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STATE OF THE ART ON NEW PROCESSING TECHNIQUES USED FOR PRESERVATION OF AGRICULTURAL PRODUCTS - A CRITICAL REVIEW

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Abstract

Food processing is the process of transforming raw materials into consumer products and maintaining their quality during storage, transport and sell time. The food processing objectives are focused in particular on adapting the properties of the finished products to the physiological and nutritional requirements. In this framework, the avoidance and reduction of microbiological contamination by using thermal processing treatments, food quality is lost due to enzyme reactions, and limiting these losses is a major concern of the food industry. Alongside conventional methods of thermally treating food, a number of modern methods of treatment are being applied to food processing, such as: PEF-pulsed electric field treatment, irradiation with x-ray, utilization of antimicrobial essential oils and many others. The reasons for developing and applying new, modern methods in food processing are as follows: maintaining and increasing nutritional values; preventing microbiological spoilage; increasing the technological characteristics of raw materials and semi-finished products; increasing product diversity and increasing the value of ready-made products. In this review are shown the newest techniques used in the processing and conservation of agricultural food products.

Key words*: novel, processing techniques, food safety, shelf-life, trends.*

INTRODUCTION

Food products may be internally or externally contaminated with alteration microorganisms that are naturally present in the food product or on the product surface, but also with microorganisms that may appear during the processing stage, storage and transport of the food products, either by direct contamination or by cross-contamination. The main problem in the food industry is the contamination with microorganisms of the food products, and new techniques are developed by researchers and industry every year (Belalia R. et al., 2002).

The internal tissue of a healthy plant is usually free of microorganisms. However, the external surface of plant products is contaminated by soil, air, insects, handling personnel, or packaging. Root plants such as potatoes, beets, or carrots are contaminated at the outside with microorganisms in the soil. Fruits that grow far above the ground can be contaminated by insects and microorganisms in the air. Fruits very rich in sugars and acid can be broken down by yeasts, as in the case of grapes, or by moulds, as in the case of citrus fruits (Siebel et al., 2003).

Animal products are subject to both internal contamination and external environmental contamination. Surface microorganisms cannot penetrate into the depth of muscle tissue until the alteration process has been triggered due to the considerable increase in the number of bacteria (García A. et al., 2014). The delay of penetration of bacteria into the depth of the meat is due to the lack of bacterial proteolytic enzymes, which only form in the logarithmic growth phase. In order to avoid contamination during the storage of the raw materials, the optimal conditions of temperature, humidity, aerobiosis must be kept. The main factors influencing the degradation of physical foods are: light, temperature, humidity, air composition and mechanical injuries that can act independently or in complex (Nabar Y. et al., 2004).

FOOD PROCESSING IMPORTANCE

Food processing techniques are used to transform raw food materials into food products or to transform foods into other forms that can be consumed for human or animal consumption in both the household and food

processors. Most foods are processed to eliminate the risk of microbial alteration and increase availability and conservability (Hui et al., 2006).
The processing method applied to raw materials has a decisive role in the quality and consistency of finished products. Not all processing methods are applied to food for preservation, but some are used to change or stabilize the food texture. Food processing methods can be divided into two main categories: chemical (food with intermediate moisture, water activity, addition of chemicals, pH control) and physical (sterilization, pasteurization, scrubbing, microwave treatment, roasting and freezing).
Currently, most of the processing methods based on the use of conventional heat treatments are widely used to produce foods with a prolonged conservative period. Within these processes the treatment temperature and the retention time play an important role in ensuring the innocuity of the obtained foodstuffs.

