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High Pressure Processing A Novel Food Processing Technique: Food Industrial Applications.

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ABSTRACT

With an ever increasing consumer demand towards healthy, real ingredients, fresh and minimally processed food. High-Pressure Processing plays an important role these days as due to its nature of not disturbing what is present in the product naturally. Over the period of time, this technique has gained a lot of prominence at commercial scale because it results in the destruction of microorganisms and stabilizes the product without affecting the sensory attributes and nutritional values. Hence it is considered as a potential substitute for the conventional heat treatments in which the nutritional values and quality attributes are compromised during the processing. This technology offers a good potential and is being applied to the processing of vegetables and fruits to preserve their sensory and quality parameters which are severely compromised in traditional heat treatment process.

Keywords: High-pressure processing, Non-thermal process, Microorganism destruction, Nutritional retention, Fruit and vegetable novel products

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INTRODUCTION

High-pressure processing (HPP) technique is a novel and alternative method used now a day in the pasteurization of many food products due to its non-thermal benefits over thermal processes nature. Its treatment could result in the destruction of microorganism due to which the product gets more stable in shelf for a longer period of time and the sensory attributes are preserved. In contrast to the conventional methods of heating food, which affect the nutritional attributes of fruits and vegetables, this technology offers more potential for their processing in food industry[1].Ultra-High Pressure processing (UHP) also regarded as High-Pressure Processing (HPP) or High Hydrostatic Pressure (HHP) could be used for solid or liquid foods packaged or naked in pressure ranges between 100to 800MPa. The temperature range could be set depending upon the nature of product lower than 0°C or more than 100°C. The experimental containers are designed in such a way that they could easily withstand the temperature and pressure ranges for repeatable usage. The exposure time used at industrial scale could vary from few seconds pulse to over 20 min, however with taken the cost factor into consideration normally; the pulse time at once is less than 20 min. The covalent bonds in foods have been reported to have a very little effect of applied pressure on them. To achieve better results of inactivation, in some cases, high pressure and heat are applied in combination to the product, and the chemical changes in food greatly depends on the process time and exposure temperature[2, 3]. Spoilage and pathogenic microorganism could be inactivated at refrigerating, normal or at slight heating temperatures by using Ultra High Pressure (UHP) or HPP technique and the effects of processing conditions on various organoleptic properties of foods such as color, taste, texture and nutritional values are very little if compared with those heating application methods conventionally currently used.[4-6]. Despite the fact that this technology has been introduced in food industry for sometimes, it has become more popular in the upcoming food trend and is widely accepted among the consumers due to its benefits that match their demands of fresh, nutritious, good organoleptic properties with no preservative. One of the reasons is because High-Pressure Processing inactivates the enzymes and microorganisms as well without disturbing the molecules of smaller size such as vitamins and the nutrient value of product after treatment almost remains intact[7]. Heat liable emulsions could be treated using pressures as it would not disturb its stability[8].The main idea of writing this review was that a lot of scientific work has been on specific portions of this technology but a room was present for an overview which touches the major properties and application of this novel food processing technology

Historical perspectives of HPP technique:

In 1985, Herger was the first person who reported the killing of Microorganisms using pressure but for food science perspective B.Hite work is considered to be the opening in which he practically demonstrated the work by experimenting the high pressure processing technique on fresh unprocessed milk and meat in outcomes he noted that the wholesomeness of fresh milk could be extended to as many as 4 days at pressure application of 600MPa for 60min at normal temperature of room moreover he also stated that for 1 day the souring could also be overdue if a pressure of 200MPa could be applied on it all this work was published in 1899,June. He kept on working with his coworkers and found that if fruits are also treated with this technology the shelf-life could be increased many folds such as he demonstrated practically that if a pressure within a range of 400-820MPa is applied afterward processing on than they could remain shelf stable for as long as 5 years. In the end, he also applied this HPP technique on viruses he treated the tobacco mosaic virus (TMV) at an elevated pressure of more than 930MPa but inactivation of the virus was not consistent. [9-11]

Working principle of High-Pressure Processing:

''Le-Chatelier'' principle and ''Isostatic pressure'' phenomena are basically the two principles on which the HPP working relies on. The first principle states that if the equilibrium of a system is disturbed by any means such as applying pressure, changing the temperature or altering the concentration of components of the medium. The system would result to go back to its original equilibrium position so that the effect of applied stress could be nullified. While the second principle clarifies that if pressure is applied on an object it is distributed equally and instantaneously regardless of the size and geometry of that object.

