HIGH PRESSURE FOOD PROCESSING: AN ALTERNATIVE TECHNOLOGY TO REDUCE FOOD ADDITIVES USED IN PROCESSED MEAT PRODUCTS

การแปรรูปโดยใช้ความดันสูง: เทคโนโลยีทางเลือก เพื่อลดปริมาณการใช้วัตถุเจือปนอาหารในผลิตภัณฑ์เนื้อสัตว์แปรรูป

Nattaporn Chotyakul[1] and Nutdanai Boonnoon[2]
[1,2]Faculty of Agro-Industry, Panyapiwat Institute of Management

Abstract

Consumer behavior has changed dramatically nowadays that ready-to-eat foods are particularly popular choice than fresh or unprocessed foods. Therefore, food industries are growing rapidly to serve in variety of different choices to consumers, especially processed meats such as sausage, ham, bologna known as cured meats which is normally classified in a group of low-acid food and easily spoiled by microbial contamination. To control microbial growths in processed meats, food additives are most frequency added in forms of nitrite and nitrate. Consuming over the legal limit of nitrite and nitrate for 125 and 500 mg/kg, respectively can become a health risk or even death. Therefore, a technology of High Pressure Processing (HPP) is helped to inactivate microorganisms and stabilizes their growth during storage which reduces the need of food additives in processed meats. However, production cost is directly proportional to the level of pressure and time applied. Thus, a practical guidance to industrial pressure conditions affecting spoilage microorganisms in meat to extend the shelf life are in the range of 400-700 MPa combined with low to moderate temperature at 0-70 °C for 1-10 minutes. The potential benefits of HPP are maintaining product characteristics including color, flavor and texture.

Keywords: High Pressure Process (HPP), Processed Meat, Food Additive, Shelf life

Corresponding Author
E-mail: nattaporncho@pim.ac.th

บทคัดย่อ

พฤติกรรมของผู้บริโภคอาหารในปัจจุบันมีการเปลี่ยนแปลงไปมาก โดยอาหารพร้อมรับประทานได้รับความนิยมมากกว่าอาหารสดหรืออาหารที่ผ่านการแปรรูปต่ำ ทำให้อุตสาหกรรมอาหารในปัจจุบันได้เติบโตอย่างรวดเร็วเพื่อตอบสนองความต้องการที่หลากหลายของผู้บริโภคโดยเฉพาะเทคโนโลยีแปรรูปอาหารประเภทเนื้อสัตว์ เช่น ไส้กรอก แฮม โบโลน่า ซึ่งจัดอยู่ในกลุ่มผลิตภัณฑ์แปรรูปประเภทเนื้อหมักที่มีความเป็นกรดต่ำจึงเกิดการเสื่อมเสียจากจุลินทรีย์ได้ง่าย ผลิตภัณฑ์แปรรูปกลุ่มนี้จึงต้องใส่วัตถุกันเสีย เช่น ไนไตรท์และไนเตรท โดยปริมาณที่กฎหมายกำหนดไม่เกิน 125 และ 500 มิลลิกรัม/กิโลกรัม ตามลำดับ เพื่อควบคุมการเจริญของจุลินทรีย์และยืดอายุการเก็บรักษา หากบริโภคเกินมาตรฐานที่กำหนดจะเป็นอันตรายต่อสุขภาพหรือเสียชีวิตได้ เทคโนโลยีความดันสูงจึงถูกนำมาประยุกต์ใช้ในเนื้อสัตว์แปรรูปเพื่อลดปริมาณการใช้วัตถุกันเสีย แต่เนื่องจากต้นทุนการผลิตแปรผันตามระดับความดันและเวลาที่ใช้ ดังนั้นในทางอุตสาหกรรมจึงใช้ความดันอยู่ในช่วง 400-600 เมกกะปาสคาล ร่วมกับความร้อนต่ำถึงปานกลางในช่วงอุณหภูมิ 0-70 องศาเซลเซียส เป็นเวลา 1-10 นาที ซึ่งเพียงพอต่อการทำลายเชื้อจุลินทรีย์ที่ก่อให้เกิดการเน่าเสีย เพื่อช่วยยืดอายุผลิตภัณฑ์ โดยที่ยังคงรักษาคุณภาพผลิตภัณฑ์ ทั้งในด้านสี กลิ่น รส และเนื้อสัมผัส

