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HIGH PRESSURE TECHNOLOGY FOR CHEESE PROCESSING- A REVIEW

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ABSTRACT

High Pressure Processing (HPP) has potential to produce a microbiological safe food and to modify the functional properties of proteins, polysaccharides and alter biochemical reactions without significantly affecting the nutritional and sensory properties of food. These features have made the HPP technology, commercially attractive and have drawn the research interests worldwide. Attention in HPP applications on milk and dairy products has recently increased. In cheese manufacturing, the application of HPP technology was initially focused on making cheese from pressure treated milk, microorganism inactivation, reduced rennet coagulation time (RCT) and increased cheese yield. Recently, studies were also conducted on the effect of high pressure (HP) on cheese preservation and ripening. Present paper highlights the research findings of studies conducted on application of HPP in cheese processing.

Key words: Cheese, Cheese processing, High pressure processing

Today consumer demands 'novel foods' that are not only safe and nutritious, but also natural, economic, convenient, delicious, appetizing and much more. The need to meet these objectives necessitates the processors to look beyond the conventional thermal food processing technologies. As a result, numerous non-thermal processing technologies, particularly HP, power ultrasonic, pulsed electric field, hurdle technology, etc., have evolved. Among these, HPP seems the most promising one for food applications. HPP is also referred to as high-hydrostatic pressure processing or ultrahigh-pressure processing in the literature. Regardless of its nomenclature, the technology has been cited as one of the best innovations in food processing in last 50 years.

HPP of foods is carried out by subjecting foods to 100 - 1000 MPa pressure. Temperature during the process may be maintained subzero to more than 100°C and exposure times can be few seconds to over 20 min. The pioneering research in the application of HP to milk dates back to the end of the 19th century (Hite, 1899). HP treatment of milk increases the pH of milk, reduces its turbidity, changes its appearance, reduces the RCT of milk and increases cheese yield, thereby indicating potential applications in cheese technology. In cheese manufacturing, the application of HP is mainly focused on making cheese from pressure treated milk, microorganism inactivation in cheese, acceleration of cheese ripening and increased cheese yield, which many research groups have reviewed. Present paper highlights the research findings on application of HPP in cheese processing.

Cheese production from pressure treated milk: The physicochemical and sensory properties of cheese are the most valued. Therefore, ensuring that the processing technologies applied to them do not affect these unique attributes in a negative fashion is of utmost importance. Milk pasteurization is recognized to adversely affect the development of many sensory characteristics of cheese, leading to alteration in texture and often delayed maturation. HP processing did not alter the composition of fresh cheese particularly its total solids (TS), ash, fat and soluble nitrogen (SN) contents. However, non-protein nitrogen (NPN) of HP cheeses remained lower than the non-treated fresh cheese. In the studies of Trujillo *et al.*, (1999 a), HP treated milk cheese contained higher moisture, salt and total free amino

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acid content than pasteurized milk cheese (control). Table 1 summarizes the results from studies conducted on cheese with regard to the impact of HP treatments have on physicochemical, rheological, and sensory properties.

HP treated milk cheese (500 MPa, 20°C) had firmer, more elastic but less fracturable texture compared with pasteurized milk (72°C, 15 sec) with cheese-matrix structure similar to the raw milk cheeses (Buffa *et al.*, 2003). Cohesivity of HP treated milk cheese was higher than pasteurized milk cheese (Trujillo *et al.*, 2002). Hard surface which was apparent in a HP processed milk cheese (500 MPa in 30 ± 5 min at 25°C) was subjected to sensory analysis and sensory Judges showed preference for processed cheese over the non-processed cheese regardless of texture attributes (Trujillo *et al.*, 2000a). In contrast, Kolakowski *et al.*, (1998) reported that HP treatment up to 500 MPa applied on cheese improves sensory characteristics of HP treated compared to untreated milk cheeses. Organoleptic characteristics of the cheeses remained unaffected at HP (200 - 500 MPa for 15 min) since changes between HP processed cheese and controls were undetected by panellists (Szczawinski *et al.*, 1997). HP-treated cheeses showed a similar level of lipolysis to cheeses made from raw milk; whereas, the level of lipolysis in cheese made from pasteurized milk was lower (Buffa *et al.*, 2001c). This behavior was explained by heat-sensitive but partial pressure-resistant characteristics of the indigenous milk lipase.