The process of HPP:

It is also known as the cold pasteurization in which the product is hosted by a closed vessel which is then exposed to high isostatic pressure the medium used normally for the transportation of pressure is water. The

exposure time could be from few seconds to minutes depending upon the product type and the pressure range is kept normally between 200 to 1000MPa. The bacteria, moulds, yeast and viruses along with other parasites in food get inactivated at a pressure of more than 400MPa at low or normal temperatures ultimately the shelf life of the product gets prolonged[12]. Basically, this processing technique consists of four steps.First of all, the product is loaded in a pressure vessel than pre-filling takes place shadowed by pressurizing to the desired extent normally using water after the required pressure is attained then the vessel is held for required period of time after which the last step starts in which the pressure is released and the product is finally offloaded

Critical parameters of high-pressure processing:

Microorganism type age and conditions:

As discussed above that normally Gram (+) bacteria is more resistant to pressure than the Gram (-) class although many exceptions are also reported but it still remains a generally acceptable theory, more developed form more delicate against pressure. Normally at log phase microorganisms are more sensitive to pressure as compared to in stationary phase. Partial inactivation of microorganisms by pressure may result in a sub-lethal injury that is recoverable when optimum growth conditions are found again.

Food composition, water activity, and pH role:

Acidic pH increases the inactivation due to pressure and low activity of water will give a cushion against pressure. Due to the activity of pressure compression in food takes place as a result of which shift in pH may also take place. It was proven in a research by[13]that apple juice pH lower by 0.5 units/ 100MPa pressure increase hence it is necessary to determine the track and intensity of pH shift for every food treatment process. When the pH goes towards the acidic side the microorganisms became more susceptible to high-pressure treatment ultimately increase in inactivation takes place. Chances are there that ionic bonds may get disturbed due the activity of pressure as they are pH dependent and also responsible for the proteins folding.

[14]demonstrated that a small reduction in water activity resulted in an increased resistance of microorganisms against pressure hence the inactivation decreased sharply. Decreasing the water activity seems to help the microorganisms against inactivation due to high pressure. But on the other side we could say that the microorganisms would be injured to a sub-lethal level and if the water activity is on the lower side they are not going to get the favorable conditions for growth. Hence it is hard to determine the overall effect of water activity. As compared to microbiological Medias or buffers normally, foods are considered to be more supportive for microorganisms against the pressure effect.

Holding and compression time, pressure and temperature range:

If all the parameters are increased such as pressure, temperature and time it will result in the more inactivation of microorganisms. In several scientific findings, it's been proven that if the temperature of food during the high-pressure treatment is amplified above the room temperature or lessened below the room temperature it would favor in the microbe's inactivation. At 45 - 50^{o}C range of temperature the rate of food spoilage and pathogens inactivation increases. Spore formers such asC.botulinumgets inactivated at a temperature range of 90 to 110^{o}C with a pressure range of 500 to 700MPa. If we have to increase the temperature during the high-pressure treatment than it is important to ensure that every part of the food must have a temperature that is above the D-value. For this periodic monitoring of food would be required.

