional pasteurization techniques by use of heating is still the most widely used method for cherry products, including jams, syrup cherries and juices.

Although an efficient pasteurization of cherry products has been accomplished, there can be a significant loss of product quality during storage due to oxidation, light reactions and other chemical reactions between compounds. Poiana *et al*. (2011), analyzing the behavior of jams produced using sweet (*Prunus avium* L.) and sour cherries (*Prunus cerasus* L.) found that thermal processing of fruit jams caused a loss of 70% of the vitamin C content recorded for frozen fruits for sour cherry and 54% for sweet cherry. The storage time induced non significant alterations after 1 month for jam and, only after 3 months of storage, it revealed statistical significant difference for sour cherry jam and highly significant ($p<0.01$) for sweet cherry jam. Regarding the changes in total phenolics content , significant statistical differences were noticed after a period of 3 months.

After 3 months of storage at 20°C, antioxidant capacity of cherry jams from both sweet and sour cherries showed lower depreciation compared with the content of investigated bioactive compounds. This is confirmed by the fact that a storage period of 3 months does not induce statistically significant chan-

* marco.dallarosa@unibo.it

ges in antioxidant activity [evaluated by FRAP (ferric reducing antioxidant power)], values, while for the other measured parameters such as total phenolics, monomeric anthocyanins, vitamin C changes with statistical significance were noticed.

As a consequence, the optimization of the thermal treatments is a fundamental key point to improve the quality of processed cherries in jams or canned products. Furthermore, a hurdle technology approach could be assumed, in order to reduce the impact of the processing on the product's quality as well as the combination of a mild heat treatment with other technologies, like partial dehydration and / or refrigerated storage.

In a perspective to obtain cherry juices with a better quality, membrane filtration technologies such as ultrafiltration, microfiltration or nanofiltration can be used to obtain stable products other than for clearing or concentrating juices. In fact advanced filtration methods can be used to obtain sterile products (Echavarría *et al*., 2011). This result can be obtained with filters with a pore size of less than 45 μm in order to remove bacteria, yeasts and fungi. The effect of juice temperature, flow rate and filter pore size in microfiltration of sour cherry juice on the transmembrane pressure, juice turbidity, protein, sugar and total phenolic compound have been reported by Bagger-Jørgensen *et al*. (2002).

Emerging technologies in cherry processing

Osmotic dehydration and Vacuum impregnation

Since traditional processing operations generally have a negative effect on functionality, recent studies show that adequate management of the processing technologies can reduce their impact, even improving the functional properties of the final product (Betoret *et al*., 2015)

Osmotic dehydration (OD) is a partial dewatering impregnation process carried out by the immersion of cellular tissue in hypertonic solution. The difference in water chemical potential between the food and osmotic medium promotes the release of water from the tissue into the osmotic solution with a simultaneous impregnation of the product with the solutes, whilst the complex cellular structure of the fruit acts as a semi-permeable membrane, creating extra resistance to water diffusion within the fruit. OD decreases water mobility and availability, promoting the improvement of fresh vegetable tissue stability (Dalla Rosa *et al.*, 2011; da Conceição Silva *et al*., 2012). The osmo-dehydration process is characterized by the following aspects: uptake of solids from the osmotic solutions, increasing in sugar content, partial protection from enzymatic activity, low energy demand for water removal, improvement in flavor, taste and color of the final product (Pinnavaia *et al*., 1988).

Osmotic dehydration (OD) is a pre-treatment commonly applied prior to air-drying or other stabilization techniques like freezing, in the last case resulting an osmo-dehydration-freezing process.

In fact, that reduction of water content in foods due to osmotic dehydration has a significant influence on physical and chemical properties of the final product. It extends the fruit shelf life and improves its storage capacity due to lowering the water activity (aw), but with the OD treatment it is difficult to reach aw values able to maintain the microbiology stability (i.e. below aw=0,6) so that, in order to guarantee this stability, the tissue should be subjected to further drying or other processing methodologies to make them fully safe from the microbiological viewpoint.

The osmo-dehydration-freezing process was applied on cherries other than for other fruits firstly by Pinnavaia *et al*. (1988) where it was found that, during the osmotic treatment the pitted cherries were able to loose up to 40% of the initial water, after 8 hours of osmotic treatment and around 55% after 16 hours.