Effect of HP on rennet coagulation time: Desorby-Banon *et al.*, (1994) reported that HP treatment of < 150 MPa had no effect on the RCT. However, RCT was reduced markedly after treatment at 200 - 600 MPa. The pressure-induced disruption/ disintegration of the casein micelles appears to reduce the RCT and the cutting time, whereas the denaturation of the whey proteins increases the RCT and the cutting time, in a similar fashion to that for the heated milk. These results have been interpreted as two opposing phenomena. Temperature of treatment and pH of the milk have considerable effect on the RCT of HP-treated milk. Treatment at 50 - 60°C (200 MPa) delayed rennet coagulation of milk. Arias *et al.*, (2000) reported that the acidification of milk (pH-5.5) before HP treatment decreased its RCT whereas alkalinisation (pH - 7.0) had the opposite effect.

Microorganism inactivation in cheese: Food scientists have employed HP technology in cheese processing to inactivate toxigenic and infectious pathogens such as *Escherichia coli*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Aeromonas hydrophila*, *Salmonella enterica*, and *Yersinia enterocolitica*, as well as spoilage microorganisms such as *Staphylococcus carnosus*, *Enterococcus* spp., coliforms, yeasts, and molds including also microbial spores from *Bacillus subtilis*, *Bacillus cereus*, and *Penicillium roqueforti*. Results have revealed that HP treatments cause structural and functional alterations in vegetative cells and spores leading to cell injury or death. These include cell membrane disruption or increased permeability, ribosomal destruction, collapse of intracellular vacuoles, denaturation of membrane-bound proteins, damage to the proton efflux system, inactivation of key enzymes, including those involved in DNA replication and transcription, release of dipicolinic acid and small acid-soluble spore proteins, and hydrolysis of spore core and cortex (Black *et al.*, 2011).

Tom Beresford and Cait Lane (2000) reported that the level of microbial inactivation obtained is a function of pressure and temperature. The Gram positive *S. aureus* species was more resistant to pressure than the Gram negative *E. coli* species with the latter showing increasing sensitivity to pressure on going from 10°C to 30°C. The mold species, though at lower pressures (< 300 MPa) was more resistant than the bacteria, was much more sensitive at higher pressures. In the case of *E. Coli* and molds similar trends and degree of inactivation by HPP were observed for strains within species. Log phase cells are more sensitive to pressure than stationary phase cells. Daryaei *et al.*, (2008) reported that pressure treatments e" 300 MPa applied for 5 min to fresh lactic curd cheese were capable of effectively controlling the outgrowth of yeasts, therefore, extending product shelf-life from 3 to 6 weeks.

Microbial resistance to HP depends not only on the intrinsic resistance of the microorganisms but also on their physiological state (Manas and Pagan, 2005). O'Reilly *et al.*, (2000a) observed that cells of *S. aureus* ATCC 6538 and *E. coli* K-12 in the

TABLE 1: Effect of HPP treatments on cheese quality parameters

Parameter Evaluated	Cheese Variety	Instant of Application	HP Treatment Applied P (Mpa)/T (Min)/T (◦C)	HP Induced Modification	Reference
Color	**Mato**	1day	500/5, 10, or 15/10	L^* and a^* decreased, whereas b^* increased compared to control cheese.	Capellas *et al.*, 2001
	Cheddar, Turkish white-brined	1 day	50–400/5, 10, or 15/22–25	Increasing pressure intensity and holding time did not affect L^*, but a^* decreased and $b*$ increased compared to control cheese.	Rynne *et al.*, 2008
Rheological properties	**Cheddar**	1 and 4 month	200–800/5/25	Pressures up to 300 MPa applied to 1-month old cheese had no significant effect. At 800 MPa, cheese had similar fracture stress and Young's modulus as control cheese. Pressure applied to 4-month old cheese increased fracture work.	Wick *et al.*, 2004
	Cheddar	1 day	400/10/25	Increased fracture strain and fracture stress values, lower fluidity, flowability, and stretchability increased up to 21 day, but to a lesser extent than in control cheese.	Rynne *et al.*, 2008
	Low-moisture mozzarella	1 and 5 day	400/20/25	Reduced time required to attain satisfactory cooking performance (by 15 day). Increased fluidity, flowability, stretchability, and reduced melting time on heating at 280 ^{0}C.	O'Reilly *et al.*, 2002b
	Gouda	3 day	50, 225, or 400/1 h / 14	Less rigid and solid-like, more viscoelastic, and had less resistance to flow at longer times.	Messens *et al.*, 2000
Sensory properties	**Hispanico**	15 day	400/5/10	Treatments applied to immature cheese limit the formation of volatile compounds. However, differences become less significant during ripening.	Avila *et al.*, 2006
	Ewes' milk cheese	1 or 15 day	200 or 500/10/12		Juan *et al.*, 2007b
	Raw goat milk cheese	1, 3, or 50 day	400 or 600/7/10	Treatments applied at more advanced stages do not cause significant differences compared to control cheese.	Delgado *et al.*, 2011

