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CRITICAL REVIEW ON PROCESSING EFFECT ON NUTRITIONAL COMPOSITION OF FOOD PRODUCTS

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Abstract

An increase in the intake of food and constant changes in the formulation of food products has become evident in recent years. Therefore the efforts of processors together with academic circles in attending consumer demands for high quality food and dealing with raising economic standards, and nowadays particularly with ecological concerns, has triggered the development of emergent technological approaches for food processing. Recently, unconventional treatments technologies in food processing have gained increased industrial interest and have potential to replace, at least partially, the traditional well-established preservation processes (Pereira and Vicente, 2010).

The objective of this work is to make a short review in respect to unconventional treatments of food, which are used nowadays in industry or are in the research and development phase. The paper presents the effects of novel techniques on the quality of food products, especially on the nutritional value.

***Key words**: unconventional treatments, nutritional composition, food safety and preservation.*

INTRODUCTION

The food industry is one of the most important markets in the world, which struggles to get food from producer to consumer in the best possible conditions at the least expense (Cheng et al., 2010).

In recent years, attention has been increasingly paid to the nutritional characteristics of traditional foods and recipes, in order to accurately estimate dietary intake of the population, prevent diseases such as cardiovascular diseases, cancer, diabetes, etc., provide dietary information, and preserve some cultural elements. (Costa et al., 2013; Durazzo et al., 2017). The health-beneficial effects are thought to be related to macronutrients, micronutrients and bioactive compounds present in vegetables (Kim et al., 2016), meat, milk, eggs and other valuable products. In human nutrition food choices depend on a wide range of factors: culture, tradition, ethics, environment, consumption patterns, personal preferences, etc. (Durazzo et al., 2017).

A diversified diet is needed to meet daily micronutrient requirements (Uusiku et al., 2010).

Cooking is essential to achieve a palatable and safe product. Moreover, it may affect basic traits related to consumer preferences, such as flavor, tenderness, color and appearance (Dominguez et al., 2015).To maintain food products in conditions that are acceptable for consumption, the industry relies on different treatments and on the introduction of food additives, which are used especially to maintain the best conditions during the final steps of preparation, expedition and shelf-life (Carocho et al., 2015).

More than two decades ago, novel food processing technologies that were based on high-tech or cutting edge advances started to emerge to address productivity issues, extending product shelf life without affecting the nutritional content, organoleptic attributes and product specifications. Despite some of the technological advancements developing since the early 20th century, their applications for foods are still in a phase that needs a substantial amount of research to prove their pragmatic feasibility.

Current limitations related to high investment costs, incomplete control of variables associated with the process operation and lack of regulatory approval have been delaying a wider implementation of these technologies on an industrial scale (Jermann et al., 2015). This study presents some unconventional treatments of food and how does or doesn’t affect the nutritional composition of food products.

INFRARED TREATMENT (IR)

Infrared (IR) radiation has unique characteristics in its ability to transfer energy directly by radiation to a product, without heating the air. IR radiation is an electromagnetic radiation that falls between the region of visible light (0.38–0.78 μ m) and microwaves (1–1000 mm). It is transmitted as a wave and converted into heat when impinging on the food surface. Based on the wavelength, it can be divided into three regions – near- (0.78–1.4 μ m), mid- (1.4– 3.0 μ m) and far-IR (3.0–1000 μ m)IR technology has long been underestimated in the food field, despite its great potential.

It is generally applied to: the dehydration of vegetables, fish, pasta and rice; heating flour; frying meat; roasting cereals; roasting coffee and cocoa; and baking biscuits and bread. The technique has also been used for thawing, surface pasteurization of bread and packaging materials (Rastogi, 2015).

Uysal et al. (2009) demonstrated that the combination Microwave-IR oven for roasting of hazelnut resulted in a product of comparable quality with conventionally roasted ones with respect to colour, texture, moisture content and fatty acid composition.

Far-IR radiation resulted in higher antioxidative activity of extracts from peanut shells as compared to heat treated sample. The antioxidative activity was found to increase with an increase in exposure time (Rim et al., 2005).

