



Short Review

Sous-vide: An Emerging Technology for Fish Preservation

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Abstract

Sous-vide products are gaining importance nowadays as it employs steam cooking thereby preserving the nutritional status of the food products. This process engages an immediate chill treatment followed by heat treatment and its subsequent storage at low temperature arresting the microbial growth. Over time, frequent advancements had taken place to make this technique more effective for long-term preservation; integrating various factors in the form of low pH, inclusion of spices, seasonings improving the texture, flavour of the product and at the same time preserve it for long duration in hermetically sealed plastic packages; preventing from the attack of aerobic microbes. Many varieties of food can be preserved by this technique. Fish being a rich source of delicate nutrients can be efficiently preserved by this technique maintaining its characters like the fresh fish. Many sous-vide fish products are already ruling the market like fish fillets, fish steaks and fish chunks which can be effectively preserved for long term by this technology.

Keywords: Sous-vide, chill, thermal, microbial, hermetically

Introduction

With the advent of industrialization and globalization technological advancement had been seen in every facet of life. Be it medical science or food science, every sector has been developing over time. Food being a very basic necessity of life for survival

also received this technological advancement so that it reaches every corner of the world without much sensory and nutritional variation. Modernization has not only changed the lifestyle of people, but it makes them health conscious too with increasing awareness of nutrients and its importance in our body. But at the same time modernization has engaged women in the business sector that earlier were considered responsible for cooking. Consequently, this modern world with health awareness and a shortage of time demands convenience food that can be quickly cooked but at the same time has a nutritional and sensory status alike fresh seafood. In this scenario, sous-vide technology wins the race as it arrives as an emerging technology for preservation (Armstrong, 2000; Calderón et al., 2010), different from conventional cooking techniques which leave the food low in the sensory as well as nutritional attributes.

The discovery of sous-vide technology for preservation of food dates back to mid-1970's in Briennon, France when a chef Georges Pralus found that raw food when vacuum packed in laminated pouches followed by an indirect thermal sterilization process with hot water bath increased the shelf life of the product by reducing shrinkage of the product significantly (Tiampo, 2006). Apparently, vacuum heating also enhanced the other sensory characters of the product as the food is heated under vacuum pouches in its own liquid retaining the flavor bearing volatile compounds too which could otherwise have been lost *via* evaporation. This technique of food preservation had also been recourse in Western Hemisphere in many restaurants for enhancing the shelf life of the food products.

Background

"Sous-vide" term has been derived from French word meaning underneath vacuum (Baldwin, 2012;

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Church & Parsons, 2000; Vajda et al., 2015) customising a simple technology to prolong the shelf life and retaining the characters near to the fresh product. Being a minimally cooked or processed product it employs hermetically sealed flexible plastic pouches (Ghazala et al., 1995; Korkeala et al., 1997) preventing invasion of aerobic group of microflora and also preventing the threat of oxidation of the product making it secure from any flavour losses (García-Segovia et al., 2008; Stea et al., 2007). The product to be processed through sous-vide technique is first heated to pasteurization temperature 60 to 80°C then sudden cold treatment is given rendering the microbial population inactive thereafter the product is stored at low temperature 1 to 4°C which augment the shelf life up to 6 to 42 days depending upon the chemical composition of the product (Garc & Gonzalezfandos, 2004; Schellekens, 1996). It augments the shelf life of mussel upto 21 days without brine and 30 days when processed in brine (Bongiorno et al., 2018). The thin profile of the sous-vide package makes reheating quicker (Ghazala et al., 1995).