คำสำคัญ: ความดันสูง เนื้อสัตว์แปรรูป วัตถุเจือปนอาหาร อายุการเก็บรักษา

Introduction

Today people's food consumption style has changed dramatically towards the fast foods served as convenient options responding to environmental variations such as time, traffic, and economy (Waratornpaibul, 2013). A popular food choice that fits for today busy lifestyle is ready-to-eat products, especially processed meat such as smoked sausage, cooked-cured sausage, ham, and bologna. Thus, there are not surprised to see more and more shoppers fill their carts with ready-to-eat meat products. Buying habits for modern consumers are conscious about unhealthy of processed meats and are aware of the possible health risk problems due to high fat, salt, and food additives. Nevertheless, how can consumers correctly classifying a type of retailed meat products in supermarkets? This point is still a bit of confusion surrounding the term of "processed meat products" which manufacturers should be clear for labeling categories. A term of traditionally processed meats is labeled as "cooked-cured meats" which requires mainly cured ingredients containing sodium nitrite (nitrite) or sodium nitrate (nitrate). Some processed meats are prohibited containing these additives called "uncured meat products", "natural meat products" or "organic meat products". Consumers desire processed meats that taste like freshly prepared and minor used harmful food additives like phosphates, nitrite, nitrate, and sodium chloride (NaCl). These are frequently used to enhance the texture, inhibit microbial growths, improve color, and extend shelf life (Ruusunen & Puolanne, 2005).

According to consumer demands on food safety and quality perception, High Pressure Processing (HPP) is an alternative choice interesting to worldwide attention. HPP equipment has become commercially accessible in many countries such as Japan, Europe and the U.S. (Norton et al., 2008). HPP has been considered as one of the most important innovations in food technology during the past 50 years. A market value earns about $2.5 billion (Balasubramaniam, Martínez-Monteagudo & Gupta 2015). In 2012, meat industry owned 30% (Figure 1) of the machines installed in the world following by fruit and vegetable products industry (Balda, Aparicio & Samson, 2012).

HPP is described as a traditional non-thermal treatment with the key challenges of ensuring high performances of microbial inactivation; maintaining product characteristics; improving nutrient retentions, sensory attributes, freshness, and safety (Houška et al., 2006). The objective of this article are 1) to review and discuss about the harmful food additives in processed meats 2) to give a basic principles of HPP 3) to review the effects of non-thermal process technologies and 4) to understand the limitation of HPP technology. This alternative will be able to reduce food additives commonly used in processed meat after pressurization without compromising on quality and safety (Jofré & Serra, 2016).

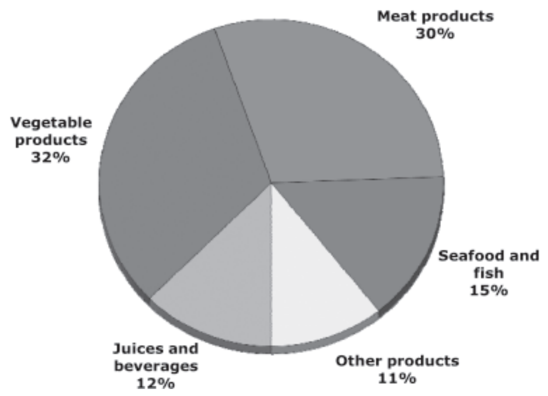

Figure 1 Distribution of HPP equipment in food industry (Hiperbaric S.A.)
Source: Balda et al. (2012: 546)