Because of the reduced water content, the osmosed fruits showed a higher freezing rate and an evident depression of the freezing point (around -2,5°C). The partial water removal of the fruit prior freezing process leads to the concentration of the cytoplasmatic components within cells, the reduction of free water content and thus the freezable water, the depression of the freezing point and the increase of the degree of undercooling. All those factors are capable to lead to the following chemical and physical modification in the subsequent freezing process:

- reduction of total latent heat of freezing;
- less energy demand into the freezing process;
- higher freezing rate;
- increasing of micro crystallization owing to the lower solids/crystals ratio;
- weight and volume reduction of frozen fruit;
- better texture and taste of the thawed fruit;
- less drip loss at thawing.

Osmo-dehydro-frozen pitted cherries showed after thawing higher sensorial score for better taste, flavor, color and a richer aroma profile than the fresh fruit. Other than, the consumption facilitation, the stone removing is useful to improve the mass transfer since the cherry waxy skin hampers

Furthermore, the fresh untreated fruit at frozen state generally has a very hard texture while the osmodehydrofrozen cherries showed a well-firm texture but still pleasant for consumption and thus successfully used as an ingredient in low temperature final products such as into an ice-cream formulation (Pinnavaia *et al*., 1988).

Looking to the process sustainability, osmotic dehydration permits lower energy demand during concentration (theoretically = zero since non phase change occurs and the water removal can occur at ambient temperature even the process is temperature-dependent).

In figure 1 a general scheme of the water removal phenomenon during osmotic dehydration is represented.

On the other hand, applying the osmodehydration as a pre-treatment to air drying, as a so call osmo-convective drying of fruit, in order to enable the reduction of water activity in dried samples to a level close to 0.75, reducing the risk of microbial spoilage, the benefits are mainly the maintenance of natural color, flavor, aroma, and the reduction of the oxidative reactions and enzymatic degradation reactions.

In particular for sour cherries, due to high acidity and astringency, the infusion and uptake of sugars from the osmotic hypertonic solution occurring during the osmotic water removal is able to improve the dried sour cherry consumers' acceptability.

In fact, to encourage consumers to increase sour cherry consumption, the development of new products based on this type of fruit would be desirable. To achieve this purpose, the technology of osmo-convectively dried sour cherry production had been proposed by several authors, as well as reported by Siucinska *et al*. (2016). Thus, after convective drying (CD), the

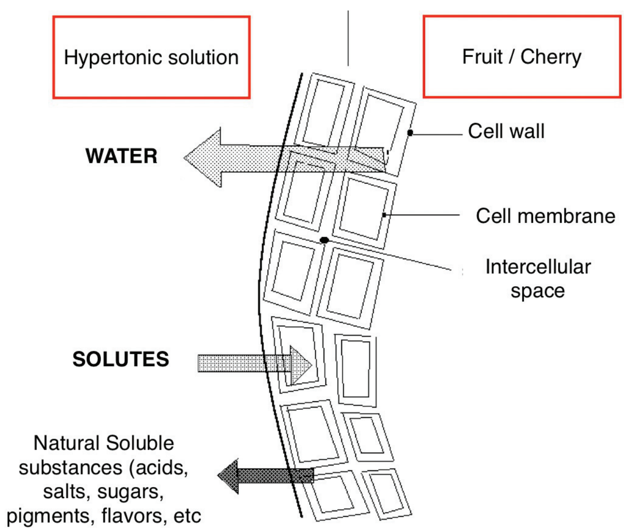

Fig. 1 - General scheme of the water removal and soluble fluxes phenomena during osmotic dehydration.

Fig. 1 - Schema generale dei fenomeni di rimozione dell'acqua e dei flussi dei soluti durante la disidratazione osmotica.

osmo-treated sour cherries (*Prunus cerasus* L.) become similar to raisins and may be consumed as a ready-to-eat snack (Siucinska *et al*., 2016).

Ultrasound pre-treatment

Unfortunately, the production process (osmo-convective drying) of such a product is time-consuming and energetically demanding. Furthermore due to the properties of cherry skin, offering a serious barrier against effective diffusion during both osmotic dehydration and the drying process, ultrasound (US) pre-treatments have been proposed to improve the process efficiency in term of time consumption and mass transfers.

The utilization of sonication treatments in food technology is linked to its effect that can exert in biological tissue and to the fact that vast majority of food (plant and animal origin) is rich in water content. Power ultrasound promotes alternately compression and expansion of material (so called "sponge effect"), which can lead to the local rupture of the native cellular structure of the material and microchannels formation. Those phenomena related to the microstructural changes and promotion of the main mass/heat transfers can be utilized in order to enhance the mass and/or heat transfer based processes (Nowacka *et al*., 2018).