IR heating of grass pea seeds resulted in a decreased TIA (trypsin inhibitor activity) compared with that of raw seeds. Reactive lysine proved to be relatively stable in the applied heating conditions. In addition, the process reduced the value of breaking load required for destructing a single seed. This may facilitate further processing, for example, flaking. Therefore, IR heating can be applied in processing of grass pea seeds (Sagan et al., 2016).

The effect of irradiation on nutritional or sensorial characteristic and physicochemical properties, as well as the interaction of food components under IR radiation, may further justify the use of IR radiation as a future food processing option (Rastogi, 2015).

PULSED ELECTRIC FIELD (PEF)

Pulsed electric field (PEF) processing is a non-thermal food-processing technology, which uses short bursts of electricity (Wang et al., 2014), which causes electroporation in the cell wall of microorganism and inactivating them (Li and Farid, 2016) providing fresh-like, safe foods and reduces loss of quality (Wang et al., 2014).

Pulsed electric field (PEF) has been used in active substances extracted (Lin et al., 2012), sterilization and destroy enzyme to prolong shelf life, and maintaining physical and chemical characteristics and nutritional value (Chen et al. 2009; Lin et al., 2017).

In general, PEF treatment systems are composed of PEF treatment chambers, a pulse generator, a fluid-handling system, and monitoring systems. The treatment chamber is used to house electrodes and deliver a high voltage to the food material. It is generally composed of two electrodes held in position by insulating material, thus forming an enclosure containing the food material. Therefore, the proper design of the treatment chamber is an essential component for the efficiency of the PEF technology (Elez-Martinez et al., 2012; Stefanoiu et al., 2015).

Zhao et al. (2008) showed that *E. coli* and *S. aureus* were inactivated by PEF treatment at 38.4 kV/cm for 160 and 200 ms reached 5.6 and 4.9 log reductions, respectively. PEF processing caused no considerable changes in color, GTP(green tea polyphenols) and total free amino acids.

In a study by Lin et al. (2017), pine nut protein hydrolysate was used to separate and identify antioxidant peptides. There were four peptides obtained including Gln-Cys-His-Lys-Pro (QCHKP), Gln-Cys-His-Gln-Pro (QCHQP), Lys-Cys-His-Gln- Pro (KCHQP), or Lys-Cys-His-Lys-Pro (KCHKP) QCHKP, QCHQP, KCHKP, and KCHQP. Among those peptides, KCHQP was with the strongest antioxidant activity. In addition, the antioxidant activity of KCHQP can be improved by PEF treatment. With the optimal conditions of pulse frequency 1800 Hz and electric field intensity 15 kV/cm, the DPPH radical inhibition of KCHQP was increased from 89.10% ± 0.20% to 93.22% ± 0.09%.

The combination of PEF and PAA(peracetic acid) was able to achieve up to 3 log reduction of *E. coli* and *Listeria* as well as 2 log/g reduction of native microbiota. PEF treatments did not cause any changes in colour and appearance of the blueberries. The concentration of anthocyanins and phenolic compounds in blueberries increased by 10 and 25% after PEF treatments (Jin et al., 2017).

The potential of pulsed electric technologies to improve the recovery of high-added value components such as proteins, total phenolic compounds and anthocyanin from berries was demonstrated by Barba et al. (2015). HVED (high voltage electrical discharges) technique was more efficient in terms of energy input compared to PEF and US (ultrasounds) treatments. Moreover, HVED + EE (supplementary extraction) (30%) showed at least two fold higher recovery yield of proteins and higher yield of polyphenols compared to other treatments. However, the maximum anthocyanin yield was found after applying PEF treatment and supplementary extraction with hot water at 50°C. The results obtained showed that PEF + HVED or PEF + supplementary extraction + HVED, can have good prospects for use in the food industry, i.e. by recovering in a first step sensitive compounds such as anthocyanins and subsequently more resistant compounds.