1. Food additives in processed meats

Raw meat has high water activity (aw), low NaCl and nitrite contents, and high microbial contaminations from slaughterhouse (Neetoo & Chen, 2012). Cured-cooked meats are mainly contained NaCl, nitrite/nitrate, and phosphate. These additives help to slow almost all phatogenic and spoilage bacteria, also improve flavor and taste (Sebranek & Bacus, 2007). The essential ingredients, nitrite with an addition of NaCl, help to inhibit the growth of *Clostridium botulinum*. Botulinum is a spore- and toxin-forming bacteria which resists to high temperature (> 100°C) for long time (5-10 hr.) and produces neurotoxin. Signal of symptom cases in food-borne botulism include difficulty in swallowing or speaking, nausea, vomiting and abdominal cramps (Keto-Timonen et al., 2012). However, the legal used of nitrite and nitrate in finished products are 125 and 500 mg/kg, respectively or two compounds combination must be no exceeding 125 mg/kg (FDA, 2013). Phosphate is another kind of additive which provides benefits on improving water holding capacity and gel characteristics, cooking yield properties, retarding the formation of oxidative rancidity or moldy, retaining moisture and tenderness, improving color and firmness, and stabilizing meat emulsion (Kerry & Kerry, 2011). Sodium chloride brings out the characteristic taste and flavor of meat products (Ruusunen & Puolanne, 2005) and improves water and fat binding properties resulting in the formation of desirable gel texture upon cooking (Supavititpatana & Apichartsrangkoon, 2007).

Even food additives improve the microbial inactivation, texture, and flavor but those are generally not preferred in healthy food markets. Consumers believe that additives may be harmful and increase human risk of colon, pancreatic, and stomach cancers (Parthasarathy & Bryan, 2012). For example, the reaction between ingested amines and nitrites in acid condition presented in stomach can form nitrosamines known as carcinogenic substances. Thus, a reduction in the use of nitrites is essential and beneficial to processed meat manufacturing to diminish the risk of nitrosamine formations. Table 1 is common used additives as preservatives along with health hazards namely hypersensitivity, asthma, and cancer.

Table 1 Health hazards of some commonly used preservative in meat products

Additive	Health hazards		
	Hypersensitivity	Asthma	Cancer
Sorbic acid	✓	✓	
Benzoic acid	✓	✓	
Sodium benzoate	✓	✓	✓
Sodium nitrite	✓	✓	✓
Sodium/Potassium nitrate	✓		✓
Sodium metabisulfite		✓	

Source: adapted from Anand & Sati (2013: 2499).

A big issue in Phra Nakhon Si Ayutthaya, Thailand, was reported by Food and Drug Administration, FDA (2013) on May 14th, 2007. Children consumed chicken sausage containing 3,000 mg/kg exceeding the legal limit (125 mg/kg) of nitrite compounds and caused methemoglobinemia incidence. A symptom showed high level of methemoglobin in body that caused a slate gray-blueness of the skin (cyanosis) because of insufficient oxygen. According Bryan (2006), the fatal dose of nitrite is in the range between 22–23 mg/kg body weight. Moreover, people in most of industrialized countries consumed sodium in exceeding the nutritional recommendations. The total amount of dietary NaCl consumption is maintained at about 5-6 g/day (Ha, 2014). Therefore, the consumer wants even reduction in or elimination additives used than the currently approved levels in processed meats. From these issues, a modern food processing technology called HPP is represented as another safety concern to reduce food additives in processed meat products.

2. Principles of HPP

HPP is non-thermal technology which represents a great deal of attention as shown by research and commercial efforts performed worldwide (Jofré et al., 2009). HPP is subjected to the Le Chatelier's principle representing as the pressure increase, the volume decrease (Hugas, Garriga & Monfort, 2002). Food packaging materials used in HPP equipment are typically flexible and high-barrier properties. The packaged foods are loaded into the pressure chamber. The pressure vessel is sealed and filled with a pressure transmitting fluid, most commonly uses water and glycol solutions. Pressure system is enforced by the use of a pressure pump with additional quantity of fluid injection. Pressure levels are applied between 100-700 MPa with holding time for few seconds to 20 minutes. The uniform pressure is distributed to food products with the same in all directions (Figure 2) according to isostatic rule. After pressure is applied and released, the product will be returned to their original shape. The basic for applying HPP to foods is to compress the fluid transmission food. The compression is independently of the product size and shape because transmission of pressure to the core is mass and time independent (Yordanov & Angelova, 2010). HPP is considered for non-thermal treatment because food is processed below thermal pasteurization (~72°C), then the covalent bonds are not broken by pressure which has minimal effect on food chemistry and physical characteristics such as color, flavor, texture and nutritional contents (Shankar, 2014). However, HPP affects only weak chemical bonds such as hydrogen, ionic and hydrophobic bonds which cannot be reversibly modified (Hugas, Garriga & Monfort, 2002).