On the basis on those knowledges, looking to the need to accelerate the production of osmo-treated dried sour cherries, ultrasound treatment has been identified as a promising factor, which could potentially be useful to intensify and to accelerate the sour cherry dehydration processes. The ability of US to mechanically interact with cellular structure of the fruit tissue appeared to offer new possibilities for the realization of new products such as dried sour cherries. Especially interesting was the expected structure modification in the surface layer, which can lead to possible micro perforations of the skin, and thus reduce diffusion barriers due to the cherry skin. Furthermore, the use of US-assisted osmotic dehydration should lead to a faster solid gain and shorten consecutive drying time, thus favoring bioactive component retention, which would be highly beneficial for the final quality of the dried product.

On the contrary, some authors reported that US treatments could lead to substantial losses or deterioration of biologically active compounds, especially when considering constituents of hydrophilic properties as well as color modification (Siucinska *et al*., 2016; Nowacka *et al*., 2018).

In the case of sour cherry osmo-convective drying, combined to US application as pre-treatment, no significant effect of sonication on mass transfer intensifications during osmotic dehydration and subsequent drying were observed. A longer US application rather than creating anticipated micro-channels, caused the breakdown of the parenchyma cell walls in the deeper part of the tissue. The results reported by Siucinska *et al*. (2016) confirm the role of tissue porosity and firmness to contribute to the potential usefulness of US for mass transfer enhancement and highlight the role of low-pectin tissue composition that is not the case of sour cherry, orchid be considered as an exception. These special optimization procedures have to be developed to improve the process combination.

An interesting development of this technology was reported by Kowalski and Szadzinka (2014) where a intermittent drying was introduced after US-assisted Osmodehydration. The purpose of intermittency was to equalize the moisture distribution in dried products during tempering periods (without heat supply) and thus to improve the efficiency of drying, as well as the product quality. Working with Frozen, pitted cherries (P. cerasus L.) the authors found a significant difference between the values of Solid Gain and Water Loss, obtained after pretreatment with and without ultrasound enhancement. Ultrasonic application to the osmotic dehydration increased the water loss from 18 [% wb] to 24 [% wb], as well as the sugar gain by 3 [% wb].

Vacuum Impregnation

Another variation of the osmotic dehydration was introduced to perform better mass transfer efficiency by the application of vacuum to reduce, even with pulses, the pressure conditions. Vacuum impregnation technology (VI) is a mass transfer operation between a liquid medium and a solid porous food. Pressure gradients created in the system with the capillary pressure in the pores entrance promote a significant gas and liquid transfer be-tween the liquid and the solid. Based on the porous structure of some foods and the existence of gas occluded on it, explained the hydrodynamic mechanism, as the main phenomenon involved in the VI operation. When the solid product, submerged into a liquid, it is submitted to a lower pressure than atmospheric conditions, the gas occluded into the solid undergoes an expansion to equilibrate with the pressures reached. This leads to a degasification of the porous structure depending on the applied pressure, and on the other hand a penetration of liquid by capillarity when the equilibrium is reached. The restoration of the atmospheric pressures in the system will promote a new pressure gradient that will act as a driving force and the intercellular spaces of the solid product will be filled partially from external liquid (Betoret *et al*., 2015). Apparently, The only research work on the application of VI on cherry fruit is from Mao *et al*. (2017) on Lupins cherry, where the impregnation process was using a calcium rich solution. Authors showed that the process of VI with calcium treatment had no significant effect on the content of cell wall polysaccharides, but VI with calcium treatment significantly affected the chain widths of the chelate-soluble pectins with more chains with higher width (120~160 nm) than those in the control group and calcium ions could enhance crosslinking between pectin molecules.

High Pressure Processing - HPP

High-pressure processing (HPP) treatment of food, including fruit juices and purees, can be used to inactivate microorganisms and enzymes. A great amount of studies are referring to different food and microorganism, showing that different strains of a species can have widely varying pressure resistance and the stage of growth of bacteria is important in determining pressure resistance, so that cells in stationary phase are more pressure resistant than those in the exponential phase.

The application of a high pressure over 300 MPa, with no or little heating, is of growing interest as a method for pasteurization as an emerging technology with already several plants operating in all continents. HPP treatment of sweet cherry juice at 400 MPa for 5 min or 550 MPa for 2 min at 10°C was compared with thermal pasteurization at 70°C for 30 s (Queirós *et al*., 2015). All treatments reduced microbial load to non-detectable levels during a 4-week refrigerated storage period.