There is the lowest level of pressure below which if pressure is applied then no inactivation would take place regardless of the fact that for how long it is subjected to that pressure. Important aspects of the high-pressure treatment which need to be remembered are that the time taken to gain the specific required temperature, the time required to release the pressure and the fluctuations in temperature which may come due to the compression in the volume of the food. These are also important factors for the development of process because if it would take too long in attaining the required temperature obviously it will add cost in the operations and also a time of the overall process would also increase and they also have an effect on the inactivation of microorganisms. Per100MPa the increase in temperature due to compression could be 3^{o}C or in some cases more than this. Hence these parameters are needed to be optimized very carefully

Response of microorganism's onHPP treatment:

Normally it is considered that those microorganisms which could tolerate high temperatures also remain unaffected at high pressures, but many exceptions are also reported. It's been testified that pressure conditions ranging between 200 to 300MPa are enough to inactivate eukaryotes such as moulds and yeast[15]. At a pressure of 400MPa moulds and yeast spores could be easily deactivated. Only Byssochlamys (ascospores) are found resistant to both heat and pressure[16]. At 700MPa for 15 `min with a temperature of 70°C was found enough to cut down the ascospores by a value of more than 10^3.

While the story for bacterial spores as compared to the spores of moulds and yeast is quite different because they could withstand the pressures of more than 1000MPa. In meat and carrot broth the sporesof Clostridium supergenes requires a pressure treatment of more than 1000MPa for the inactivation[17]. Gram-positive bacteria are more resistant to high pressure because of the fact that they have a very thick layer of peptidoglycan which contributes more than 90% of it hence making cell more resistant to high-pressure conditions[18]Normally it is considered that Gram(+) bacteria could withstand more pressure and heat as compared to Gram(-) but it was found remarkable that. Senftenbergwhich is very well known to be heat resistant was not pressure resistant. Than mutants came into the game having the capacity to tolerate the pressure of 750MPa for about 15min but interestingly they were not found resistant at high temperatures. The notorious strain ofE.Coli(0157:H7)was found resistant to high pressure but not much is known about its resistance to heat[19].C. perfringens type A is a food borne pathogen associated both with poultry and meat consumption and considered to be ranked 3rd in the list of most common illnesses found in food[20]. The spores of this notorious strain are very much pressure resistant and have found that even a pressure in the range of 100-200MPa can't even have any considerable effect on their germination.[21] developed an approach to trigger the germination of spores and then using the high-pressure technique to inactivate the bacteria the main steps of this approach were: (1) heat the meat product at 80^{o}C for 10 minutes to activate the spores. (2) cooling at 55^{o}C, 20 min and then incubate at the same temperature for just 15 minutes to let the spores germinate (3) and finally when they germinate apply the high pressure along with temperature to inactive them (pressure 586MPa, time 10 min and temperature 73^{o}C. The authors recommended the use of KCL and L-asparagines for efficient spores' germination[22].[23]concluded that saline solution has the capacity to inhibit the spores of C. gloeosporioides at a pressure of 350MPA for about 30 minutes and if this technique is used in combination with 75ppm of lemon grass or citral essential oil the same results could be achieved by applying only a pressure of 150MPA. He further found that use of essential oils in combination with the high-pressure processing increases its effect on microbes and reduces the pressure, time combination also or we could say that both have synergistic effects on each other.[24] while using the high-pressure processing on meat found that Listeria, Campylobacter and Salmonella could be easily inactivated by 200MPA for just 20 minutes at 20^{o}C and also a very low CFU 3.6 log/ g of meat sample was an indication that meat quality is in good hygienic condition.

Coming on Viruses they are very versatile in nature due to which their resistance against pressure also differs a lot. High pressure may cause damage to the envelope of viruses as a result of which they lose their binding ability with the cells or in some cases complete virus particles separation may take place which could go either waysuch as fully irreversible or reversible separation[25].Poliovirus is considered to be having the maximum resistant against the pressure. HPP denatures the proteins in capsid either in an irreversible or reversible way as it depends on largely how much the pressure is applied. Normally the inactivation of viruses takes place in a non-linear kinetics, by either log-logistic or fitting Waybill models[26]. Apartfrom hepatitis A virus most of time the inactivation takes place at chilling temperatures. The main extrinsic factors which play an important role in the efficiency of high-pressure processing are temperature and the ionic strength which the food matrix have[27] and [28]. In viruses, the resistance against pressure differs a lot even in strains or taxonomic groups related to each other and it could be because of the structure and sequence of proteins difference[27].In the proteins dissociation for viruses, it has been observed that only pressure can't do the separation alone temperature at which the process is being performed also holds a very vital role hence it is not amazing that viruses' stability against pressure depends greatly on temperature of the process also[29]. The pressure application of 300 to 400MPa was found enough to limit the number of bacteriophages which have a protein in nature DNA present in their coat[30]. Those viruses which have a lipid coat present in them, for example, theSindbisvirus could be inactivated completely at 300-700MPa pressure and lowering the temperature to as low as -20°C[19]. So far the microorganism's destruction process of HPP is not been fully revealed but it has some relation to the external and internal factors which affect the cell wall causing cell