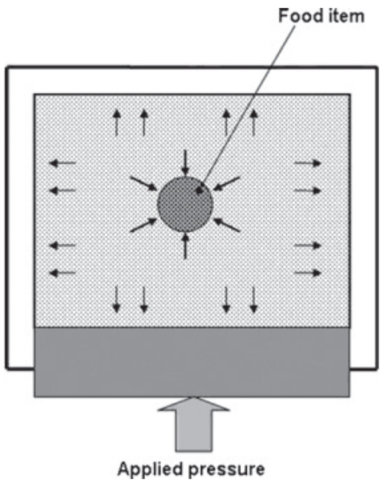

Figure 2 The principle of isostatic pressure
Source: Ortega-Rivas (2012: 304)

HPP has led to considerable interest due to many benefits of equipment advances, product commercialization successes, requiring for less processed, high food quality and safe (Torres et al., 2009; Torres & Velázquez, 2005).

3. HPP applications on processed meat products

The main purpose of HPP treated meats is to inactivate and stabilizes microbial growth. However, the properties of meat product bindings treated by HPP are depended on various factors including animal species, muscle types, pH and ionic strength, levels of fat and protein, pressure levels, times and temperatures (Iwasaki et al., 2006).

HPP can apply at several steps on comminuted meat manufacturing reported by Allais (2010): 1) apply at low temperature between 0-5°C on raw meat before chopping to improve tenderness after cooking (Simonin, Duranton & de Lamballerie, 2012). 2) apply on comminuted meat batter before heating to increase elastic gels and to reduce cooking losses (Hong et al., 2008). 3) apply during heating to increase gel strength which influent on meat texture (Supavititpatana & Apichartsrangkoon, 2007). 4) apply after heating to decrease microbial load found in meat, then prolong shelf life (Ruiz-Capillas, Carballo & Jiménez-Colmenero, 2007). Moreover, many food companies have proved that the success of this technology is confirmed by commercially pressurized meat products (Table 2).

Table 2 Examples of pressurized meat products in the market

Product type	Company	Country
Cooked and cured meat	Campofrío Alimentación S.A	Spain
Serrano hams, sausages, cooked hams, bacons	Esteban Espuña S.A.	Spain
Italian cured meats	Vismara Ferrarini)	Italy
Ready-to-eat meats	Abraham	Germany
Beef	Fuji Mutterham	Japan
Hams, bacon, franks, luncheon meats	Hormel Food Crops.	USA

Source: adapted from Garriga & Aymerich (2009: 184).

Table 3 demonstrated the HPP meat products after evaluating the compositions of cooked ham and dry cured ham pressurized at 600 MPa for 10 min at 30°C compared with control (Hugas, Garriga & Monfort, 2002). A slight decrease in nitrate and phosphate contents were detected in dry cured ham after HPP treated. In cooked ham, most additives levels were reduced after the pressure treatment. This is the advantage of HPP to avoid or reduce food additives used.

Table 3 Proximate compositions of pressurized meat products: cooked ham (A) and dry cured ham (B) pressurized at 600 MPa, 10 min 30°C

Sample	Control (mean±SD)	HPP (mean±SD)
Cooked ham		
Nitrite (ppm)	103.3±6.66	91.0±3.00
Nitrate (ppm)	38.33±3.06	38.0±3.61
Sodium Chloride (%)	2.06±0.04	1.80±0.01
Phosphate (ppm)	4592±74	3061±269
Ascorbate (ppm)	234±16	219±14
Dry cured ham		
Nitrite (ppm)	5.00±0.0	7.67±0.58
Nitrate (ppm)	98.67±3.51	81.67±12.7
Sodium Chloride (%)	3.76±0.10	4.63±0.14
Phosphate (ppm)	4590±360	3663±980
Ascorbate (ppm)	58±1	74±6

Source: adapted from Hugas, Garriga & Monfort (2002: 368).

