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High Pressure Processing: A Novel Approach to Preserve Fresh and Value Added Meat and Meat Products.

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ABSTRACT

High pressure processing (HPP) is a non-thermal, chemical free, convenient and novel technique that reduces the nutritional losses, provides safe, fresh color, appealing aroma and natural flavor to the end product of meat. It also preserves the organoleptic properties, kills vegetative & spore form of microbes and inactivate enzymes in meat products. The synergistic effects of pressure with low temperature (HPLT), low pH, pulse electric field (PEF) and with CO_2 combination are prime parameters to achieve the characters. HPP also induces changes on quality parameters like protein and lipid oxidation which have effect on product's shelf life. The current review article summarize the effective role of HPP in meat based products regarding improving the shelf life, sensorial attributes, and inactivation of microbes.
Keywords: HPP, meat products, enzymes, innovative technique

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INTRODUCTION

Consumers are becoming more aware of the use like fresh, minimal-processed, convenient and healthy-oriented food products with natural flavor, taste, aroma and long shelf life. In the last decade without compromising safety, there are multiples another non-thermal preservation techniques such as irradiation, high pressure processing (HPP), natural bio-preservatives, light pulses, and active packaging (Aymerich et al., 2000).

Meat is a flesh and edible part of animals which is used source of nutrition for growth and development of the body. Vacuum-packed meat from the processed animal and fresh meat without applying any treatment other than chilling is ensured the preservation. There are several processes which are used to preserve the meat through inhibiting microbial spoilage, but minimizing other deteriorative changes i.e. oxidative changes and color (Aymerich et al., 2008).

A number of factors are used to determine the quality of the meat preservation, air including oxygen (O_2), temperature, humidity, endogenous enzymes, microorganisms and light (Faustmann, et al., 1990). These factors can cause the detrimental changes in the odour, colour, flavor, and texture of meat (Zhou et al., 2010). High hydrostatic pressure (HHP), a natural anti-microbial compounds, new systems of packaging (such as active packaging (AP), modified atmosphere packaging (MAP) and bio-preservation are the most investigated new non-thermal inactivation fresh meat preservation technologies. These alternative technologies are energy saving, soft, guarantee natural appearance, an environmentally friendly while inactivating spoilage micro-organisms (Zhou et al., 2010).

HPP is one of the minimal processing food preservation technology among all thermal (radiofrequency, ohmic heating, microwave) and non-thermal (ultrasound, pulsed-electric fields) technologies (Bermudez-Aguirre and Barbosa-Cánovas, 2011). Prior to these food processing technology, and more concerned about the health and safety specifications, they can be applied in the food industry (Ghasemkhani et al., 2014). In HPP, sealed food commodity is placed into an enclosed and insulated container with y transferring water medium along with an ultra-high pressure of 100- 600 MPa to process the food (Hsiao et al., 2014).

Over the past few decades, the level of operating pressure is from about 300-400 MPa and 800 MPa and holding time increases from 15 to 30 minutes to 5 minutes or less (Bermudez-Aguirre and Barbosa-Cánovas, 2011). HPP deals with the consumer's needs for organoleptic properties and for nutrition by improving the texture and flavor of emulsion-type products (Cofrades et al., 2013). The primary objective of HPP is to enhance the shelf-life of ready-to-eat (RTE) meat products due to its unique, post-packaging, non-thermal and safe technology in meat industry (Ikeuchi, 2011). Bajovic, et al. (2012) determined that meat can be tenderized by applying pressure in form of hydrodynamic pressure that induce mechanical tissue decay. This non-thermal technology is mainly depending on temperature, pressure, processing time, product type, aW, pH, antimicrobials presence and salts content (Rendueles et al., 2011).

There are different combinations for the effective preservation like combining the HP with pH, pulsed electric fields, CO_2 and high pressure with low temperatures (HPLT) and also provide an opportunity in food application like freezing supported by pressure, defrosting and storage below zero. In the development and optimization of HPLT process, much work has been carried out and the food industry has many benefits with the transition of phase in water. There was increase in the deactivation of bacterial spores with the combination of HP and thermal processes (Norton et al., 2008).