death. Hydrogen bridges are first to break with the effect of high-pressure processing which is responsible for keeping the cell membrane held together. As cell membrane is of vital to cell in carrying out certain biochemical activities hence once it is disrupted cell no longer remains more functional [31]

High-pressure mechanism of microbe's destruction:

The effect and ability of HP to pasteurize and sterilize the food is reported by many authors[32, 33]but the exact mechanism of action onmicroorganisms is still not very much clear following predictions are made so far on the destruction mechanism of microorganisms by HP

- HP disturbs the cell mechanism for active transport which is the key player for maintaining the optimum pH conditions in the cell. High pressure could also disrupt the membrane-bounded organelles such as bacterial cell sites and ATPase. Once the essential ATPase gets disturbed the pH drops abruptly in the cell ultimately leading to cell death[12]
- As we know that cell membrane is a partially permeable membrane but when pressure is applied it causes the permeablization of the cell membrane and wall as well hence resulting in the movement of materials in and out of the cell unchecked ultimately leading to the death of the cell. It is believed that cell membrane is the most affected organelle with high pressure in a bacterial cell. [34]

Different types of food response to HPP treatment:

If HPP technique is going to be used specifically to preserve the food than the processor could take advantage from some limited combinations of pressure and time which have proven to be effective in inactivating 10^6/g of pathogens found mainly in food such as the notorious strain 0157:H7 of E.Coli, species of Listeria, Staphylococcus and Salmonella. Those foods having pH in acidic range inactivation takes place even at the room temperature and at refrigeration for low acidic foods. Studies have shown that those foods having a pH value of <4.0 could be well-kept-up at just a pressure of 580MPa with a holding time of not more than 3 minutes. It inactivates same amount and species of microorganisms previously mentioned I-e (10^6) especially in the juice of apple and salsa. A pressure treatment of 580MPa and holding time of 15 minutes was found enough for the commercial sterilization of foods having pH in the range of 4.0 to 4.5. These foods could have a temperature of 22°C at the start with this pressure and exposer time combination but if at the end one has to refrigerate the food than the exposure time could be reduced also. But before the application of HPP at such high pressures one has to keep in mind that at above 200 – 300MPa of pressure changes in the food color and texture may also take place which is one of the major limiting factors in HPP application[35].

Different types of medium and pH role in HPP treatment:

[36]reported that the effectiveness of high-pressure processing also depends on the type of medium being used for the treatment of microorganisms many examples are found in this regard such as it was reported by[37]that salmonella is more prone to high-pressure treatment in a buffer solution than a chicken medium. This is because the resistance comes due to the protection being provided by the medium itself to the bacteria also confirmed this by proving that Listeria Spp. is more vulnerable to high pressure when in phosphate buffer medium as compared to a medium in which milk is used. [38]reported that if the pressure of 500MPa is applied on Listeria Spp. With low pH such as 3.0 or 4.0 in a citrate buffer, it could be as effective as reducing the pollution by seven logs.[39]also reported thatB.coagulansalso became more sensitive to pressure treatment if the pH of the buffer is decreased. But[40]stated that whenE.Coliwas treated with high pressure it showed that presence of oxygen and the oldness of culture has no relation with the pressure resistance but if we decrease the pH also alter the pressure treatment at 44 ^oC the resistance against pressure gets decreased.