NEW TECHNIQUES USED IN THE PROCESSING AND CONSERVATION

1. Food processing through pulsed electric field (PEF)

Pulsed electric field (PEF) treatment is a novel technology which has an electroporation effect on the cells structure and possess a wide range of practical applications, especially in the food industry. (Knorr et al., 2011). Studies have shown that PEF technology enables inactivation of vegetative cells of bacteria and yeasts in various foods. PEF treatment has been applied for the processing of liquid and semi liquid food matrices, as well as the treatment of different solid foods (Barba et al., 2016). PEF can be defined as the application of high-voltage pulses applied to food matrices with the help of two electrodes. A high-voltage direct power current is connected to a capacitor bank in order to store large amount of energy which is going to be discharged as a high-voltage electric pulse on the food product in a treatment chamber. PEF treatment can inactivate microorganisms and in the same time help the treated food products keep their initial characteristics like flavours, nutrients and freshness (Knorr et al., 2011).
The highly effective inactivation on pathogenic microorganisms of the PEF treatment, as well as other advantages when compared to conventional thermal processing, has been widely investigated for food pasteurization and preservation. (Barba et al., 2016). For example, PEF technology with electric field strengths ranging from 20 to 250 kV/cm for short periods of time (ms or μs) has the potential to pasteurize liquid foods at temperatures below 30-40^{o}C, which is much lower than temperatures used in thermal processing (Beebe et al., 2003). Physical methods like high intensity pulses, ultrasound, high preassure carbon dioxide and UV light were combined with the PEF treatment of some food products in order to enhance the effect of the inactivation treatment (Gachovska et al., 2008). Further studies have to be made in order to establish more efficient use of the PEF treatment on food products.

2. Irradiation with X-rays or β-rays of food products

Irradiation or ionizing treatments applied to food products are methods of physical processing for prolonging the shelf-life of these products (Niculiţă et al., 2007). The principle of this method involves the production of a controlled amount of beta or X-rays, through the ionized radiation from cobalt or cesium radioactive isotopes or accelerator electrons. The food products treated do not become radioactive.
Research has been made in this area for more than 40 years and the results shown that irradiation of food products can lead to the destruction of insects and parasites in cereals, dried beans, dehydrated fruits and vegetables, meat and seafood. Also there have been cases that showed that the irradiation treatment lead to the prevention of potato or onion sprouting, delaying the maturation of fruits and vegetables and reducing the number of microorganisms in food (Nabar Y. et al., 2004).
The shelf-life of fresh vegetables such as mushrooms, potatoes, tomatoes, onions, mango, papaya, banana, peaches, and strawberries may be prolonged if the irradiation process uses low doses of radiation, so loss of quality does not occur.

3. Ultra High Pressure Technology (UHP) treatment

Ultra High Pressure Technology (UHP) is a new, non-thermal processing technique in which the food products undergo a treatment of high hydrostatic pressures, generally in the range of 100-600 MPa, at room temperature (Niculiţă et al., 2007). Ultra high hydrostatic pressure is a novel food processing technique which opens new opportunities for the food industry to develop new products with superior sensory and nutritional qualities, without unwanted changes in flavor, color, and nutrients value.

When using high pressure processing, microorganisms are destroyed, but covalent bonds do not break and the effect on processed food is minimal. In addition, the positive effect consists of the avoidance of excessive thermal treatments and chemical preservatives (Muntean et al., 2016)

Under the influence of high pressure, the food products molecules alter their behavior according to the Le Chartelier-Braun principle (Hendrick et al., 1998). Due to this principle, at a relatively low temperature (0 to 400ºC) the covalent bonds are almost unaffected by the high pressure, instead the tertiary and quaternary structures of the molecules, which are maintained primarily by the associated hydrophobic and ionic interactions, change after treatment with a high pressure of 1200 MPa (Hendrick et al., 1998). Consequently, high pressure inactivates micro-organisms, while factors that determine food quality, such as nutritional factors or functional characteristics, remain unchanged. High pressure gives the possibility of improved food processing techniques, and the unique features of keeping intact covalent bonds during treatment, selective activation / inactivation of enzymes, bacterial destruction, and sensory quality retention capacity at a much higher rate than in a thermal process some of the benefits of this process, which results in the production of high quality food (Hui et al., 2006).

4. The use of antimicrobial agents to increase the shelf-life of food products

Plants produce a series of secondary metabolites in order to ensure protection against potential predators and pathogenic microorganisms. It is believed that there are approximately 100,000 secondary metabolites that fulfil various beneficial roles in plant life that helped them survive for millions of years (P. Tongnuanchan and S. Benjakul, 2014).