exponential phase of growth were more sensitive to HPP treatments in cheddar cheese slurry than cells in the stationary phase. Ding *et al.*, (2001) reported that higher pressure conditions (345 and 550 MPa) and longer exposure times (10 and 30 min) achieves a greater reduction in numbers of undesirable bacteria in the natural microflora of swiss cheese slurries (coliforms, presumptive coagulase-positive *Staphylococcus*, yeasts, and molds) and in lactic acid bacteria starter added to milk for acid production and flavor development. A greater antimicrobial impact can be achieved with moderate pressure treatments and shorter pressure holding times when combining high temperatures with HPP treatments. However, the use of high temperatures could lead to undesirable effects in certain cheese quality parameters. Treatments at 50^{0}C caused high whey losses and unacceptable textural characteristics.

Acceleration of cheese ripening: Cheese ripening is a time-consuming and expensive process due to high storage cost. So, an efficient technique to reduce aging time without significantly affecting other quality attributes would provide significant savings to cheese manufacturers. Pioneering research on this topic was performed by Yokoyama *et al.*, (1993) who significantly reduced ripening times of Japanese cheddar and parmesan-type cheese without affecting sensory attributes. Many food scientists have assessed the application of HP treatments to accelerate the ripening of cheese (**Table 2**).

HP treatments are able to accelerate cheese ripening by altering in enzyme structure, conforming changes in the casein matrix making it more prone to the action of proteases and bacterial lysis promoting the release of microbial enzymes that promote biochemical reactions (Voigt *et al.*, 2010). HP treatments also increases pH (0.1 to 0.7 units) and modify water distribution of certain cheese varieties, promoting conditions for enzymatic activity.

The initial hydrolysis of caseins in milk is carried out mainly from the action of plasmin, chymosin, and to a lesser extent by pepsin. HP treatment of 800 MPa for 60 min at 8^{o}C did not inactivate plasmin in 14-day-old Cheddar cheese, while at 20 ^{o}C and 30 ^{o}C its activity was reduced by

TABLE 2: Effect of HP treatments on the ripening process of different cheese varieties

Cheese Variety	**Instant of Application**	**Treatment Applied P (MPa)/t (min, h)/ T (æ%C)**	**HP Induced Changes**	**Reference**
PROTEOLYSIS				
Cheddar	After salting	50/72 h/25	Similar taste and FAAe content of a 6 mo-oldcommercial cheese obtained in 3 d (Cheddar: 26.5mg/g, Parmensan: 76.7 mg/g).	Yokoyama *et al.*, 1992
Cheddar	2, 7, 14, or 21 day	50/72 h/25	Faster ás1-casein hydrolysis and accumulation ofás1-I-casein. Increased pH 4.6 SNf/TNg and FAAlevels.	O'Reilly *et al.*, 2000b
Blue-veined	42 day	400–600/10/20	Accelerated breakdown of â- and ás 2-casein andincreased levels of PTAh SN/TN.	Voigt *et al.*, 2010
Gouda	After brining, 5 or 10 day	50 or 500/ 20–100/14	No changes in pH 4.6 SN, PTA SN/TN, FAA contentand SDS-PAGE profiles.	Kolakowski *et al.*, 1998;
LIPOLYSIS				
Full-fat Cheddar	1 day	400/10/25	Lipolysis was not significantly different from controlover 180 d	Rynne *et al.*, 2008
Ewes' milk cheese	1 or 15 day	200–500/10/12	Lowest concentration of total FFA at pressuretreatments of 400 to 500 MPa applied on d 15after 60 d of ripening compared to othertreatments. Highest levels of FFAs were obtainedat 300MPa applied on day 1 compared to othertreatments.	Juan *et al.*, 2007b
Blue-veined	42 day	400–600/10/20	Reduced lipolytic activity of *P. roqueforti*.	Voigt *et al.*, 2010
GLYCOLYSIS				
Full-fat Cheddar	1 day	400/10/25	Concentration of total lactate in HHP-treated cheesewas significantly lower compared to the controlafter 180 d of ripening	Rynne *et al.*, 2008

h = time in hours, FAA = free amino acids, SN = soluble nitrogen, TN = total nitrogen; PTA = phosphotungstic acid; FFA = free fatty acids.