High-pressure application in fruits and vegetables:

So far this technology was mainly being used for high-pressure processing of acidic foods (pH <3.5) and also for chilled products. The first presentation on this technique was on heat labile products having some value addition in them. Normally for the pasteurization of foods, the temperature remains less than 45^oC while the pressure may rise as high as 800MPa. These conditions were found to be sufficient to inactivate the vegetative form of pathogens which are frequently found in the food products. In the Western and Asian

markets, there are high-pressure processed products such as juices, yogurt, deli meats, meat, jellies and jam, and now moving significantly to other products as well due to their high commercial demand.[41]

Enzymes inactivation and microbe's destruction are the main motives of using high pressure in vegetables and fruits. By inactivating the enzymes, the shelf life of product is enhanced along with increased quality and the aging process could also be slow down; while from getting rid of microorganisms, the product became more safe and healthy for consumption. One more plus point of using this technology is that it also preserves the natural nutritional and quality aspects of vegetables and fruits, in other words, it does not destroy them and they remain intact during high-pressure processing, unlike other processing techniques[42]

The application of high pressure on fruits and vegetables proved to be favorable for some while unfavorable for others such as,[43]described that when peach was treated under high-pressure conditions it increased the benzaldehyde content in it which resulted in improved flavor of peach juice while on the other hand[44]stated that n-hexanal content increases when juice of tomato was treated with high pressure which is responsible for the unwanted rancid flavor. Strawberry jam retains its freshness including the natural color, flavor and about 95% of vitamin C if high pressure processed at 400 to 600MPa. In a sensory comparison between a thermally processed strawberry jam and high pressure treated strawberry jam the sensory panel preferred the once which was treated with high pressure because it retained most of the freshness it was noted that in storage the changes in flavor and color, however, took place this was due to the residual oxygen and enzyme left behind during the high-pressure treatment hence the authors recommended for chilled storage of products treated with high pressure stated by [45].However,[46]reported that in comparison the quality attributes of jam of strawberry was on higher side right after the pressure processing as compared to the same thermally processed he further added that if pressure processed jam is stored at lower temperature than it could retain its freshness for as long as three months, however, the room temperature storage is not recommended for the pressure processed jam because it results in the inedible flavor formation, loss of color and also the residual enzymes and oxygen also results in the breakdown of vitamin C and sucrose. To overcome this issue[14]stressed on the pressure and temperature treatment in combination.

Consumer trend for HP in food industry:

Almost 3000 consumers of high-pressure products in France, Germany, and UK were interviewed (who were mostly young and educated) to determine the acceptance and perception of high-pressure processing products and the researchers found that this technology was accepted by the majority of people in France and Germany because of two big reasons. 1) The price difference was not much among the high-pressure treated products and those in which conventional methods of heating were used 2) against those typical methods the products which were treated at high-pressure gave them more health benefits because the products were more nutritious and wholesome. Further, the researchers also found that this technology was even more accepted for those consumers who found some more personal health benefits from it and tend to buy those products even if was a bit costly for them [47]. From these findings, it was evident that if the consumer is getting the required health benefits such as free of preservatives and chemicals (which this high-pressure technology has the potential to deliver) they are ready to purchase those products no matter if it is a bit expensive for them. In 2007 [48]collected data to determine among all emerging novel food processing technologies being used in the US which one is more acceptable for consumers the data was collected from 225 potential consumers who were using those products which were processed by using novel processing techniques. The findings, was that high-pressure produced products gave the most satisfying results.[49] in 2011 stated that European consumer also believe that novel technologies like high-pressure and pulse electric field are more respectable alternatives especially for those juices which are simply pasteurized but at the same time cost factor was also important for them as they were not willing to pay extra for these technologies. In conclusion, the author claimed that people recognize and appreciate these technologies if they are rightly educated about the health benefits which these technologies have to offer to them.