The product is also gaining popularity due to retention of nutrients and sensory attributes near to the fresh product (Kumari et al., 2016). Nevertheless sous-vide tends to increase the shelf life of the products relying on the type of the product and the amount of moisture it holds as in case of red meat the freshness and sensory attributes are retained for a very long time, i.e., for 23 days (Hansen et al., 2007; Simpson et al., 1994); 14-30 days for white meat (Light et al., 1988; Schafheitle, 1990; Shamsuzzaman et al., 1992); 35 days for whiting fish (Mol et al., 2012) and only a week for fish and vegetables being highly perishable food commodity (Gittleson, 1990; Light et al., 1988; Petersen, 1993). It was also apprehended that sous vide technique integrating various seasonings and spices enhancing flavor, acts as hurdle technology due to its antimicrobial and antifungal properties hampering the growth of the microbes (Antoun & Tsimidou, 1997; Tajkarimi et al., 2010). The aforementioned cook-chill process for fish products is gaining importance owing to absence of preservatives (Írse et al., 2017) offering high nutritional value without jeopardizing its harmful residues and therefore have a very high market potential (Rybka-Rodgers, 2001).

Fish and Fishery Products

Fish being a highly perishable commodity provide excellent habitat for the multiplication of all group

of microflora ranging from food spoilers to the most lethal toxin-producing pathogens (Calderón et al., 2010), ruling it out from another group of meat products available. Hence incorporation of this technique for fish needs very precise and standardized methodology as treatment can lead to loss of fragile nutrients (protein denaturation, fat oxidation and loss of vitamins and important minerals) leading to a loss in nutritional quality of fish urging to utilize low temperature or low heat for the fish based products. The conventional preservation techniques using thermal sterilization has adverse effects on the textural parameters of the fish like loss of freshness, texture, softness and flavors. In sous-vide the products are cooked at pasteurization temperature and therefore the product is prone to microbial invasion at times of thermal abuse during storage and distribution, therefore require special refrigeration system (Stringer & Metris, 2017).

Sous-vide cook chill (SVCC) technique in fishery products serves as a kernel for many emerging types of research. Recently a study concluded sous vide technique causes a significant reduction in the viable count in *Oncorhynchus mykiss* receiving a core temperature of 90°C for 3.3 min while thermal sterilization. Another researcher when evaluated a sous vide product stored at 2°C recorded lower limits of psychrotrophic and mesophilic for 45 days. Another interesting outcome was microbes like *Bacillus* sp., *Clostridium* sp. and *Listeria* which are generally encountered from seafood had not been isolated (Can, 2011) till 45 days of storage (Gonzalezfandos, 2004).

Sous-vide being a convenience product offers wide acceptability in terms of quality standards employing steam cooking reducing the weight loss in contrast to the traditional cooking methods utilizing dry cooking at high temperature for a long time (Írse et al., 2017; Rhodehamel, 1992) possessing flavor, juiciness, tenderness etc analogous to the product over a long period of time. Consequently, this technique proves to improve the shelf life of the product without much effect on the nutritional quality of the fish products. Indeed, these are known to improve the texture and raw flavor of the fish products (Schafheitle, 1990) employing various hurdles in the process of cooking, the addition of various seasonings and spices acting as antimicrobials constraining microbial growth. Apart from other preservation techniques like freezing, drying, curing; sous-vide for fishes is gaining popularity,

where many products like fish steaks (Kumari et al., 2016), fish loins (Picouet et al., 2011), fish fillets (Mol et al., 2012) are being preserved through this process. Among various sous-vide packages available the see-through package is now gaining popularity making it more appealing to the consumers and also hermetic packaging drives off many bottlenecks of earlier MAP and CAP packages (Ghazala et al., 1995) like swelling of the packages.

SVCC (Sous-vide cook chill) for Fish and Fishery products

For any fishery product to be processed via SVCC technology, preparation of raw material is the fundamental stride. It is a critical step too as the quality of raw material decides the nutritional status and shelf life of the prepared sous-vide product (Carlin, 2014). Scientifically, it is known that fresh products will harbor fewer microbes and therefore

the heat treatment required to keep the bacterial load under check will be low, this is the reason why freshly caught fish are more suitable for sous vide production (Venugopal, 2006). As stated above, a major component of fish muscle provides perfect ambience for the microbial growth, therefore, a simple heating and rapid chilling process will not serve the purpose. Alongside other hurdles like altering pH, the addition of antimicrobial agents present in various seasonings and spices need to be incorporated in the fishery product exist. After entire treatment with various seasonings and spices, the targeted products are then sealed in hermetically laminated pouches which were further directed for vacuum packing to exclude the air vital for the microbial growth. Subsequently, the vacuum-packed product is then pasteurized at a controlled temperature of 65 to 95°C followed by rapid chilling; stored at a temperature of 0 to 3°C. Generally, heat treatment of 70°C for 2 min is ideal which is found