Processing of orange juice by pulsed electric fields (PEF) and thermal pasteurisation was carried out to compare changes in total phenolic concentration, hydroxybenzoic acid, hydroxycinnamic acids, flavonols, flavones and flavonones before and after being stored at 4°C for 180 days. Changes in the initial total phenolic concentration of the samples varied depending on the applied electric field intensity and thermal pasteurisation. Hesperidin and chlorogenic acids were detected as the most abounded flavonoid and phenolic acids in the orange juice, respectively. Except for syringic acid and neoeriocitrin, the concentration of the phenolic compounds indentified in the orange juice samples enhanced after the PEF or thermal pasteurisation. The samples treated with PEF had more stable flavonoids and phenolic acids than those treated with the thermal pasteurisation. The PEF-treated samples had higher sensory scores than the heat-treated samples (Agcam et al., 2014).

In respect to the GSH(Glutathione) antioxidant activity the conditions for PEF treatment to maximize were: 8.86 mg/mL GSH, concentration, 9.74 kV/cm electric field intensity, and 2549.08 Hz pulse frequency. The change in structure and functional groups was analysed using NIR(Near InfraRed) and MIR(Mid InfraRed). There was no change following PEF treatment using MIR (Wang et al., 2014).

Applied on the kombucha beverages, there is an influence of PEF, especially at low feed flows, when it increases the bioactive contents, although there is no effect on the antioxidant capacity of treated samples (Vazquez-Cabral et al., 2016).

In the last years, there has been considerable interest in the adoption of PEF processing, and research into process scale-up. In other applications than foods, PEF processing can also improve the performance of industrial processes such as the removal of water from sludge, or the extraction of sugars and starches from plants, because the ruptured cells release their intracellular liquids more easily into their surroundings (Kempkes, 2010; Stefanoiu et al., 2015).

OHMIC TREATMENT (OH)

Ohmic heating technology is considered a major advance in the continuous processing of particulate food products. Ohmic heating is direct resistance heating by the flow of an electrical current through foods, so that heating is by internal heat generation (Goullieux and Pain, 2014). Heat is generated instantly inside the food, and its amount is directly related to the voltage gradient, and the electrical conductivity. The uniform heat generation results to uniform temperature distribution. The obvious advantage of ohmic treatments over conventional methods is the lack of high wall temperatures and limiting heat transfer coefficients requirements. Its other advantages compared to conventional heating include maintaining the color and nutritional value of food, short processing time, and higher yield (Icier, 2012).

Ohmic treatment is used in a wide range of applications such as preheating, cooking, blanching, pasteurization, sterilization and extraction of food products (Yildiz-Turp et al., 2013).

A comparative study of the effects of ohmic and conventional pre-treatments used as blanching methods of artichoke heads prior to canning was investigated by Guida et al. (2013). The obtained data confirm that ohmic heating makes it possible to heat food products more quickly and uniformly than conventional methods, leading to a milder and efficient thermal treatment. Compared to conventional treatments, ohmic blanching is beneficial in terms of enzyme inactivation (for example POD-peroxidase and PPO-polyphenol oxidase) as well as preserving the colour of the fresh product, thus avoiding browning.

This treatment appears as a solution to reduce thermal damage because it heats materials in a rapid and homogeneous manner and may allow improved retention of vitamins, pigments and nutrients, resulting in less thermal damage to labile substances (Sarkis et al., 2012). Other examples for applications are the following: it's potential to increase dye diffusion in beet, its capability to extract sucrose from sugar beet, and its possibility to enhance the diffusion of soy milk from soybeans.Several past studies have shown an additional effect of electricity during the ohmic heating of plant tissues, vegetative microorganisms and bacterial spores (Somavat et al., 2013).

Ohmic heating is not only a useful thermal process in food stabilization, but also a pretreatment to prepare vegetal tissues before a mass transfer operation (e.g., diffusion, extraction, or dehydration) (Stefanoiu et al., 2015).

ULTRA HIGH PRESSURE (UHP)

High-pressure processing (HPP) is a method of food processing where food is subjected to elevated pressures (up to 87,000 pounds per square inch or approximately 600 MPa), with or without the addition of heat, to achieve microbial inactivation or to alter the food attributes in order to achieve consumer-desired qualities. The technology is also referred as High Hydrostatic Pressure Processing (HHP) and Ultra High Pressure Processing (UHP) in the literature.HPP retains food quality, maintains natural freshness, and extends the microbiological shelf-life of the food (Gupta and Balasubramaniam, 2012; Ramaswamy et al., 2013; Stefanoiu et al., 2015).