Future market predictions for HP:

Due to an increasing research activities and awareness among people about the benefits of high-pressuretechnology, it is estimated that CAGR (Compound Annual Growth Rate) would be 11.26% starting from 2016 and is expected to reach 500.3 Million USD by 2022 [50]. The main driving force behind this increasing demand is due to the consumer preference towards organic food and strictness in food safety

standards. The growth percentage for high-pressure technology is also higher because now the consumer demands for a more nutritious product having natural flavor, taste and aroma and high-pressure processing has shown its potential to do so. Due to the versatility in products treated by high-pressure now the demand for HPP machines is also increasing which is a clear indication that if the number of machines increases it means the overall usage of technology also increases [51]. Because of more suitability with the packing of beverages and packaged food items, this technology is expected to have the higher growth rate for them followed by fruits and vegetables. As the consumption of packaged beverage and food is projected to be increased hence the use of HPP would also increase. In terms of the capacity less than100L vessel is going to dominate the market in future because lesser manpower is required for its operations. In 2015 the small to medium capacity vessels led the market because they were more affordable for small-scale food manufacturers. But in the globalmarket, trend was not the same because this technology was widely welcomed by those large meat processors who want to cut down the use of preservatives in meat so larger vessels segment led 2015 in the global market. When it comes to orientation in 2015 it was led by the horizontal type equipment because of its easy assembling and disassembling and wide application range, especially for vegetables, fruits, juices, and beverages. Vertical type not much popular because it requires a lot of time for loading and unloading the product. From 2016 to 2022 United States was the fastest and biggest growing market for high-pressure processing equipment followed by North America it was mainly because of the reasons that this region has the highest number of high-pressure products exported to other areas and also the adoption rate for novel processing techniques is also very high. The high-pressure processing equipment market it is so far dominated by ''Hyperbaric Espuma'' because of a solid portfolio for high-pressure equipment and now has also established its manufacturing units in many other countries like Estonia, Malaysia, Dominican Republic and India. Some of the other prominent names in this business are Next HPP, Kobe Steel, Ltd., Avure Technologies Inc. [50].

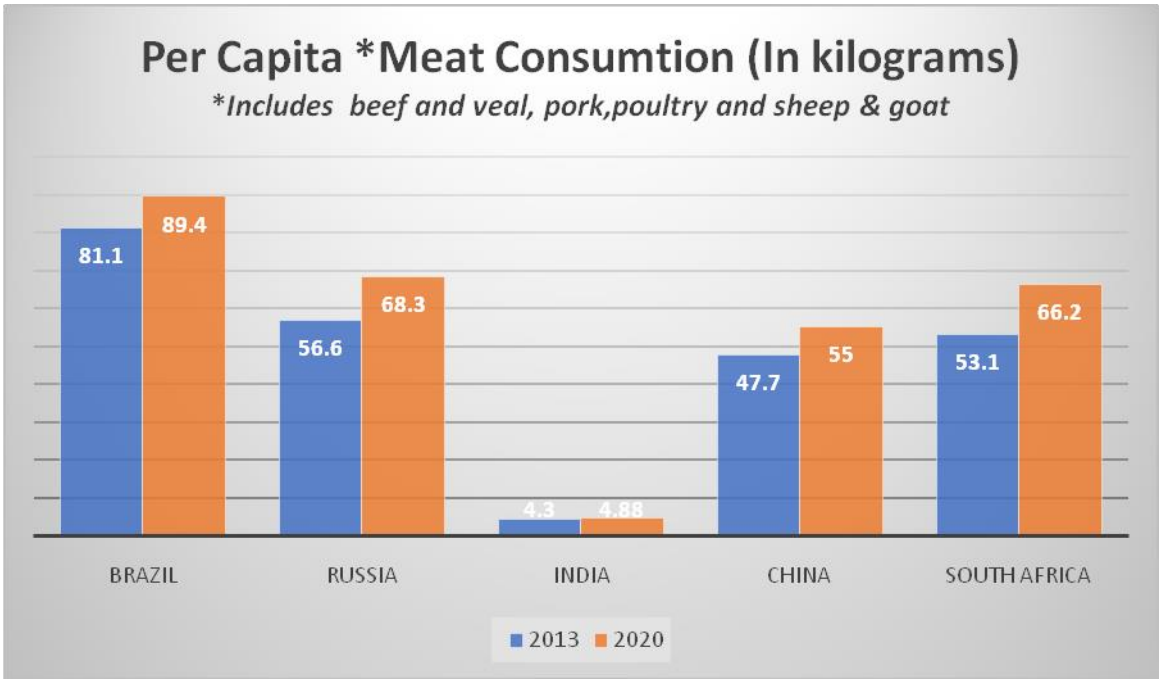

Table 12.1: [51]With an increasing consumption of meat in developing countries more opportunities would arise for the HPP technology usage