Authors showed that TP had no effect on anthocyanins, while pressure treatments increased them by 8% with also a lower loss of total phenolics during storage. Phenols were differently affected: TP increased them by 6%, P1 at 400MPa/5min had no effect while P2 -550MPa/2min decreased them by 11%. Anthocyanins decreased during storage, particularly in the control and P1 conditions (decreasing 41%). All treatments had no effect on antioxidant activity until the 14th day, thereafter high pressure processing samples showed the highest antioxidant activity.

Bayındırlı *et al*. (2006) studied HPP treatment of sour cherry juice inoculated with Staphylococcus aureus, E. coli and Salmonella enteritis and found that 350 MPa for 5 min at 40°C completely inactivated the pathogens. On the contrary, treatments at 250 MPa up to 20 min did not sufficiently put down the inoculated microorganisms to guarantee the juice stability, even though significant reductions have been found. Polyphenol oxidase enzymes were more resistant to degradation than bacteria and needed higher temperatures or longer HPP exposure to be eliminated compared with the bacteria tested.

Regarding the effect of HPP on enzymatic activity, instead of using pressures higher than 600 MPa at room temperature, the use of lower pressures at increased temperatures is possible during HPP treatments. Processing temperature must be low to minimize undesirable color and flavor changes.

The combination between mild heat treatment and high pressure processing can lead even to the complete (commercial) sterilization condition. Peng *et al*. (2018) studied the effects of high pressure and high temperature short time sterilization on the quality of cherry juice. Treatment of HPP at 550 MPa/2 min and high temperature short time (HTST, 95 °C/15 s) on microbes, total phenol, vitamin C, anthocyanin, antioxidants and antioxidative capacity and sensory quality of cherry juice were compared, and the changes of quality after storage at 4 °C were assessed. Actually, authors showed that the total number of bacteria after HPP and HTST sterilization was less than 100 CFU/m L, and the mould and yeasts were not detected. Both treatments had good sterilizing effects on cherry juice but the microbial reduction did not reach the commercial sterilization condition.

HPP had no significant effect on cherry juice pectin, total phenol, vitamin C, pelargonidin-3,5-diglucoside, and the content of catechol improved 4.6%. HTST reduced the pectin, total phenol, catechol, vitamin C, pelargonidin-3,5-diglucoside of cherry juice. Both process did not significantly change the antioxidative capacity. HPP cherry juice had a better sensory quality in the aroma, taste, color than HTST cherry juice (Peng *et al*., 2018) but in any case a refrigerated storage would be needed.

Similar results were obtained by Garcia-Parra *et al*. (2017) on HPP treatments on cherry purees, in comparison with thermal treatments, showing that the high pressure processing could be a suitable alternative to obtain cherry-derived products with better nutritional quality than by traditional pasteurization.

Pulsed Electric Fields (PEF)

Recently, new electro-technologies such as pulsed electric fields (PEFs) have been introduced as a method for pasteurization of juice and inactivation of enzymes.

Pulsed Electric Fields (PEF) is a non-thermal and preservation technology consisting in applying electric pulses through a biological tissue placed between two electrodes for very short periods of time (micro- to milli-seconds), causing structural changes in the cell membrane. This phenomenon could be called electroporation or electrocompression; depending by the electric field strength they could be reversible or irreversible. Electroporation is produced when the external electric field induces conformational changes and the reorganization of the phospholipidic bilayer,