15% and 50%, respectively compared to controls (Huppertz *et al.*, 2004 a).

Free amino acid (FAA) levels were 16.2, 20.3, 26.5, and 25.3 mg/g after HP treatments at 5, 15, 50, and 200 MPa, respectively, while in control cheese the FAA level was 21.3 mg/g. There was non-significant difference between the taste of Cheddar cheese HP-treated at 50 MPa and commercial control cheese. With increase of pressure from 100 to 400 MPa, production of total FAA was decreased. Conversely, increasing processing time up to 60 h, raised total FAA levels. These research studies on Cheddar cheese ripening clearly demonstrate that HPP treatments enhanced proteolysis. However, results were not so significant as those of Yokoyama *et al.*, (1993). HP enhanced proteolysis did not altered the pathways of proteolysis, thus flavour and texture development is very similar to traditional commercial Cheddar cheese. O'Reilly *et al.*, (2000b) reported that low to moderate HP treated (50 to 150 MPa) young Cheddar cheese shown accelerated proteolysis, whereas higher HP treated conditions (e"400 MPa) may help to arrest the ripening process at a desired stage, thus maintaining optimum "commercial attributes" for a longer time.

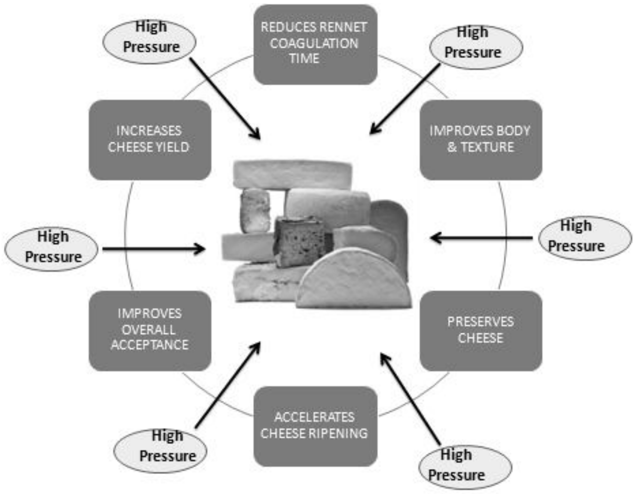

FIG 1: Effect of high pressure processing on cheese

Increased cheese yield: In cheese making process, it is very essential to obtain the maximum achievable recovery of substance from milk because the higher the recovered percentage of solids, the greater the amount of cheese obtained and therefore gain in economic terms. Drake *et al.*, (1997) in cheddar and Trujillo *et al.*, (1999 a) in semi-hard goat milk cheeses reported higher yields in cheese made from HP-treated milk. Arias *et al.*, (2000) reported that treatment of milk at 200MPa had no effect on wet curd yield, although denaturation of â-lactoglobulin was observed at 200 MPa whereas at 300–400 MPa wet curd yield significantly increased by upto 20% and reduced both the loss of protein in whey and the volume of whey. Increased treatment time, upto 60 min, at 400MPa increased wet curd yield and reduced protein loss in whey; the changes were greatest during the first 20 min of treatment (Lopez Fandino *et al.*, 1996). Arias *et al.*, (2000) reported that wet curd yield and moisture retention in the curd increased with increasing pH of milk. Similarly, the yield of Cheddar cheese made from HP treated milk (3 cycles of 1 min at 586 MPa) was 07% higher than that from raw or pasteurised milk (Drake *et al.*,, 1997). Lopez Fandino *et al.*, (1996) reported that increased cheese yield is primarily due to greater moisture retention, secondly due to incorporation of some denatured â-lactoglobulin. Additionally, the casein micelles and fat globules in HP-treated milk may not aggregate as closely as in untreated milk, therefore, allowing more moisture to be entrapped in the cheese (Drake *et al.*, 1997).

CONCLUSION

There has been a substantial progress in commercial applications of HP processing technology to foods. HP treatment when applied to cheese can influence its microbiological, physicochemical and sensory characteristics. From the available literature, it can be concluded that by using specific range of pressure a desirable change in microbial, physicochemical and sensory attribute can be made but simultaneously all pressure ranges cannot be applied on a particular product hence there is need to balance the HPP parameters. Moreover, a big challenge before researcher is to work on the engineering aspects of the processing equipment for cheese processing.

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