Advantages and application of high-pressure in food industry:

High-pressure processing has a lot of benefits to offer but one the promising feature of this technology is that it does not destroys the covalent bonds. The sensory properties of food are largely depending on small molecules such as vitamins, amino acids, flavor and pigments. Covalent bonds are responsible to the stability of these molecules if they are not disturbed it means that the sensory properties of the product are intact. This is the reason for the HPP treated products to retain all their natural wealth. In vegetables and fruit juices this theory is believed widely. Browning in fresh fruits and vegetables and especially in those which are pasteurized

is certainly not desirable high-pressure processing offer this benefit that it suppresses the Maillard reaction due to which this change in color takes place. Due to the application of high pressure proteins gets denatured and loses their all forms of structures such as primary, secondary, tertiary and quaternary which also become one of the reasons for the destruction of microbes. To high pressure may also results in the denaturation of product but [52] in 1989 concluded that pressure induced denatured products are more preferred over those which are denatured during the conventional heating methods because HPP treated denatured products still have original properties intact in them. In thermal processing one of the major concern is that non-uniform transfer of heat may take place and sloughing or scorching in the product may appear but in the application of high pressure the pressure is distributed instantaneously and uniformly as a result of which neither the product nor the package is crumpled furthermore due to this instantaneous and uniform transfer of pressure issues such as sloughing (in vegetables and fruits) and scorching (in liquids) could be easily prevented. High-pressure processing application is done independent of the shape and size of a product while in heat processing these are important factors if the shape and size are not uniform than uneven transfer of heat may take place. Hence uniform pressure transfer irrespective of product structure is also one of the advantages for using this technique. Adding further to the benefits of this technology is that it poses no harm to the environment only electricity is required for its operations to gain the required pressure. Once the required pressure is attained then it could be simply maintained and no further energy would be required in this process. Simply water could be used as a medium for pressure transportation and the benefit would be that during and after pressurization there would be no chances of product contamination, further to increase the efficiency this technology could be easily combined with treatments such as temperature or with supercritical carbon dioxide[53]. Finally, this technique has a lot of benefits proven with the help of substantial scientific studies now it's just matter of adopting this technology in food industries.

Limitations of high-pressure processing:

Pros and cons of every technology exist and same is true in the case of high-pressure processing. Some of its limitations are such as the pressure resistant spores, toxins producing molds and microorganisms which are pathogenic in nature and are also pressure resistant. They could be a serious threat if not addressed properly. But it could be solved by using high pressure and temperature in combination to avoid such conditions to build. It is also being noted that during the high-pressure treatment as it destroys the microorganisms and other unwanted elements from food products at the same time it also inactivates those enzymes which are responsible for the longer shelf life and high quality of food products enzymes such as lipoxygenase, oxidase, peroxidase, pectin-esterase. Normally during the processing of foods standard pressures are used at which the spores remain unaffected and the product get pasteurized only which makes the life easy for the surviving spores as they have no competitors now to deal with. In such situations, threat because of pathogenic spores could not be underestimated [54-56].To maintains the microbiological and sensory characteristics of high-pressure processed foods they should be stored at a refrigerated temperature as most of them are non-sterile.