3.1 HPP effects on microbial safety

Meat is mainly constituted by water (75%), protein (15-21%), fat (0.5–25%) which considers as a rich source for microbial growths (Hugas, Garriga & Monfort, 2002). HPP applied to meat has been a desirable research for years attributed to its potential to inactivate microorganisms (Balasubramaniam, Martínez-Monteagudo & Gupta, 2015). The kinetics of microbial inactivation under HPP are based on microorganism types, pressure levels, times, temperatures, pH, aw, and food compositions. HPP aims at mild preservation for food but knocking out pathogenic and spoilage micro-organisms. The characteristics of naturally occurring products are guaranteed under this technology (Hugas, Garriga & Monfort, 2002). The primary target of pressure damages on microorganism is cell membrane. Pressure leads destructions and looses of their integrity because cells are unable to control the transport of water and ions across the membranes. Then they have lost the ability to reproduce (Hugas, Garriga & Monfort, 2002). Normally, gram-positive bacteria are less pressure resistant than gram-negative. The highly resistant to pressure is bacterial spores which the temperature needs to perform higher than 100°C under pressure assisted (Wuytack, Diels & Michiels, 2002). Table 4, HPP is a powerful tool to control risks related to *Salmonella* spp. and *Listeria monocytogenes* and *Campylobacter* spp. in sliced dry cured ham. The absence of *Campylobacter* spp. and *Salmonella* spp. showed in sliced dry cured ham (n=30) under HPP at 600 MPa, 31°C for 6 min whereas *L. monocytogenes* was presented only in 25g of untreated sample at time 0. However *L. monocytogenes* was unavailable in HPP treated samples investigated for 120 days at 4°C (Table 4). These results convinced that HPP treatment could prolong the shelf life of sliced dry cured ham by controlling the growth of both spoilage and pathogenic bacteria. A condition of HPP at 600 MPa, 31°C for 6 min reduced the levels of *Salmonella* sp. and *L. monocytogenes* to levels below 10 CFU/g in cooked ham. In fresh pork sausages, 10 log reduction of the most resistant strain of *L. monocytogenes* found after HPP at 400 MPa, 50°C for 6 min. The effectiveness of treatment resulted in longer shelf life about 23 days in storage at 4°C without substantially altering sensory qualities. The results of microbial reduction controlled by HPP at 400 MPa, 17°C for 10 min was significantly reduced Enterobacteriaceae and Enterococcus levels in the finished sausages (Table 4).

Table 4 Microbial inactivation by HPP treatments in meat products

HPP Treatment	Product	Result	References
600 MPa, 31°C, 6 min	Dry cured ham	Absence of *L. monocytogenes* after 120 days	(Hugas, Garriga & Monfort, 2002)
		Absence of *Campylobacter* spp. and *Salmonella* spp. after treatment and *L. monocytogenes* after 120 days	(Garriga et al., 2004)
600 MPa, 10°C, 5 min	Cooked ham	HPP reduced the levels of *Salmonella* sp. and *L. monocytogenes* to levels below 10 CFU/g.	(Jofré, Garriga & Aymerich, 2008)
400 MPa, 50°C, 6 min	Fresh pork sausage	10 log CFU/g reduction of *L. monocytogenes* after HPP, longer shelf life about 23 days in storage at 4°C	(Campus, 2010)
400 MPa, 17°C, 10 min	Low-acid fermented sausages	significantly reduced Enterobacteriaceae and Enterococcus levels	(Marcos et al., 2007)

Source: Adapted from Alahakoon et al. (2015) and de Oliveira et al. (2015).