In recent years, interest in the use of herbal extracts and essential oils for the preservation of food products has increased. From a chemical point of view, the essential oils consist of a mixture of esters, aldehydes, ketones and terpenes. The antimicrobial properties of essential oils have been tested in combination with different treatments (edible films and irradiation) against alteration microorganisms present in processed food products, especially against fungi (Chee Hee Y. et al., 2004).

Foods producers are using more often essential oils because of their proven antimicrobial activity and because they are natural compound that are accepted by the end consumers. The most interesting area of use of essential oils is to incorporate them directly into the packaging material covering the surface of the polymer, resulting in an antimicrobial packaging that inhibits the growth or decreases of the number of pathogens in food (Asan-Ozusaglam M. et al., 2016). Tests prove that essential oils are capable of having antimicrobial effect on a large group of food pathogens and several microorganisms found in food (bacteria and fungi) (Elgayyar M. et al., 2001). These antimicrobial effects were demonstrated by two methods: the agar disc diffusion method and the volatilization method using discs. (Packiyasothy et al., 2002).

5. Food processing using ultrasound

Ultrasounds are vibrations similar to sound waves, but at much higher frequencies than those perceived by the human ear (between 18 kHz and 500 MHz). In biological environments, these vibrations produce compression and expansion cycles. The implosion of air bubbles generated at a point with very high pressures and temperatures can break the cellular structures. The lethal effect of ultrasound on some microorganisms has long been known. Ultrasonography has been proposed as a means of sterilizing liquid foods, but inactivation of the most resistant microbial forms, such as bacterial spores, would require ultrasonic treatments so drastic that the degra-

dation of the physico-chemical characteristics of the food would result (Hui et al., 2006).
The intensification of physical, chemical and biochemical operations consists of overlapping over the stationary state of a fluid or solid, or over the normal fluid flow of some oscillatory movements created by the use of ultrasonic vibrations. The oscillation may be of different shapes: sinusoidal or square, and depending on the mode of application it may be: longitudinal when the direction of oscillation is along the axis of the apparatus and transverse, when the direction is perpendicular to or inclined to the axis of the apparatus (Vorobiev, E. et al., 2008).

6. Food processing techniquest by radio waves heating (RF treatment)

Radio frequency (RF) treatment is a form of electric heating process that is applied to food products with a series of electrodes. In contrast to classical thermal treatments, radio wave treatment generates heat mainly inside the treated product by friction of ions induced by the rotation of the dipoles. In radio waves heating, electricity is first transformed into electromagnetic radiation and subsequently applied to food (Brown G. et al., 1947). The practical implications of the use of radio wave treatment consist in the fact that the radiation will go through the classic plastic packages (metal carcasses cannot be used) without the need for direct contact with the electrodes (Yanyun Zhao, et al., 2000).
In principle, an electric field with positive and negative regions is formed in an RF or ohmic heating system. Under these conditions, the positive ions in the product were oriented towards the negative regions of the field and the negative ions were oriented towards the positive regions of the field. The heating that occurs when using the ohmic system occurs because the polarity of the field is constantly changing, the field being static, which usually happens at low frequencies (50Hz in Europe, 60Hz in the U.S.). In the case of RF, the polarity changes to a much higher frequency (27.12 MHz).

7. Food processing by ohmic heating

Ohmic treatment, also known as Joule heating, is defined as the process in which the electric current is passed through food products or other materials with the main purpose of heating them to a certain temperature. Electrical resistance generates internal heat. Ohmic treatment reduces exposure to heat by reducing the time required to achieve a sterilization effect. It also ensures a more even distribution of heat in the product, eliminating the risk of overheating in certain areas, a situation encountered in classical thermal treatment (Shafiur M. et al., 2007).
Ohmic treatment is different from other heating methods due to the presence of electrode-food contact (as opposed to microwave and inductive heat where the electrodes are missing), frequency (unlimited, unlike the radio frequency range or microwaves) and the type. The antimicrobial effect of the ohmic treatment is due to its low frequency (50-60 Hz), which allows the loading of the cell walls with a certain electrical charge forming pore. This is different from high-frequency methods, such as radio frequency or microwaves, where the electric field is reversed before electric charge loading of the cell walls (Sastry S.K. et al., 1998).
The main advantage of ohmic treatment is the ability to heat uniformly and quickly the food products. This can completely reduce thermal stress of the food products compared to conventional heating, where it is necessary to maintain a higher temperature at high temperatures in order to allow heat to penetrate into the thermal centre of the product.