History of high pressure technique

High pressure processing (HPP) has been used to preserve food via using high pressure, texture, maintain the vit's, and nutritional value, and taste unlike traditional pasteurization process which requires heat. HPP is also mentioned to as high hydrostatic pressure, ultra-high pressure processing. After Blaise Pascal, pazcalization was who first explored the HPP technique. Pascal start testing HPP on bacteria in the 1890's, was getting further experimentation. At West Virginia University Agricultural Experimental Station Bert Hite was a scientist, adopted this research and Hite came to know that HPP could destroy harmful microorganisms in foods. In the early 1900's a study by W. P. Larsen established that HPP continuously killed vegetative bacteria found in foods. As supporting research continued into the 20th century, requirement and availability of HPP food increases on a larger scale due to advanced machinery and technology. Japan was the first place to commercially market HPP foods which includes fruit juices, tenderized meats, fruit toppings, salad dressings, jams and yogurt. This emerging technology added to the first commercial success for HPP food on the U.S. market. During the early 21st century further experimentation established that shellfish may be separated with ease from their shells by using HPP. Since 2000, various food products processed with HPP have become available in the U.S., includes fruit juices, meat, smoothies, and poultry. The demand for natural, less processed food increases and fuels the invention for high pressure processing of foods as the healthy alternative to food preservation.

Engineering Concepts behind the HPP

The principle behind the HPP is that when HP is applied on foods, it follows the isostatic rule and it does not depend on the size and shape of the food. The isostatic rule states that the pressure is uniformly distributed throughout the food. Means that it doesn’t matter that food has direct contact or food is in the airtight packaging material. Therefore, the time doesn’t depends upon the size of sample unlike in thermal processing (Rastogi et al. 2007).

The Le Chatelier’s principle is involved in the regulation of effect of HP on food microbiology and chemistry. This principle states that when there is an interruption in the system at equilibrium, then with the reaction, the interruption will be minimized by the system (Pauling, 1988). In other words, some physical processes like chemical reaction, transition in phase etc started by the HP that leads to volume decrease but there is increase in volume in opposite reaction. This principle also regulates the pressure on protein stabilization i.e. the negative changes in volume occur due to increase in pressure that leads to bond formation due to change in equilibrium.

Apart from this, there is increased in the cracking of ions by HP that leads to decrease in volume due to water electrostriction. Due to high pressure, much hydrogen bonds are stabilized that leads to decrease in volume without affecting the covalent bonds. So large molecules, proteins, enzymes and cell membranes are ruptured by the HP without affecting the small molecules like vitamins and flavoring compounds (Linton and Patterson, 2000).

The temperature induced by the HPP rises in the vessel of HP due to work of compression. This is called adiabatic heating. There is difference in the value of high temperature in medium carrying pressure and in the food because they depends on the composition of food rather than pressure and processing temperature (Otero et al., 2007a). The adiabatic heating in food sterilization can be as a source of heating without thermal gradients (Toepfl et al., 2006). Now a days the engineering concepts of HPP is very famous worldwide.

HPP on quality attributes of meat and meat products

HPP have impacts on the quality attributes of muscle foods. There are some latest comprehensive reviews on the impact of HHP on the quality attributes of the meat (Sun and Holley, 2010; Simonin et al., 2012; Buckow et al., 2013). These reviews focus specially on the textural changes due to meat proteins, i.e., enzymes and myofibrillar proteins, the most effective components of muscle system. HPP counting on the temperature, exposure time and magnitude of pressure alter the texture of the meats by tenderizing or toughening (Sun and Holley, 2010).

HPP on the inactivation of microorganisms

HPP technology to improve microbial safety and extends the food products shelf life by inactivating microorganisms. This treatment has been accepted as a novel technique to eliminate the *Listeria monocytogenes* in processed meat products (Fonberg-Broczek et al., 2005). It also effective to inactivate the *Salmonella, Vibrio* and *E. coli* along with many bacteria, yeasts and molds which are responsible for deterioration in many food commodities (Hayman et al., 2004; He et al., 2002).