The growing demand by consumers for more natural, minimally processed convenient food products that are safe, has stimulated food industry interest in high pressure processing (McArdle et al., 2011).

High pressure (HP) technology could maintain food quality attributes such as colour, flavour and nutritional values due to its limited effects on covalent bonds. Under pressure, (bio) chemical reactions can also be induced and it could affect those quality attributes, e.g., nutrition value.

The potentials of High Pressure processing (HP) have been pointed out for industrial food applications, allowing high retention of food quality attribute such as colour, flavour and nutritional values. The limited effect of HP (at moderate temperatures) on covalent bonds represents a unique characteristic of this technology. Therefore, in theory, most of the natural food quality aspects, for example nutritional values, can be maintained during HP treatment. Many studies on vitamin stability under HP (at moderate temperatures) have shown that HP does not significantly affect or affects only slightly the vitamin content of fruit and vegetable products, except at extreme pressure and temperature combinations (Oey et al., 2008).

Castanón-Rodríguez et al. (2013) studied the effect of high pressure processing on the lignocelluloses fraction of sugarcane bagasse and where was a function not only of pressure level and temperature, but also on the chemical used to pre-treat SCB (sugarcane bagasse). Results indicated that even though HPP, in the pressure range tested, induced changes on microstructure and crystalline structure of SCB, it did not enhance susceptibility of pre-treated SCB to the enzymatic hydrolysis and neither increased glucose yields.

HPP at the highest temperature (55 °C) had a positive effect on beef quality, by minimising meat toughening and water loss induced at high pressures. Moreover, no alteration of other quality parameters such as oxidative stability was detected after pressurising at higher temperatures. Comparison of pressure treated samples with conventionally cooked beef showed that even though HPP alters meat quality to some extent; it has a lower effect than conventional cooking on colour, pH, lipid oxidation and fatty acid composition parameters (McArdle et al., 2011). Also, HPP at ambient temperatures could be an appropriate method to produce tastier and more nutritive manuka honey (Akhmazillah et al., 2013).

High pressure processing at 400MPa induced the strongest alteration on swede quality. The results suggest that the strong structural modifications induced by HPP at 400 MPa would have played a role in the alteration of antioxidant properties of swede (Clariana et al., 2011).

Based on current knowledge, it can be concluded that in general HP treatment at moderate temperatures can maintain the vitamin content of fruit and vegetable based food products, however, mostly not at high temperatures. Vitamin stability is highly influenced by chemical reaction which can be enhanced by increasing pressure and temperature during HP treatment. As a consequence, HP treatment at extreme pressure and temperature combinations could result in vitamin degradation (Oey et al., 2008).

ULTRAVIOLET TREATMENT (UV)

Ultraviolet (UV) light is the part of the electromagnetic spectrum with wavelengths between 100 and 400 nm (Gomez- Lopez et al., 2012; Stefanoiu et al., 2015).

UV irradiation has been in use for decades for water disinfection and is an effective method for microbial decontamination of surfaces and packaging in the food industry (Bintsis et al., 2000).

The application of a combination of UV irradiation and PEF to freshly squeezed apple juice resulted in a similar total microbial reduction compared to the severe heat treatment. The relative antioxidant capacity of fresh apple juice decreased by 18.9% and the concentration of total phenolic compounds changed from 22.74 to 15.98 mg gallic acid equivalents/l after 30 min of UV illumination. These results would indicate a potential for the use of these combined technologies for processing freshly squeezed apple juice (Noci et al., 2008).

In a study, Mendes de Souza et al. (2015) demonstrated that techno functional properties are not affected or are even improved by UV-C, foam ability was only improved on the egg white fraction and the foam stability was enhanced on all LEP. Emulsifying activity index was higher and more stable with the increasing UV dose. Nutritional value is largely maintained. The main UV-C radiation nutritional effect was on retinol content, which presented higher reductions as higher the applied doses, and on vitamin C content, which is less important since egg is not a common source of this vitamin. Under the studied conditions, a significant decay in the concentration of relevant secondary metabolites (lutein and zeaxanthin) has been stated.