8. Active packaging

Active packaging is an innovative packaging method that allows the product and its protective environment to interact in order to extend the product shelf life and to ensure its microbial safety, while maintaining the quality of the packed food (Ahvenainen, 2003). The most important active packaging systems applied to food products are antimicrobial, antioxidant, and carbon dioxide emitting/generating sachets.
Packaging in modified atmosphere consists of extracting oxygen from inside the packaging and introducing inert gases such as nitrogen and carbon dioxide into its place. The method is indicated for pressure sensitive products and contraindicated for friction-sensitive products.

Nitrogen (N_2) is an inert, odorless and poorly soluble in water gas. Carbon dioxide (CO_2) is a good bacteriostatic and fungistatic agent that reduces the rate of multiplication of aerobic bacteria and the growth of molds (M.C.Villalobos et al., 2018). Although oxygen is generally avoided in the packaging process, there are cases where it is used as a component in the formation of the gaseous mixture. For example, in the packaging of meat, the presence of O_2 keeps the red colour of the product and prevents the appearance of anaerobic pathogens like *Clostridium*. Usage of CO_2 in modified atmosphere packaging (MAP) has been controversial. Low levels <0.4% CO_2 promote redness in red meats which can mask oxidation or spoilage while maintaining a desirable red colour (Michele Perna, 2016).

9. Pulsed light treatments for food preservation

Non-thermal food processing methods have become increasingly popular over the last years, and pulsed light technique is one of the newest processing methods used by the food industry. Pulsed light (PL) is a novel non-thermal processing method used the treatment of food products and food packages, consisting in short high-peak pulses of broad spectrum white light (Gemma Oms-Oliu et al., 2008). The PL method uses high frequency, high intensity pulses of broad-spectrum light in the UV fraction and is capable of inactivating microbial cells and spores (Heinrich V. et al., 2015). The pulsed light (PL) technology makes use of high-power electrical pulses that are subsequently transformed to short-duration, high-power pulses of broad-spectrum (180–1100 nm) electromagnetic radiation (light) via an inert-gas (mainly xenon) flash lamp (Victoria Heinrich et al., 2015). The PL method stands on the theory that the shorter the pulse duration, the higher the delivered energy and consequently the antimicrobial action (Dunn et al., 1989). Three main factors affect the efficiency of a pulsed light treatment and the factors are the treated food product, the degree and nature of microbial contamination and the process parameters (Heinrich V. et al., 2015). The efficiency of the pulsed light treatment is influenced by the state of microbial contamination, its physiological constitution, population density and the growth parameters, growth rate and lag time (Augustin et al., 2011). The antimicrobial effects of UV wavelengths in the PL spectrum are primarily mediated 50 through absorption by highly conjugated carbon-to-carbon double-bond systems in proteins and 51 nucleic acids (Barbosa-Canovas et al., 2000).

CONCLUSIONS

Despite the efforts made in understanding the food contamination process and improving the methods of controlling the microorganisms development, food intoxication remains a major cause of morbidity and mortality in the whole world.

Most food processing methods are based on heat treatment, which ensures the food conservability, but heat treatment also has a less desirable effect on treated food products such as color, taste, flavor and texture changes. In addition, heat treatment can partially or totally affect thermo sensitive nutrients and mainly vitamins (B and C).

With the above in mind, modern non-thermal techniques for reducing the microbiological load of processed food have been developed and used to extend their shelf-life. Among these techniques the most promising are: ionizing treatments, radio frequency (RF) treatment , high pressure treatments (UHP), electric pulse treatments (PEF), photodynamic inactivation of microorganisms, osmotic dehydration and the use of natural antimicrobials in plants.

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