The main purpose is to use HPP of products of meats, to improve the microbiological safety. Effect of high pressure on microorganisms to be fully understood and accepted. The pressure control level (10-50 MPa) to reduce the rate of growth and reproduction, and microbial inactivation by a higher level of pressure to obtain (Rademacher, 2006). Changes in the permeability of cell membrane still effected by the crystallized fatty acids from phospholipids. Assigned by the cell membrane phospholipid bilayer upward and phase transition pressure, the result of the film becomes unstable and adversely affect the permeability (Bajovic et al., 2012). Furthermore, Inactivation may have a membrane bound protein denaturation impact dissipation connection. Metabolic actions in biological systems by inactivating the enzyme system of high pressure is not completely collapse. Protein denaturation depends on external factors such as salt content, water activity and pH. Like sugars and other ingredients present. In addition to product parameters and processing conditions:

The most valued feature of HPP is that it leads to microbial death, thereby conducting towards advancement in the general quality of foods. E.g., HPP has a good ability to pasteurize food to test the paralytic disease caused by microbial species, such as *Salmonella spp*. or *Escherichia coli O157:H7*, does not change the natural properties of the product (Balasubramaniam et al., 2008).

In HHP treatments, the combination of two technologies temperature is a very vital environmental factor can be increased in a short time importantly microbial inactivation. HHP has ensured to be an effective technology for pathogenic inactivating (Jofré et al., 2008).

Treatment of 600 MPa for 6 minutes at 31°C and effective action to reduce about close to 3.5 decimal log for *E. coli, Listeria monocytogenes, Yersinia enterocolitica, Campylobacter jejuni* and *Salmonella enterica* subsp. *enterica*, in meat products. However, spores are generally very resistant to high pressure (Simonin et al., 2012).

Cell viability at high pressure can be limited by ribosomal dissociation. Involving the mode of action of pressure, 50 MPa pressure can inhibit protein synthesis and cause a reduction in the microbial ribosomes amount (Huang et al., 2014). 100 MPa pressure can cause the denaturalization of cell's protein, if pressure increased to 200 MPa, resulting external destruction in the cell membrane and internal destruction in the microbial structure. Pressure at 300 MPa cause permanent damage to the microbes, which includes discharge of intracellular constituents to the close medium and in result it cause cellular death.

Several phenomena occur in a microorganism depends on their physiological state, in HHP microorganisms more conscious in log phase than stationary phase. This phenomenon could be justified by the reason that in the log cellular division of microbes occur and the membrane is more sensitive to environmental conditions (Ayvaz et al., 2012).

The reaction of microorganisms to HHP has been widely studied according to the some factors, the most sensitive microorganisms are molds and yeasts. Gram-negative bacteria are more sensitive, whereas most resistant among all vegetative cells are Gram-positive bacteria and their spores require very high pressure to be inactivated. Combination of pressure, temperature, cycling processing and time can be used to obtain the complete destruction of spores. In the field of high temperature, generally accepted behavior coordinated pressure and temperature to inactivate vegetative bacteria (Heinz and Buckow, 2010).

The highest pressure bearable capacity for relative quantity of microorganisms is found between 20 and 30 °C. In the situation where lower temperatures are employed the constancy is decreased (Jofré et al., 2010). Resistance of bacteria to high pressure is highly varying even between strains of the same species (Liu et al., 2012).

Action of combined hurdle technologies together with HPP has been intended to increase the microbicide effect of low pressure to minimize the undesirable changes introduced by ultra-high hydrostatic pressures (above 400 MPa) in meat and meat products. HPP can also give Synergistic effects with antimicrobials, low pH, carbon dioxide, vacuum packaging and chilled storage (Garriga and Aymerich, 2009). Furthermore, additive are useful to prevent the sub-lethal cells (Jofré et al., 2010; Liu et al., 2012). However, the parameters of process are necessary to moderate levels, depending on the particular application of the particular test. Shelf-life tests should be carried out on an event basis before the product can be set up to the market. Relatively, modest pressure level (200-300 MPa) is sufficient to kill most food spoilage microorganisms (Porto-Fett et al., 2010).