3.2 HPP Effects on physical properties and sensory characteristics

Meat proteins are strongly induced by HPP with modifications of protein gelation, solubilization and aggregation. HPP has different effects on meat texture and water retention due to product compositions, pressure levels and pressure/temperature combinations (Simonin, Duranton & de Lamballerie, 2012). For example, the ability of HPP on meat protein was resulted in the solubility of myofibrillar proteins, subsequently in texture improvement (Chapleau et al., 2003). Supavititpatana & Apichartsrangkoon (2007) mentioned about the pressure induced protein gels was different from induced by heat. Texture of HPP treated meat was being glossier, smoother, softer, and having greater elasticity. The stabilization of protein structures (secondary, tertiary, and quaternary) affected on meat texture are primarily different responses to different thermal and pressure treatments (Campus, 2010). HPP also retarded lipid oxidation in pork meat after treated by HPP below 800 MPa, therefore products shelf life could be extended (Simonin, Duranton & de Lamballerie, 2012). In addition, several Japanese companies have confirmed on the development of cured pork meats under pressurizing at 250 MPa for 3 hr. could improve sensory property and texture quality (Neetoo & Chen, 2012). Mor-Mur & Yuste (2003) reported for less firm texture of cooked meat sausage treated by HPP at 500 MPa, 65°C than heat treatment alone at 80-85°C for 40 min.

Table 5 The effect of HPP at 150 or 300 MPa, NaCl, and phosphate levels on texture of cooked frankfurters and breakfast sausages

Sample	Condition	Hardness	Springness	Adhesiveness	Cohesiveness	Gumminess	Chewiness
cooked frankfurters[1]	*HPP*						
	0 MP	27.5[a]	7.6[a]	0.05[a]	0.68[a]	18.7[a]	142.2[a]
	150 MPa	28.3[a]	7.6[a]	0.06[a]	0.68[a]	19.3[a]	148.2[a]
	300 MPa	21.4[b]	7.3[b]	0.04[b]	0.66[b]	14.3[b]	106.2[b]
	SL	0.0	0.0	0.0	0.0	0.0	0.0
	NaCl						
	1.5%	26.5[a]	7.7[a]	0.05[a]	0.68[a]	18.1[a]	139.3[a]
	2.5%	25.1[b]	7.4[b]	0.05[a]	0.67[b]	16.8[b]	125.1[b]
	SL	0.04	0.0	NS	0.0	0.01	0.0
Breakfast sausages[2]	*HPP*						
	0 MP	40.2[a]	6.60[a]	0.09[a]	0.64[a]	25.63[a]	168.65[a]
	150 MPa	52.9[b]	6.91[a]	0.12[b]	0.59[b]	30.48[b]	214.62[b]
	300 MPa	37.8[a]	6.45[a]	0.10[a]	0.54[c]	20.39[c]	132.64[c]
	SL	0.0	NS	0.0	0.0	0.0	0.0
	Phosphate						
	0%	42.4[a]	6.9[a]	0.09[a]	0.60[a]	25.3[a]	178.4[a]
	0.25%	44.8[a]	6.6[a]	0.11[a]	0.58[a]	25.7[a]	172.2[a]
	0.5%	43.8[a]	6.4[a]	0.10[a]	0.60[a]	25.5[a]	165.4[a]
	SL	NS	NS	NS	NS	NS	NS

[a,b,c] : different letters in the same column indicate significant differences ($P < 0.05$).

SL: significance level; NS: not significant

Source: Crehan, Troy & Uckley (2000)[1] and O'Flynn et al. (2014)[2]

Table 5, the effect of HPP on cooked frankfurters and breakfast sausages at 150 MPa were chewier than samples treated at 300 MPa or untreated samples. The profiles of hardness, adhesiveness, gumminess were improved after HPP at 150 MPa in both samples. The results in frankfurters and sausages demonstrated that HPP was a feasible process to improve meat textures. However, many of textures analysis contained food additives were enhanced when NaCl and phosphate contents of frankfurters and sausages were reduced from 2.5% to 1.5% and 0.5% to 0.25%, respectively. HPP and additives comparisons, HPP at 150 MPa improved the hardness, gumminess, and chewiness in sausage better than phosphate added of 0, 0.25, and 0.5% and treated HPP at 150 MPa in frankfurters showed better than NaCl added of 1.5 and 2.5%. Therefore, this study showed apparent that HPP can be used to improve the functionality of frankfurters and sausages formulated with lower NaCl and phosphate levels.