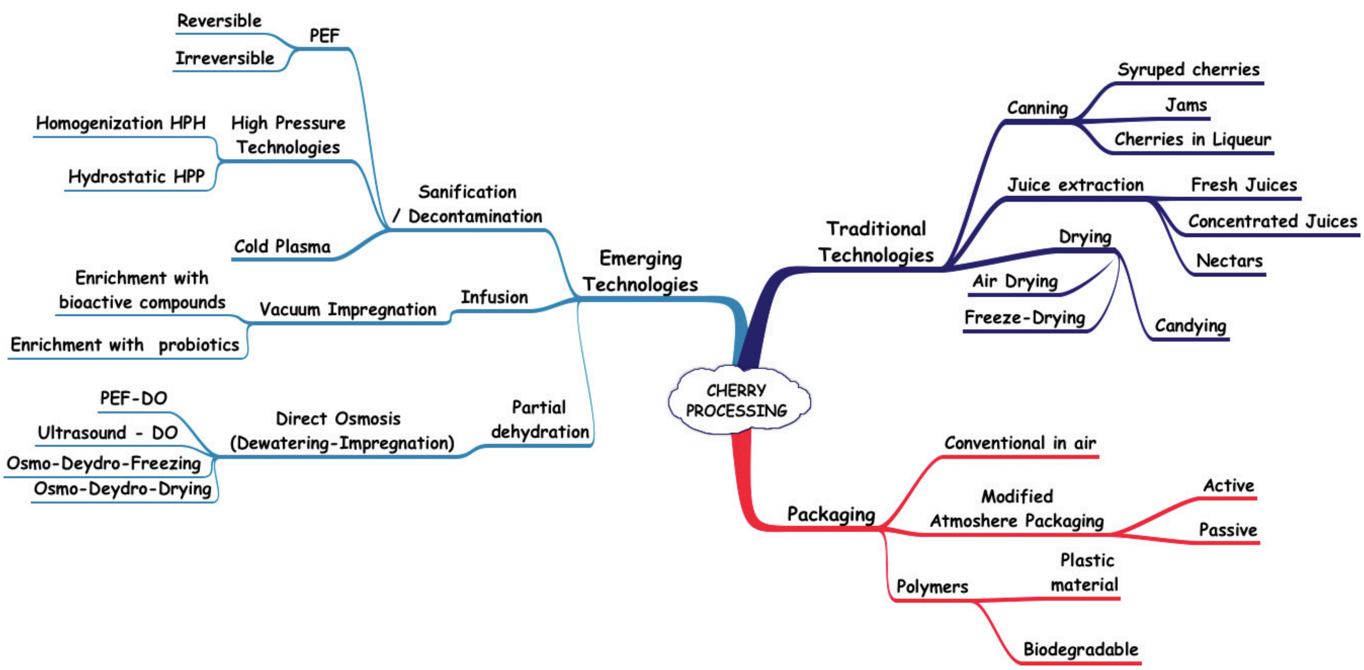

Fig. 2 - Mind Map of Cherry Processing including both traditional and innovative technologies.
Fig. 2 - Mappa concettuale del processo di trasformazione delle ciliegie, includendo sia le tecnologie tradizionali che quelle innovative.

generating pores. The electrocompression is produced due to the accumulation of charges (electrolytes) at both sides of the cell membrane, which attracts each other, compressing it. When this compression exceeds the elastic restoration force, the disruption of the membrane generates pores. The use of a coupled treatment (PEF/OD) in organic kiwifruit (Traffano-Schiffo *et al*., 2016) has demonstrated that water losses have increased and accelerated compared to samples which had not been pretreated with PEF.

Regarding the application of PEF treatment on cherry products, Jensen (2017) reported the results showed by several authors using PEF treatment on cherry juices, evaluating the growth of different bacteria and fungi inoculated into sour cherry juice and also investigating the effect on the quality of the juice. Sour cherry juice at pH 3.1 inoculated with *Penicillium expansum* and treated with a PEF at 30 kV cm^{-1} field strength for 218 µs completely inhibited spore germination. Similarly, PEF treatment of sour cherry juice at 20 kV cm^{-1} for 123 µs inhibited spore germination of Botrytis cinerea inoculated into the juice. Although the survival of all bacteria and fungi was reduced significantly at increasing electric field strengths up to 30 kV cm^{-1} and with longer treatment time up to 200 µs, these conditions were not enough to completely eliminate most of the pathogen species. Generally, a reduction in survival of bacteria and fungi but not a complete elimination was found in most PEF studies (Evrendilek *et al*., 2012). None of the PEF treatments affected quality parameters like °Brix, pH, total acidity, L–a–b colour, ascorbic acid or anthocyanin concentration in the juice, significantly.

Reversible electroporation as a mild or moderate PEF intensity treatment can induce reversible pore formation which facilitates extraction of bioactive compounds such as anthocyanins and polyphenolics. These compounds can affect the growth of probiotic bacteria by either exhibiting stimulatory or inhibitory effects. Soweto *et al*. (2018) showed that the effects of application of mild or moderate PEF influenced physico-chemical and microbiological characteristics of sweet cherries.

On the anthocyanin content of cherry samples, the cyanidin glucoside was significantly affected by PEF treatments. Polyphenol increased significantly as the electric field intensities decreased and PEF treatment stimulated LAB growth. Therefore, low or moderate PEF treatments were shown to have positive effects on the physicochemical properties and bioactive components of cherries that would meet current consumer demand for healthy minimally-processed and fresh-like food products.