The previous findings of Kruk et al. (2011) investigated the role of HPP in chicken breast meat against *Salmonella Typhimurium* at different pressure levels (300, 450 and 600 MPa /43,510; 62,265 and 87,020 psi)) for 5 min at refrigeration temperature for two weeks. They observed that instantaneous lethal effect of HPP on *salmonella* improved by enhancing the pressure above 300 MPa (43,510 psi). HPP pressure 450 MPa (62,265 psi) or higher pressures showed approximately 4-log inactivation throughout cold storage. Earlier, (Carlez et al., 1993) determined the maximum pressure resistance of microbial organism inactivation was 15-30ºC. HPP cause many changes morphology, biochemical aspects, cell membranes, and genetic makeup in microbial cell and spores and all these processes are associated with the inactivation of microorganisms. Furthermore, membrane of the cell of the vegetative microorganisms is most probable site of disruption. This pressure technique also alters the functions of the membrane including active transport or passive permeability (Carlez et al., 1994). Obviously, the contact pressure tends to loosen the attachment between the enzyme and the `membrane surface, resulting in a change of the physical state of the lipid controlling enzyme activity. Leakage of intracellular components by the cell membrane permeability is the most direct cause of cell death after the high pressure treatment (Heremans, 2003).

In foods, HPP significantly inactivate the food borne microorganisms i.e. *Escherichia coli O157:H7, Campylobacter jejuni, Salmonella spp,* and *Listeria monocytogenes*. Under pressure, foods can be pasteurized at low or moderate temperatures whereas foods can be sterilized at higher pressure at high temperature can sterilize foods (Juste et al., 2007). HPP has the potential as a phytosanitary treatment to control in fresh or minimally processed fruits and vegetables quarantine pests, in order to prolong its shelf life (Wu et al., 2004). The treatment of HPP at 300, 400, or 500 MPa for 4°C, 0-25 min significantly reduced the uropathogenic E. coli (UPEC) levels in poultry meat and provide safer poultry products for at-risk consumers (Sommers et al., 2016). HPP at 600 MPa, significant change of the texture and visual appearance in the meat, which as HPP at 175 MPa signifies no significant visible change compared to the color and texture of raw meat (Kaur et al., 2016; Huang et al., 2016). The application of HPP (500 and 600MPa) at mild temperature (53°C) can be used for novel food development, providing novel textures and colors (Pingen et al., 2016).

The combined effect of modified potassium chloride with partial salt replacement and HPP (600 MPa at 8°C for 3min) naturally cured ham's quality and shelf life were studied over 12 weeks of storage time period. Curing agent used in restructured hams is Celery powder which had valuable effects on moisture retention, improved binding of restructured hams and water holding; nevertheless, with respect to nitrite consumer acceptability of aftertaste and flavor received significantly lower scores (Pietrasik et al., 2016; Martínez-Onandi et al., 2016). The poultry meat was contaminated with campylobacter jejuni (108 CFU g-1) and packed in a polyamide-polyethylene bags and further treated with different pressures of HPP (200 MPa, 300 MPa and 400 MPa) and time (5 min, 10 min and 15 min). They concluded that as compared to other food-borne pathogens *Campylobacter jejuni* is more sensitive to high pressure processing treatment and *Campylobacter jejuni* viability loss in a dose and time dependent manner increases (Jackowska-Tracz et al., 2015). HPP is used to improve food safety and it is an effective and safe technology via inhibiting Shiga-Toxin producing *Escherichia coli* (STEC) Non-O157:H7 in meat (Hsu et al., 2015).

HPP on meat proteins

HPP cause expansion of the protein structure, folding again after the completion of pressure release. This may cause depend on the specific protein and partially or completely denatured and electrostatic interactions for the regulation of the conditions (Bajovic et al., 2012). It also breakdown the salt bonds because of hydrophobic and electrostriction interactions. Hence, hydrogen bonds changed under pressure and myofibrillar proteins at 300 MPa pressure to unfolded. HPP more than 300 MPa enhanced the denaturation, agglomeration of proteins an gel formation (Sun and Holley, 2010). HPP significant impact on meat are modifications in actin–myosin complex, causes structural modifications (muscle filaments) by applying pressure above 150 MPa (Nishiwaki et al., 1996). A group of peers, Begonya et al. (2014) and (Picouet et al., 2012) determine that HPP induced changes in beef muscle proteome, can affect protein adjustation, cause protein denaturation, and aggregation, respectively.

High Hydrostatic Pressure treatments alter the non-covalent links like ionic, hydrophobic, and hydrogen links of proteins. Impact of HPP on proteins is primarily linked to the separation of Non-covalent intramolecular interactions of protein (Morshedi et al., 2014). That means the secondary, tertiary, and quaternary structures can be unfolded and seperated while the primary structure remains intact (Dzwolak, et al., 2002).