No interference of UV-C light was observed on the mineral composition of liquid egg products.

Foods rich in reducing sugars and proteins are susceptible to Maillard reaction, which reduces the nutritional value. No evidence of Maillard reaction in milk has been observed after 10 light pulses of 2,200 mJ/cm^2 each but the Vitamin A present in milk is degraded by UV treatment (Elmnasser et al., 2008).

It is common knowledge that preservation treatments degrade nutrients, a phenomenon that has to be assessed and minimized. UV-C illumination decreases ascorbic acid content of juices at a similar level to that caused by thermal treatments. Ascorbic acid present in orange juice is degraded by UV-C following first order kinetics at a rate of 0.175% per mJ/cm^2, with a reduction of 17.0% caused by 148 mJ/cm^2. Also for orange juice, a treatment of 299 mJ/cm^2 destroyed about 50% riboflavin and β-carotene, 17% vitamin C, 11% vitamin A, and did not affect folic acid or vitamin E. In apple juice, the reduction is reported to be from 5.4 to 4.0 mg/100 ml of juice (Gomez- Lopez et al., 2012).

However, UV light should not be considered as a harmful treatment to the nutritional and antioxidant quality of fruit juices if it is evaluated from a broader point of view. UV treatment of fruits before juice extraction has been shown to yield excellent results to enhance phytochemical content. For example, UV-C illumination of grapes induces stilbene synthesis, especially that of trans-resveratrol, which will yield a phytochemical-enriched grape juice (Gonzalez-Barrio et al., 2009).

As far as the macro and micro-nutrient composition of milk is compared some different effects were noted between the treatments. The most noticeable change was a 35% reduction in cholesterol with UV treatment and 18% reduction in cholesterol with the UVP treatment, which indicates that UV does reduce the cholesterol and result in the possible conversion of cholesterol to COP's.Furthermore quantitative and qualitative measurements on enzyme activity also indicated no differences. The analysis of the fatty acid profile indicated difference in C18:1 cis n9 (Oleic acid) in the UV sample and C 18:0 (stearic acid) in the RM sample when compared to the other treatments (Falguera et al., 2011; Cilliers et al., 2014;).

Applied on cold-stored shiitake, quality retention by the UV-C treatment of mushrooms following an additional shelf-life period at room temperature resulted in maintenance of tissue firmness, increase of flavonoid and ascorbic acid contents, and enhancement of antioxidant ability, which could be useful from the nutritional point of view. These results suggest that UV-C treatments may be a useful non-chemical way of maintaining shiitake mushroom quality and extending their postharvest life (Jiang et al., 2010).

Finally, the success of UV technology for low-UVT liquids depends on the correct alignment of the UV source parameters to the specific demands of the UV application (Gomez- Lopez et al., 2012).

OZONE TREATMENT

Ozone is a triatomic form of oxygen and is characterized by a high oxidation potential that conveys bactericidal and virucidal properties. Ozone inactivates microorganisms through oxidization, and residual ozone spontaneously decomposes to non-toxic products (oxygen), making it an environmentally friendly antimicrobial agent for use in the food industry (Patil and Bourke, 2012).

In this research, polyphenols were used as indicators to evaluate the degree of oxidation by ozone. It was apparent that the observed polyphenols and resveratrol contents showed no significant difference between treated and untreated groups ($P > 0.05$), which indicated that polyphenols and resveratrol were not affected byozone treatment under the optimal conditions (Chen et al., 2014).

The effect of continuous exposure to ozone at 0.45, 0.9 and 2 $\mu mol\ mol^{-1}$ on quality changes during the storage of red and green chilli peppers at 10°C was investigated by Glowaczand Rees (2016). Total phenolic content was not affected by ozone but antioxidant activity was reduced in green chilli peppers exposed to ozone at 2 $\mu mol\ mol^{-1}$, due to lower ascorbic acid content in those samples. Ozone at 0.9 $\mu mol\ mol^{-1}$ 1 extended the shelf-life of chilli peppers.