Cold Plasma

Among advanced emerging techniques, gas plasma is currently used for bio- treatments; it is an ionized gas (so called the fourth state of the matter) characterized by active particles such as electrons, ions, free radicals, and atoms, which are both in ground and excited states. The excited species emit a photon (including UV photons) when they get to the ground state. The ionization occurs by applying energy to a gas mixture and particularly to electrons which transmit the energy to the heavy species by collisions. Non-thermal or non-equilibrium plasmas are produced at low pressure (e.g. atmospheric), and the behaviour of electrons and ions is in turn influenced by the excitation frequency. When atmospheric air is used as working gas to generate non-equilibrium plasma (Tappi *et al*., 2014). Plasma technology ensures microbial safety of food without addition of preservatives and allows processed food to maintain natural flavors and nutritional value of the original food material. Therefore, it is recognized as a minimal processing technology that ensures both food safety and flavor. Due to low operating temperatures and simultaneous high antimicrobial effects, cold plasma may be regarded as an alternative for thermal pasteurization.

Cold gas phase plasma treatments is a method that generates reactive chemical species by exposing for example argon gas to a strong electric field to generate ionized gas that juice can be exposed to. A short exposure of 3 min to an argon gas phase including a resultant heating to about 50°C of sour cherry juice where experimented by Garofulić *et al*. (2015) who reported a higher content of anthocyanins and phenolic acids than by a traditional pasteurization, at 80°C for 2 min. The higher level of anthocyanins was believed to be a result of dissociation of small-sized agglomerates or particles by the treatment (Jensen, 2017).

Dasan and Boyaci (2018) reported a study on the effect of cold atmospheric plasma on inactivation of Escherichia coli and physicochemical properties of apple, orange, tomato juices, and sour cherry nectar. The authors showed how cold atmospheric plasma treatment can be used as an emerging technology for fruit juice processing as it does not affect quality of juice in terms of its phenolic content, color, and pH and provides a processing temperature below 40 °C while showing a great reduction in E. coli concentration. The optimal cold plasma treatment reported in their study could be potentially used as an alternative to conventional pasteurization due to the phenolic quality of fruit juices. Compared to untreated samples, authors demonstrated how, in their experimental conditions, plasma treatments showed higher total phenolic content (10-15%), which confirms that the plasma has a positive effect on stability of phenols.

Finally, application of atmospheric non-thermal plasma to liquid food materials still needs further investigation in terms of the parameters affecting the inactivation mechanism allied to food matrix and also plasma-liquid interactions.

Packaging

An extension in the storage life of cherries at low temperature is possible when used in combination with controlled atmosphere (CA) or modified atmosphere packaging (MAP), where lower levels of oxygen (O_2) and higher levels of carbon dioxide (CO_2) in the storage atmospheres have been shown to improve the storage life of cherries. Modified atmosphere packaging (MAP) has been extensively studied and is widely commercially used to extend the storage life of cherries as well as reviewed by Chockchaisawasdee *et al*. (2016).

The benefits of MAP are the same as CA where low O_2 and high CO_2 could be used to reduce respiration rates, chemical oxidation rate, and growth of aerobic microorganisms, which consequently increases the storage life of the fruit. MAP has also been shown to reduce the loss of soluble solid content, fruit softening and to minimize weight loss in the fruit during storage.

Active CO_2-enriched MAP has also been reported to effectively delay the respiration peak of cherry fruits, retarding ethylene production, and maintaining firmness and soluble protein and sugar contents in the fruits. Primary effects of low O_2 and high CO_2 suppressing cherry fruit respiration rate, changes in the levels of O_2 and CO_2 can also affect other quality parameters such as pigment metabolism, phenolic metabolism and volatile compound metabolism. The levels of CO_2 and O_2 need to be carefully maintained as excess CO_2 or too low O_2 can cause irreversible fruit injury and induce off-flavours and therefore shorten their storage life. Under regular low O_2 and/or high CO_2, many positive effects of atmospheric-controlled storage of sweet cherries have been reported to retard the decline in soluble solid content, retention of firmness, stem colour and brightness, and the reduction of surface pitting and microbial decay.

Active packaging has been experimented by using essential oil in combination with MAP. The use of eugenol, thymol, and menthol essential oils in MAP have been showed to enhance the effects of MAP alone, in terms of delaying stem browning, retarding TA loss, and reducing the proliferation of moulds, yeasts, and aerobic mesophilic bacteria during the storage of sweet cherry, as reported by Chockchaisawasdee *et al*. (2016).