The primary structure of the covalent bond to the protein are believed not to be changed by HPP. Denaturation of proteins induced by pressure is probably to occur due to the dissociation in tertiary structure of non-covalent interactions (Chapleau et al., 2004). When pressurized proteins hold most of their secondary structure, expand a small level, showing the hydrophobic regions of proteins, can lead to protein aggregation (Sikes et al., 2010). It is necessary to uses around 150 MPa pressure, observed in the quaternary structure modification, but also the need to employ more than 200 MPa and substantially modified secondary and tertiary structure (Messens et al., 1997).

Observed protein chart of pressure treated and non-treated meat by applying a two-dimensional electrophoresis. Protein have showed considerable differences between the treatment method by mass spectrometry. More than 200 MPa pressure, it strongly changed bovine LTL proteome and others are major changes in sarcoplasmic protein insolubilisation and myofibrillar proteins solubilisation. Myofibrillar, sarcoplasmic proteins are more sensitive to the effects of HPP. Single protein varies widely associated with protein solubility and WHC, by encouraging further penetration into the mechanical process to define the quality of basic HPP and encourage future improvements on the basis of protein markers to determine the quality of processed meat (Marcos and Maria, 2014). HPP significantly affect the solubility of myofibril protein and solubility of myofibril protein increased up to 400 MPa whilst decreased at more than 600 MPa. Likewise, solubility rate was higher at 35 °C and lower was at 55 °C under all pressure. Turbidity always lowered whereas particle size decreased up to 400 MPa and then increased up to 600 MPa. Similarly, high pressure induced enhancement of α-helix, reduction of β-sheet structures, and random coil and β-turns segments whereas at high temperature these parameters reversed. Additionally, they improve physical-chemical and processing properties of meat at moderate pressure and temperature (Huang et al., 2016; Bièche et al., 2010). HPP (100 pressure levels, 250, and 400 MPa; 8 and 14 MPa/s pressurization rates; pressure holding time 0, 5, 15 and 30 minutes) to the protein concentration in meat. The increase in pressure level and holding time decreased the protein concentration in sarcoplasmic extracts. HPP also leads to lysosomal rupture and degeneration, aggregation, and sarcoplasmic protein fragmentation, and evidence of this may be particularly at 400 MPa of reduced enzyme activity (Teixeira et al., 2013; Bowker et al., 2012; Souza et al., 2012; Bièche et al., 2012). High Pressure Processing (HPP) is higher than 200 MPa induced reduction in protein solubility. It strong modification of meat color and more than 200 MPa at a higher pressure to reduce the water holding capacity (WHC). It significantly modified the composition of the sarcoplasmic protein fraction (Marcos et al., 2010; Yamamoto et al., 2010).

HHP on Enzymes:

There are two important areas of the enzyme, 1 responsible for a distinction between the substrate and other responsible for substrate bonding catalytic reaction. The enzyme functionality can be completely affected by a minimal change in structure. According to the effect of treatment by HPP enzymes can be divided into two groups. The first group consists of enzyme that activated of 100-500 MPa pressure, this activation occurs only in monomeric protein (Huang et al., 2013). The second group comprises a high temperature combined with pressure higher than 500MPa to inactivate the enzyme (Bello et al., 2014).

There are multiples enzymes such as pectin methyl esterase (PME), peroxidase (POD), polyphenol oxidase (PPO) and lipoxygenase (LOX) which are present in food stuffs and deteriorate the quality of the foods (Ludikhuyze, et al., 1998). Both, PPO and POD enzymes are inactivated using HPP more than 400 MPa in combination with temperatures (20-90 °C). By applying these conditions, activity of enzyme can be reduced up to 50% (Bello et al., 2014). The enzymes glutathione peroxidase and superoxide dismutase in dry-cured ham are inactivated at 900 MPa at 12°C for 5 minutes. The treatment of HPP (300MPa) decreased the initial activity of calpain (calcium-activated neutral proteases) and due to an inactivation by a change of structure in a muscle and also prevented from the degradation of muscle tissue during postmortem storage (Chéret et al., 2007).