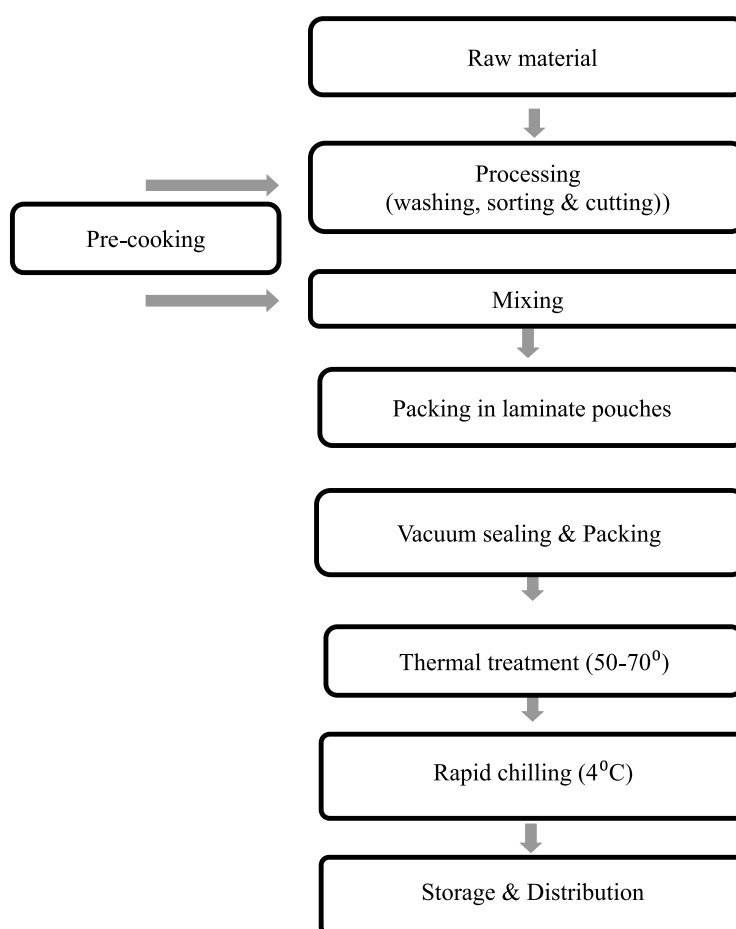


Fig. 1. Flow diagram of SVCC for fish

to be sufficient to kill the *Listeria monocytogenes* in sous vide uncured fish fillets (Gaze et al., 1989).

The fish products intended for SVCC can either be packed raw or in pre-cooked state mixed with ingredients. The product is then filled in plastic pouches without any preservatives thereafter the product is vacuum packed, and heated to 50- 70°C. Further, heat processing is followed by rapid chilling as thermal shock for preservation owing the product to come under cook-chill process. One of the most important criteria during thermal sterilization is the heat treatment, sufficient enough for pasteurization in the laminated pouches to restrain the loss of volatile flavor components and also impedes nutrient leaching and oxidation (Creed, 1995).

Sous-vide processed package assumes the shape of the product due to expulsion of air. The final product is then kept under refrigerated conditions for storage and distribution (Irvine et al., 2017). SVCC products are organoleptically similar to the fresh as no other additives/preservatives are added (except salt in concentration not affecting its aW) maintaining its pH near to the fresh products (meat, poultry or fish) and also minimal cooking preserve its organoleptic characters at par to the fresh one (Calderón et al., 2010). Shelf life of the product varies from 7 to 90 days depending upon the product to be processed (Carlin, 2014).