Conclusion

As reported by Chockchaisawasdee *et al*. (2016), sweet but also sour cherries contain high levels of nutrient and non-nutrient compounds associated with human health benefits and technologies for preservation and processing should be improved to better maintain their quality attributes and to approach the increasing of the global market value, the production and the harvested area of sweet cherries. Those factors are rapidly increasing over the last 15 years and continue to grow, signifying their growing importance in the food and horticultural industries. Apart from improving the quality and market access of cherries in the fresh market, valorization of market-second grade cherries is an important component to add-value to this currently under-utilised resource. Furthermore it is necessary also to extend the valorization of the first market grade cherries, highly perishable, using new or emerging technologies with lower process impact on the fruit quality and to exploit the potential of the great sweet and sour cherry nutritional, functional and sensory quality, more research and development on cherry preservation and processing is needed.

Abstract

The evolution of food technologies through the use of the so-called emerging technologies lays the basis for obtaining products with at least partial stabilization level against microbial alterations with minimal modifications of the intrinsic sensory and nutritional qualities of the finished products. High hydrostatic pressures, pulsed electric fields, cold plasma and osmodehydration can be used for the processing of sweet and sour cherries, with obtaining products of good quality and medium-long shelf-life avoiding highly impacting thermal treatments. High hydrostatic pressure can be used to obtain a partial stabilization of pitted cherries to prolong their shelf-life up to 15 days in refrigerated conditions without any severe thermal treatments. High pressure homogenization could be instead useful to multiple purposes like partial microbial stabilization, viscosity changes and bioactive compounds incapsulation of cherry juices. Water removal without state exchanges can be performed using the direct osmosis dewatering technology. Up to the 70 % of the initial water had been showed to be removed with the immersion of sweet cherries to a

hypertonic solution taking advantages of the difference of osmotic pressure between the fruits and the solution, even with any increase of temperature and very low energy demand. Since this technology is time consuming, pre-treatments like application of Ultrasounds or Pulsed Electric Fields (PEF) have been successfully applied in fruit osmotic dewatering. Furthermore, combining the osmotic dehydration and vacuum pulses it has been possible to introduce interesting enriching components like bioactive substances, probiotics and vitamins to reinforce the healthy contents of cherries. Eventually, surface treatments could be adopted to optimize the cherry skin permeability. Among the new technologies potentially able to help the sanitation and thus the extension of the cherry shel-life, cold plasma could be applied to decontaminate the fruit surface also in this case without any temperature increase. The packaging of the fresh and finished products through the use of modified atmosphere pakaging (MAP), combined with the choice of the most suitable flexible films can be a further key to improve the shelf life of the products.

Keywords: PEF, Ultrasound, Vacuum Impregnation, MAP, High Pressure.

References

Bayindirli, A., Alpas, H., Bozoğlu, F. and Hizal, M. 2006. *Efficiency of high pressure treatment on inactivation of pathogenic microorganisms and enzymes in apple, orange, apricot and sour cherry juices.* Food Control 17, 52–58.

Betoret, E., Betoret, N., Rocculi, P., Dalla Rosa, M. 2015. *Strategies to improve food functionality: Structure property relationships on high pressures homogenization, vacuum impregnation and drying technologies.* Trends in Food Science & Technology 46, 1-12.

Dalla Rosa, M., Tylewicz, U., Panarese, V., Laghi, L. Pisi, A., Santagapita, P., Rocculi, P., 2011. *Effect of osmotic dehydration on kiwifruit: results of a multianalytical approach to structural study.* Journal on Processing and Energy in Agriculture 15, 3, 113-117.

Dasan, B. G., Boyaci, I. H., 2018. *Effect of cold atmospheric plasma on inactivation of* Escherichia coli *and physicochemical properties of apple, orange, tomato juices, and sour cherry nectar.* Food and Bioprocess Technology, 11 (2), 334–343.

Echavarría, A.P., Torras, C., Pagán, J., Ibarz, A. 2011.) Fruit *juice processing and membrane technology application.* Food Engineering Reviews 3, 136–158

Evrendilek, G.A., Baysal, T., Icier, F., Yildiz, H., Demirdoven, A. and Bozkurt, H., 2012. *Processing of fruits and fruit juices by novel electrotechnologies.* Food Engineering Reviews 4, 68–87.

Garcia-Parra, J.; Masegosa, R.; Delgado-Adamez, J.; Gonzalez-Cebrino, F.; Ramirez, R. 2017. *Effect of the thermal treatment and high pressure processing for the preservation of purees from two different cherry cultivars ("Pico Negro" and "Sweetheart") grown in "Valle del Jerte" (Spain).* Acta Horticulturae, 1161, 497–502.

Garofulić, I.E., Jambrak, A.R., Milošević, S., Dragović-Uzelac, V., Zorić, Z., Herceg, Z. 2015. *The effect of gas phase plasma treatment on the anthocyanin and phenolic acid content of sour cherry Marasca (*Prunus cerasus var. *Marasca) juice.* LWT Food Sci. Technol. 62, 894-900.