The purpose of this experiment was to evaluate the high pressure on the participatory role during storage of fish muscle degeneration major proteolytic enzyme. Enzymes extracted from Dicentrarchus labrax sea bass white muscle in sarcoplasmic proteins. Cathepsin B, D, H, L activity and protein extracts were quantified, whereas the activity of calpain evaluated from its endogenous inhibitor after isolation. Up to 500 MPa HPP enhanced cathepsin B, H and L activity, whereas the cathepsin D activity increased to 300 MPa and reduced above 300 MPa. On calpain activity, resulting in reduced activity of the HPP, which is 400 MPa or more is zero. Our recommendations are based on inactivation of the enzyme at the same time, and from the solution of the subunit lysosomal cathepsin and calpain increase from the leading explanation liberation (Chéret et al., 2005).

HPP on lipid oxidation

Meat is high source of trialglycerols and cholesterol-derivative which are associate with oxidation. HPP first to discover the work of the lipid peroxidation effect in the early 1990s, with the corresponding consider this technology as an alternative to thermal sterilization (Rivalain et al., 2010). The lipid oxidation in meat products can be determined by using thio barbituric acid (TBA or TBARS) or peroxide value (POV) tests. The pressure treatment between 300 to 400 MPa produced noticeable changes in meat (Ilce et al., 2014).

Dry cured ham processing 6 minutes at 600 MPa at 12℃, to be produced off-flavor by lipid-derived aldehydes i.e. hexanal nonanal and pentanal (Fuentes et al., 2010). While Clariana et al. (2011) noted that 600 MPa, dry cured ham oxidation stability has not changed. More announced by the lipid oxidation effect on the color of fresh meat than HPP cured meat (Clariana et al., 2011).

HPP introduced by the lipid oxidation mechanism is not completely figured out. Typically, HPP has been proposed by two mechanisms activated lipid oxidation:

The leakage of iron from hem proteins can encourage lipid oxidation. Many studies indicate that the addition of ethylene diamine tetra-acetic acid (EDTA), that is able to chelate metal ions reducing processed meat lipid oxidation by HP's correlation, that shows a metal ion catalyzed conversion is the main reason underlying the increase lipid-oxidation (Bajovic et al., 2012).

From the interaction between membrane damage causes of unsaturated lipids and membrane enzymes and non-heme and heme iron or other metal cations may cause lipid oxidation catalysis. Oxidation is encouraged in turkey meat only if samples are dealt at lower pressure under 400 MPa for 30 min (Medina-Meza, Barnaba, et al, 2014). In beef, low pressure at 200MPa is used to initiates lipid changes. Likewise, yak fat is very sensitive to lipid oxidation, showing a noticeable increase of malondialdehyde at 200 MPa. In this specific fat source, high pressure above 200 MPa leads towards a decrease in the ratio of polyunsaturated/saturated fatty acids and n-6/n-3 PUFA, as well as the amount of docosahexaenoic acid (Wang et al., 2013; Nuora et al., 2015; Bolumar et al., 2014).

In another study conducted by (Kruk et al., 2014) explore the role of HPP (300 or 600 MPa) with combination of 10% (w/w) of olive oil (OO), 10% (w/w) of soy sauce (SS), and a mixture of both 5% olive oil (w/w) (SO) and 5% of soy sauce were pressurized into 100g cut meat pieces. At higher HPP (600 MPa), oleic contents of olive oil were enhanced whereas total unsaturated fatty acids were the highest in soybean and olive oil at 600 MPa. Similarly, HPP with olive oil retarded the lipid oxidation and addition of olive oil and soy sauce lowered volatile basic nitrogen during storage and decreased the population of pathogens. These combinations with HPP also significantly improved the chemical, health, sensory qualities and safety of chicken breast. The earlier findings of Clariana et al. (2011) investigated the effect of different HPP (600 and 900 MPa) on cholesterol oxidation products in vacuum packaged sliced dry-cured ham. They concluded that 600 MPa HPP did not impart any changes in the cholesterol oxidation products whereas higher HPP (900 MPa) significantly enhanced the contents of 7β-hydroxycholesterol, 7α-hydroxycholesterol, α-epoxycholesterol, β-epoxycholesterol, 7-ketocholesterol, and 25-hydroxycholesterol.

HPP on the Sensory Attributes of Meat and Meat Products

The quality, acceptability and safety of food based products are significantly affected by the processing methods. Meat processing is a difficult process that requires a complete balance between processors' and consumers' demands, by establishing real developments in quality and safety at convenient cost, together with environmental stability (Khan et al., 2013).