Fresh-cut papaya was treated with ozone (9.2 ± 0.2 l/L) at 10, 20 and 30 min to investigate its effect on phytochemicals and microbial load. Following a 20 min ozone treatment, the total phenolic content of fresh-cut papaya increased by 10.3% while the ascorbic acid content decreased by 2.3% compared to that of untreated control fruit (Yeoh et al., 2014).

Ozone, as a potential oxidant, is applied in various treatments including water treatment and equipment disinfection, as well as for the preservation of perishable items, namely fruits, vegetables, and meat (Seydim et al., 2004; Karaca and Velioglu, 2007;Priyanka et al., 2014).Ozone treatment was shown to be a promising technique for enhancing the antioxidant capacity of some fresh fruits such as banana, but at the same time a reduction in vitamin C content was also observed (Alothman et al., 2010).Minas et al. (2012) demonstrated that the ozone treatment resulted in blocked ethylene production, delayed ripening, and stimulated antioxidant and antiradical activities of the fruit. The ripening induced carboxylation of kiwifruit protein, but it was reduced by ozone treatment, leading to improved postharvest behaviour.

Tiwari et al. (2009) demonstrated that ozone treatment (7.8% w/w, 10 min) resulted in significant reductions in anthocyanin content and ascorbic acid of the order of 98.2% and 85.8%, respectively in strawberries.

Ozone is an innovative athermal mode of disinfection with potential applications in the modern food industry. It is a safe way to oxidize contaminants while leaving no residues and without affecting the quality of food.

MICROWAVE TREATMENT (MW)

Microwaves are electromagnetic radiation with wavelengths from 1 mm to 1 m in length and with frequencies from about 300 MHz to 300 GHz (Scaman et al., 2014).

Microwave heating differs from conventional heating due to the fact that the microwave heating occurs via direct microwave material interaction, while the conventional heating requires the heat to be transferred from the external heat sources. Microwave causes the polarized or charged molecules to rotate back and forth in order to align to the periodically changing direction of the alternating electric field. The rotation leads to the inevitable frictions between the molecules and that causes volumetric heat generation within the material (Bhattacharya and TanmayBasak, 2017).

Microwave cooking is recommended for lentil preparation, not only for improving nutritional quality, but also for reducing cooking time (Hefnawy, 2011).

Carew et al. (2013) studied the microwave macerated must and assessed wine phenolic after two different hold times in a 70 °C water bath (1 and 8 h). As regards total phenolics and total and pigmented tannin, both long and short time wine was equivalent to control; conversely, for mean concentration of total pigment, free anthocyanin, and colour density, only the short hold time wine was significantly lower than control. Also, MW treatment has the possibility to eliminate laccase and better manage phenolic outcomes with evident benefit for the wine industry (Clodoveo et al., 2016).

The influence of simultaneous combination of microwave and steam cooking on contents of specific phytochemicals, carbohydrate and antioxidant activity of purple sweet potatoes (PSPs) was investigated by Xu et al. (2016) and compared to those of individual steaming and microwaving. Results showed that the contents of phytochemicals including total phenolics, flavonoids and anthocyanins and phenolic acids except caffeic acid increased after cooking to different extent depending on cooking methods. The PSPs cooked by simultaneous combination of microwave (500 W) and steam (1700 W) for 12 min (M500-S1700-12) contained the highest of total phenolics, flavonoids, phenolic acids and anthocyanins. Simultaneous combination of microwave and steaming resulted in higher content of soluble sugar in PSPs. PSPs cooked by M500-S1700-12 showed the highest antioxidant activity, which was well accordance with higher contents of phytochemicals.

In a study, Conte et al. (2017) demonstrated that microwave treatment on honeybee had a damaging action on antioxidant compounds (i.e. reduction in the content of tocopherols).

Microwave-pretreated samples of pomelo retained higher amounts of pectin, naringin, and limonin compared with non-pretreated samples. No obvious change in the degree of pectin esterification was observed. Microwave pre-treatment process is a promising methodology for both preserving valuable compounds in pomeloflavedo during storage and acquiring essential oils (Liu et al., 2017).