Handong Zhao, Bangdi Liu, Wanli Zhang, Jiankang Cao, Weibo Jiang 2019. *Enhancement of quality and antioxidant metabolism of sweet cherry fruit by near-freezing temperature storage.* Postharvest Biol. Technology 147 (2019) 113–122.

Jensen, M., 2017. *Processing for Industrial Uses.* In "Cherries, Botany, Production and Uses", Quero-Garcia, J., Iezzoni, A., Pulawska, J. And Lang, G. (eds.), CAB International.

Kowalski, S.J., Szadzinska, J., 2014. *Convective-intermittent drying of cherries preceded by ultrasonic assisted osmotic dehydration.* Chemical Engineering and Processing 82, 65-70.

Mao, J., Chen, F., Zhang, L., Lai, S. 2017. *Effect of vacuum impregnation with calcium on impregnation properties and cell wall polysaccharides of Lapins cherry.* Modern Food Science and Technology (No. 1), 112–118.

Mccune, L.M., Kubota, C., Stendellhollis, N.R., Thomson, C.A., 2011. *Cherries and health: a review.* Crit. Rev. Food Sci. Nutr. 51, 1–12.

Mirtes Aparecida da Conceição Silva, Zaqueu Ernesto da Silva, Viviana Cocco Mariani, Sébastien Darche, 2012. *Mass transfer during the osmotic dehydration of West Indian cherry.* LWT - Food Science and Technology 45, 246-252.

Nowacka, M., Fijalkowska, A., Wiktor, A., Dadan, M., Tylewicz, U., Dalla Rosa, M., Witrowa-Rajchert, D. 2018. *Influence of power ultrasound on the main quality properties and cell viability of osmotic dehydrated cranberries.* Ultrasonics 83, 33–41.

Peng, P., Hou, Z., Xu, Z., Liao, X. 2018. *Effects of high pressure and high temperature short time sterilization on the quality of cherry juice.* Science Technology Food Industry, 17, 71–78.

Petriccione, M., De Sanctis, F., Pasquariello, M.S., Mastrobuoni, F., Rega, P., Scortichini, M., Mencarelli, F., 2015. *The e ect of chitosan coating on the quality and nutraceutical traits of sweet cherry during postharvest life.* Food Bioprocess Technol. 8, 394–408.

Pinnavaia G., Dalla Rosa M., Lerici C.R., 1988. *Dehydrofreezing of fruit using direct osmosis as concentration process.* Acta Alimentaria Polonica, Cracow, Poland, 14 (1), 51-57.

Poiana, M.A., Moigradean, D., Dogaru, D., Mateescu, C., Raba, D. and Gergen, I. 2011. *Processing and storage impact on the antioxidant properties and color quality of some low sugar fruit jams.* Romanian Biotechnological Letters 16, 6504-6512.

Queirós, R.P., Rainho, D., Santos, M.D., Fidalgo, L.G., Delgadillo, I. and Saraiva, J.A., 2015. *High pressure and thermal pasteurization effects on sweet cherry juice microbiological stability and physicochemical properties.* High Pressure Research 35, 69-77.

Sotelo, K. A. G., Hamid, N., Oey, I., Pook, C., Gutierrez-Maddox, N., Ma, Q., Ying Leong, S., Jun Lu. 2018. *Red cherries (Prunus avium var. Stella) processed by pulsed electric field –Physical, chemical and microbiological analyses* Food Chemistry 240 (2018) 926–934.

Sotelo, K. A. G.; Hamid, N.; Oey, I.; Pook, C.; Gutierrez-Maddox, N.; Ma, Q.; Ying Leong, S.; Jun Lu 2018.) *Red cherries (Prunus avium var. Stella) processed by pulsed electric field - Physical, chemical and microbiological analyses.* Food Chemistry; 240, 926–934.

Suwimol Chockchaisawasdee, Golding, J. B., Vuong, Q. V., Papoutsis, K., Stathopoulos, C. E., 2016. *Sweet cherry: Composition, postharvest preservation, processing and trends for its future use.* Trends in Food Science Technol. 55, 72–83.

Traffano-Schiffo, M. V., Tylewicz, U., Castro-Giraldez, M., Fito, P. J., Ragni, L., Dalla Rosa, M. 2016. E*ffect of pulsed electric fields pre-treatment on mass transport during the osmotic dehydration of organic kiwifruit.* Innovative Food Science & Emerging Technologies, 38, 243-251.