Since the 1980s, most of the meat is tender research quality traits. We all know, due to changes in the tenderization of fresh meat occurs during the conditioning of the muscles discussed below (the activity of endogenous proteases are main cause) (Simonin, et al., 2012). A swelling of actin-myosin in turkey meat is observed at pressure of up to 300 MPa, which leads to increased swelling and hardness of the meat. Actin-myosin interaction weakens below this pressure and leads to meat tenderization (Scheibenzuber et al., 2002). The level of myofibril fragmentation is increased by, aging with high pressure, the release of α-actinin and because of the dissociation (separation) of myosin filaments (Iwasaki et al., 2006).

During aging, the application of high pressure (150-500 MPa) for 5 min at 8 ◦C can cause structural weakening of separated intramuscular connective tissue (Ichinoseki et al., 2006). On the other side, beef connective proteins do not show any change by pressure (200 MPa) (Fernández-Martín et al., 2000a). HPP causes gelation of muscle protein and produce textural changes due to their gel forming character in meat. Similarly, low HPP with low temperature enhance the rheological and functional properties of meat of turkey (Chan et al., 2011; Sun and Holley 2010).

Fresh meat treated with pre-rigor by HPP was appeared to be very efficient to enhance the tenderness of fresh meat. HPP pre-rigor muscle in front of about 100 MPa and 30°C usually causes muscle significantly shorter (about 35%) and tenderness developed after cooking (Sun and Holley, 2010).

Tenderization is associated with activation of enzymes which are involved in the meat tenderization during aging. From lysosomes an enzyme named cathepsins is released when the muscle is treated at 100 MPa just after animal death, and by the myofibrils they can be absorbed quickly (Kubo et al., 2002). Pressure process in the muscle calpain activity increased pressure to 200 MPa, because the activated protease calpain system due from the sarcoplasmic reticulum Ca2 + release and to suppress the inactivation of calpastatin inhibitor under pressure (Simonin et al., 2012). In meat, tenderization is caused by enzymes which are regulated by pH changes. Normal, pH value, reducing pressure during the process can be revoked, because of changes in the solution of the acid and base dissociation constant (Stippl et al., 2004), and the slight increase of about 0.5 pH units after instantaneous pressure treatment of post-rigor meat pH (Hugas et al., 2002; Sikes et al., 2010).

HPP modify the post-rigor muscles' tenderness at by applying conditions such as 20-30 min at 150-200 MPa and at 60 ◦C with the above mentioned conditions in post-rigor meat, tenderization can be achieved since some protease activation meat aging (Sikes et al., 2010). In previous findings of (Clariana et al., 2012), they observed the effect of high pressure processing (400 MPa and 900 MPa) on the oxidative stability of sliced and vacuum packaged commercial dry-cured ham. The color and sensory changes are noticed in dry-cured ham pressurized at 400 MPa. Despite of this, superoxide dismutase (SOD) and glutathione peroxidase (GSHPx) activities decreased and vitamin E content increased at 900 MPa pressure. Similarly, pressurization at 400 MPa, increased the SOD activity, and increased the instrumental color as well as also modified the hardness, chewiness, saltiness and color intensity.

HPP effects on the color of meat and meat products:

Color is the prime parameter for determination of the quality of fresh meat which is used by consumer during purchasing. Meat color is mainly depend upon the visual properties of the meat's surface and amount of myoglobin. A group of researchers show that HPP produced the forceful changes in fresh meat color, whereas cured meat products changes are mainly depended on water content and water activity (Ferrini et al., 2012). The hind-quarter muscles were treated with different heat treatment (60, 64, 68, 72 or 76°C) for 20min by applying high pressure (200MPa) resulted in higher lightness scores and improved the tenderness at 76°C (Sikes et al., 2014; Canto et al., 2012; Hsu et al., 2010).

Effect of HPP on Raw Meat's Color:

Everyone understood that the definition of a high pressure raw meat color. Pressure above 200 MPa to increase the brightness (L*) was published in the main raw meat color changes (Del Olmo et al., 2010;

Marcos et al., 2010). The increase in L value results in a whitening effect and has been found in beef meat which is exposed at 200 to 600 MPa and 10 ◦C (Marcos et al., 2010). Protein coagulation because the solubility loss of myofibrillar or sarcoplasmic protein which changes the surface and structure characters. Globulin denaturation and heme group displacement. A significant impact on the value of a∗ is a high pressure has also been found in beef muscle.