In such conditions, studies should be conducted to keep a check on the evolution of especially those pathogens which are psychrotrophic. Those cells which were injured sub lethally may recover themselves if they found favorable conditions again[57] and those who could withstand the extremely cold conditions such asL. monocytogenes may also be a threat[58].In many scientific findings now it is being proven that during the high-pressure treatment either completely or till the commercial level inactivates the pectin esterase enzyme. [15]also reported the same results at low pH with pressure and low supercritical carbon dioxide. Sometimes high pressure also causes the damaging effect to the firmness in some vegetables and fruits but this issue could be solved by treatment at high temperature in a combination of supercritical carbon dioxide keeping pressure at the lower side to avoid the damage. The major limiting factor so far for high-pressure processing is still the cost although at industrial scale now equipment's are available for processing of food but still room is present for improvement in the process efficiency and configuration to cut down the cost. Adding more to the cons of this technique is that so far it failed to provide commercially sterile food products which are low in pH because of the spores which remains unaffected if treated at room temperature moreover high-pressure processing may also lead towards changes which include reactions catalyzed by enzymes, polymerization chemical reaction and some modification in the cell structures such as denaturing the proteins, formation of gel and inactivation of enzymes. [59]stated that according to the Le- Chatelier principle when we apply the pressure of about 600MPa for the pasteurization of foods it may inhibit or accelerate the chemical reactions in it and gave an example such as when pressure is applied a reduction in the volume takes place which may lead towards the condensation reaction. So it is evident that by this reaction the quality of the product may or may

not alter just after processing but surely changes would take place during the storage period. [60]stated that in order to get the fruitful results the process parameters for high-pressure processing should be set carefully because oxidation may also take place due to this partial inactivation of enzymes and microorganisms. If compression rate is slow a gel-like material is formed in the case of proteins and precipitation occurs if it is fast. Those foods which have a delicate structure high pressure may cause some structural changes in them like softening and serum loss of cell due to deformation and damage of cell [61]

Future research needs:

Knowledge gaps have been identified in certain areas such as the bacterial toxin inactivation by the high-pressure processing stills requires some more data [62-64].Nowadays allergen city is a major concern especially in the novel foods safety assessment and unfortunately no concert information of high pressure on allergens, nutrients and toxins are available. A room is still present for new studies on the effects of high-pressure on allergenicity in foods [61]. Care should also be given to the presence of those molecules which are lower in weight, such as biotoxins, as they lack secondary, tertiary and quaternary structure which may be resistant to high pressure and chances are there that they may remain in the product even after the HPP treatment because this event has already been reported with other conventional treatments such as heating [64] . HPP causes stress on bacterium which may induce a response known as SOS (a system which repairs the damages in DNA after replication or such errors which allow the replication) which may lead to induce parallel gene transfer of virulence and antibiotic resistance [65, 66]. So far focus on this technology is to be used as a processing technique but still room is present to validate this technology as a preservation technique also.

Furthermore, the areas which still needed to be explored are that the evaluation of interactive effects of variables such as pressure, temperature and time still needs to be done. A proper experimental model is required to investigate the effect of pressure on microbe's reduction (valid statistically the data should be collected at diverse pressure ranges while keeping the product and temperature in control). It would help in quantifying the kinetic parameters. By doing this we could evaluate the critical process parameters against the survival of microorganisms and in this way, we could predict the inactivation of microorganisms.

CONCLUSION

High-pressure processing has the potential to be used as an alternative to the conventionally used processing techniques. Due to its unique nature of minimally disturbing the sensory and nutritional aspects of foods it's getting popular specially in for the processing of delicate products such as fruits and vegetables but at the same time process optimization is also very necessary to get the best results because a very high pressure could be damaging for the product and a very low may not be effective against the microorganisms hence in both the cases the variables needs to be set very precisely, before the processing of a product information about its physiochemical properties would help in designing the process for it. The sensory attributes of high pressure treated products are also more superior when judged in comparison with the thermally processed food items. So this technology is gaining a lot of commercial importance now a day specially for the processing of fruit juices. High pressure processed juices are available in markets of USA and Europe now. High cost may be a limitation currently for the slow growth of high-pressure technology but as the more progress in technology and commercialization of this technology takes place bright chances are present that the cost in future would also come down and as a result of which wholesome, nutritious and safe products would be available for the majority of people at good affordable rates.

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