Jouquand et al. (2015) showed in a study that beef burgundy cooked by microwave has the level of CML (carboxymethyllysine) product similar to that measured after traditional cooking. However, lysine degradation was more pronounced when traditional cooking was used compared to optimized microwave.

RADIOFREQUENCY TREATMENT

Radio frequency is another technique of dielectric heating that is quite similar to the principles of microwave technology. Heat is generated inside the product, resulting from the polarization of molecules and migration of ions that occurs at high frequency (Wang et al., 2003). The advantage of radio frequency over microwave energy is that penetration depth is deeper due to the frequency. The selected frequencies for industrial, domestic, scientific, and medical applications are 13.56, 27.12, and 40.68MHz (Awuah et al., 2005; Barbosa-Canovas and Bermudez-Aguirre, 2010).

A study by Orsat et al. (2001) was conducted to develop a processing method for the RF treatment of fresh-like carrot sticks to reduce their microbial load and their enzymatic activity while ensuring their quality.Results showed that when compared with chlorinated water dipping and hot water dipping, RF-treated carrot sticks had better quality in terms of colour and taste.

Schuster-Gajzágó et al. (2006) exposed white mustard seed to RF with the intention of inactivating the endogenous enzyme myrosinase which was responsible for the development of pungent sharp flavour. In addition, these workers also assessed the impact of RF on compounds with health beneficial effects found in these seeds. They found RF could effectively inactivate myrosinase to a sufficient level to inhibit pungent flavour development while causing no damage to compounds of nutritional significance.

An atmospheric RF plasma treatment (20W and 40W) was used to improve the yield, expansion volume, and content of essential amino acids in the popped rice. The effects of atmospheric RF plasma treatment on the surfaces of popped rice were examined using a microscope. The results demonstrated that the percent yield (42.2 ± 6.6%) and expansion volume (2.53 ± 0.72 ml g^{-1}) of popped rice when using an electric frying pan were approximately 4 times higher than those observed when using a kitchen oven and approximately 3 times higher than those observed when using a microwave oven. However, the crude protein and elemental composition (P, K,Mg, Ca, Zn, Na,Mn, and Fe) of popped rice using a direct heat from an electric frying pan were found to be significantly lower than obtained using other methods. Atmospheric (RF) plasma at 40W could improve the quality of popped rice when it is popped in an electric frying pan. Higher percent yield (53.2±1.6%), expansion volume (3.59±0.06ml g−1), and essential amino acid content (5 mg amino acid g^{-1}protein of arginine, leucine, phenylalanine, threonine, and lysine) in the popped rice were observed after plasma treatment.

This research suggests that a combination of an electric frying pan and atmospheric RF plasma is highly effective for increasing the producing of popped rice (Puangjinda et al., 2016).

Nonetheless, the industrial potential of RF processing is interesting with its greater penetration depth than MW with well-designed applicators and heating/drying applications. The potential of RF is even greater when used in hybrid systems that take the volumetric heating advantages of dielectric heating and couple them with conventional processing for efficient, rapid, and high quality results (Orsat and Raghavan, 2014).

CONCLUSIONS

In today's food market, consumers want healthy, biologically grown, preservative-free, high-quality produce.

Freezing, sterilizing, drying, refrigeration, and distribution of fresh product are used to replace the use of preservatives. Pasteurization can solve some shelf-life problems if a producer can distribute a refrigerated product. On the other hand, sterilization can offer greater shelf stability to foods. In some applications, dielectric sterilization can deliver quality products because the electromagnetic waves are able to heat the product 3-5 times faster than conventional sterilization systems. The sterilized product is not temperature abused; therefore, the food has better overall quality attributes than that processed by other available technologies (Orsat and Raghavan, 2014).

The conventional processing of products often requires a long heating time and those results in the degradation of food qualities, texture and nutritional values (Bhattacharya and Basak, 2017).

The unconventional treatments have been found to upgrade the processing by preserving the quality, texture and nutritional values.

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