In a* values increase at less than 300 MPa pressure enzymatic system activation responsible for the reduction in metmyoglobin (Jung et al., 2003). A reduction in the value of a∗ in the above tests also 350 to 400 MPa pressure by Marcos, et al. (2010) For beef, treated at 10 to 30°C. This reduction is connected to the ferrous-myoglobin to ferric-met myoglobin and may promote denaturation of myoglobin ferric species (Wackerbarth et al., 2009).

Effect of HPP on Processed Beef:

The L* and a*-values were best maintained in high pH and high salt reconstituted ham and had no result on ham dried to 50% weight loss (Bak et al., 2012). By applying different HPP (400MPa, 500MPa and 600MPa) with low temperature at 0–5 °C and at room temperature 20 °C inactivated the microorganisms and caused the denaturation of the myofibrillar and sarcoplasmic proteins (Szerman et al., 2011).

Commonly, the negative effect of HPP on meat products and fresh meat depends on different parameters, which are yet not fully understood. HPP introduced the overall color change according to change in the amount of myoglobin, and is even more impressive for the products of fresh red meat than white meat and cured meat. HPP can be optimized processing parameters to reduce unnecessary changes such as temperature, pressure, increase pH, oxygen removal and curing time (Bajovic et al., 2012).

The color of raw meat is more effected by pressure than cured meat color. For example, in dry-cured ham a decrease in redness was observed above 200 MPa (Cava et al., 2009). In order to prevent change of color in cured products of meat, cooking is recommended before the high pressure treatment. Nitrosyl myoglobin pigment oxidation resistance is likely the reason for the color stability of cured meat products which use nitrites or nitrates (Simonin, et al., 2012).

HPP on Aroma and Flavor

Aromatic compounds in meat processing HPP progress rarely analyzed. 400 to 600 MPa on raw meat in 5°C flavor chart when we open the package, was released volatile compounds and odor sensory judgment results in 15 minutes by evaluating the HPP (Schindler et al., 2010). After 14 days of storage after opening the bag, feeling a skilled team found an unpleasant odor of raw beef are untreated, which is characteristic of microbial spoilage. However, during the re-processing of beef and HPP weak odor typical of each type of meat taste sensing initiated orthonasal. Pressure is found to be below 600 MPa vacuum-packed beef does not cause noticeable changes in the raw aroma chart of either meat type during 14 d of chilled storage in comparison with fresh untreated meat.

Improving the meat flavor is also connected to the presence of amino acids and peptides, the reaction may be in the cooking process and the formation of aroma compounds Maillard. 20°C for 10-minute amount of the high pressure from 300 to 400 MPa, was found to reduce the cut Maillard reaction meat from drying and curing of volatile compounds (Simonin et al., 2012). 10 minutes at 25◦C, the pressure between 100 and 300 MPa resulted self-destructive activity of raw meat that produces the higher amount of free amino acids.

In dry-cured loins, high pressure in the reservoir (300-400 MPa at 20◦C for 10 minutes) can stabilize the free amino acid content, due to the decreased activity of aminopeptidase. High-pressure treatments (200 to 400 MPa at ambient temperature) is not limited changes in the meat flavor (peptides, nucleotides and the amount of amino acids) stored in chilled condition after seven days (Suzuki et al., 1994).

CONCLUSION

HPP is a unique, novel and innovative technique for the preservation of meat and meat products. This technique mainly depends upon the several factors such as conventional process like temperature, PH, and time. HPP inactivate the micro-organisms through cell membrane destruction, ribosomal denaturation, protein denaturation, and crystallization of fatty acid. HPP also effect on colour quality of meat by changing myoglobin pigment. Tenderization of meat is also its quality attribute which depends on actin-myosin interaction, activation of some enzymes, pre rigor and post rigor treatments and it also effected by HPP. Lipid oxidation also occurs due to the presence of lipid derivatives aldehydes when meat is treated at 600 MPa for 6 min at 12 °C. Spore form of bacteria's could not be killed at lower pressure and temperature and for their killing temperature needs to be high which causes loss of nutritional as well as sensory properties of meat. Conclusively, HPP improves the quality, nutritional and sensory characters of meat.

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