Table 6 Influence of reduced phosphate levels on the sensory characteristics of breakfast sausages manufactured with untreated meat or meat high-pressure treated at 150 or 300 MPa

Pressure (MPa)/ Phosphate level (%)	Saltiness	Juiciness	Overall flavor	Overall firmness	Overall Texture	Overall acceptability
0/0	2.98	4.44	3.64	3.28	2.47	3.58
0/0.25	3.11	4.20	3.83	3.94	2.16	3.84
0/0.5	3.70	4.36	4.14	4.06	2.11	4.20
150/0	3.34	4.62	4.08	3.44	2.36	3.70
150/0.25	3.03	3.86	3.61	3.97	2.11	3.87
150/0.5	2.81	3.84	3.55	4.06	2.14	3.75
300/0	2.76	3.56	3.58	2.45	2.31	2.78
300/0.25	3.06	3.83	3.76	2.55	2.20	3.09
300/0.5	3.41	3.73	4.22	2.67	2.08	3.03
LSD	0.40	0.49	0.37	0.51	0.41	0.42

Sensory characteristics are scored for six point hedonic scale where one and six are the extremes of each condition

LSD: Least significant difference

Source: O’Flynn et al. (2014)

The approval results from O’Flynn et al. (2014) in Table 6, a case of HPP treated at 150 MPa without phosphate added was significantly ($p<0.05$) juicier than HPP at 300 MPa condition. The overall flavor of sausages allowed in phosphate reduction from 0.5% to 0.25% under HPP at 150 MPa with no significant difference ($p>0.05$). HPP at 150 MPa combined with lower phosphate (0.25%) presented higher overall acceptability than phosphate level 0.5%, also better than HPP at 300 MPa. The condition guidelines from publications showed for HPP exceeding 150-200 MPa might have an effect on textural and sensorial properties of the final meat products.

4. The limitation of HPP technology

Commercially scale HPP unit is high capital cost (75-80%) which effects on processing facility in food companies. Even pressure treated meat products are higher sensory quality, the prices are highly sold in three to four times of the conventional products cost (Balasubramaniam, Gustavo & Huub, 2016). The reported case from Joye (2014) is clear that HPP represents a significant cost ($1.27/kg) over the conventional retort processing ($0.34/kg) of sliced meat approximately 30-40%. Production cost is directly proportional to the level of pressure and time applied. After review from some researches, HPP levels used to preserve physical properties in meat products should be lower than 200 MPa. However, the most important point that manufactures need to consider is microbial safety which mentioned on previous. Therefore, the best practical pressurized condition in industry for processed meat products are conducted in the range between 400-600 MPa at 0-70°C for 1-10 minute (Jofré et al., 2009).

The manufacturers hope that HPP systems will continue to improve their capabilities in design and lower cost to optimize the industrial-scale units. The advancement of instrumentals and new technologies could bring down the equipments' price to be widely available at an affordable cost. The increasing equipment efficiency to support product quality and safey are highly desired. Pressurized level and processing time are part of the reason to determine products' cost. It is important to identify the best practical conditions for pressurization as the same to control operational costs.

Conclusions

In the future, processed foods need to be more tolerant in processing to preserve quality changed without consumers' ignorance. Growing demand for processed food concerns over food safety all over the world are the key forces the growth of the global HPP technologies market. The development of effective HPP treated meats at lower pressure is challenged to reduce additives and inactivate microbial growths as the same time without affected on physical properties and safety in processed meats. Researches and developments in meat processing have to keep continue and provide greater consumer satisfaction for all ages. Even HPP technology costs a lot of money for manufacturing but the manufactures need to consider as a big picture in the future gaining a better trend in food processing and response to the understanding of consumers' need.

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Name and Surname: Nattaporn Chotyakul
Highest Education: Ph.D. Oregon State University, USA
University or Agency: Panyapiwat Institute of Management
Field of Expertise: Food Process Engineering
Address: 85/1 Moo 2, Chaengwattana Rd., Bangtalad, Pakkred, Nonthaburi 11120

Name and Surname: Nutdanai Boonnoon
Highest Education: MSc. University of Stirling, UK
University or Agency: Panyapiwat Institute of Management
Field of Expertise: Aquaculture Business Management
Address: 85/1 Moo 2, Chaengwattana Rd., Bangtalad, Pakkred, Nonthaburi 11120