Nutritional status

Being a cook-chill process sous-vide is mild on the nutritional aspects of the food and as it does not cause any major alterations in the nutrient content (Sampels, 2015). Instead, it can retain the flavor and nutrients in the pouch which otherwise would have been lost by direct heat treatment or conventional cooking. It can also retain the heat-labile vitamins, i.e., ascorbic acid (vitamin C) and vitamin B as the sudden chilling process after heat treatment help in preventing the loss of such labile vitamins (Tiampo, 2006). Due to exclusion of air it also prevents oxidation of the highly unstable unsaturated fatty acids of the fish in turn curtailing the production of toxic metabolites of the fat oxidation process (Hansen et al., 2007).

Microbial safety

Sous-vide foods are not commercially sterile due to minimal heat treatment they receive. Consequently,

it harbors microbes posing threat to consumers from various pathogens like *Vibrio*, *Salmonella*, *Listeria* etc. The heat treatment determines the number and nature of the survival microbial flora in the product by log linearity of the survival curve. In case raw material contains more microbial flora then the log reduction (D value), these microbes requires more heat. The vegetative cells though are heat sensitive can be rendered inactive at lower temperature of 65-70°C but the inactivation of spore formers require higher temperature for their inactivation as compared to the vegetative cells thereby effecting the product quality. Minimal heating for a long time in sous-vide products kill most of the vegetative cells but the spore formers like *Listeria monocytogenes*, *Clostridium botulinum*, *Bacillus cereus* being resistant to low heat, survive (Peck & Stringer, 2005). Furthermore, as the product is vacuum packed flushing out oxygen creates favorable conditions for the most lethal toxin producing anaerobes, *Clostridium botulinum*. The quality of the raw material thereby has an impression on final product quality since it only can reduce the numbers of microbes harboring in food.

Bacterial resistance to heat treatment is expressed as the decimal reduction time or D-value. In other words, D-value can be defined as the time in minutes where heat treatment causes a 90% reduction (10-fold reduction in the survivors) in the microflora (Fellows, 2009). For any organism, with increase in temperature the D-value decreases establishing a linear relationship between temperature and number of survivors. The temperature on the D-value is expressed as 'z' value, that is the temperature yielding a 10-fold reduction in the D-value. In media of high water activity (aW) the heat resistance of spores for vegetative cells is much lower.

Advantages of sous-vide technology:

1. Absence of air in the package facilitate improved heat transfer to the product.
2. No chances of contamination of food after packing.
3. Minimal nutritional changes in the product.
4. Minimal chances of developing rancidity in the product due to absence of air.
5. Indirect heat processing (via steam) facilitate controlled heating conditions to assure the best organoleptic properties.

Guidelines

For any food product, safety guidelines are extremely essential in the processing unit or industry certifying the food to be healthy and safe from all the health hazards. Sous-vide, minimally processed food also requires specific guidelines to certify its safety every time it reaches the consumer. In favour of safety certification for sous vide a code for packaged refrigerated foods has been prepared by the Codex Alimentarius Commission (CAC), *i.e.*, ALINORM 99/13 APPENDIX 111 CAC/ RCP39-1993 (Codex Committee on Food hygiene practice for Refrigerated Packaged Foods with Extended Shelf Life (Alinorm 99/13, Appendix 111), agreeing on food safety standard be imposed in preview of GMP and HACCP. In addition, HACCP plan for such food industry should deal with all the microbiological hazards which are the biggest threat to the sous-vide products should be well defined with proper and sound critical control points. Apart, guidelines are given by the association of USFD (United States Food and Drug) official and European chilled food association for minimally processed products like sous-vide ("Codex Committee on Food hygiene practice for Refrigerated Packaged Foods with Extended Shelf Life (Alinorm 99/13, Appendix 111"; Tucker, 2006). Guidelines for the sous vide products in terms of their storage conditions like low pH, low water activity, packaging, heat treatment, the risk of pathogen survival are in action. For highly safe sous vide fishery products these guidelines should be followed by the fish processing units to avoid any possible risk.

Potential Threats

Employing a pasteurization temperature to retain the quality of the product similar to the fresh one, it poses a threat of germination of injured bacterial spores (Hyytiä-Trees et al., 2000) producing lethal toxins if temperature is not maintained properly temperature lag in the cold chain provide a perfect ambiance for the spores to germinate (Schellekens, 1996). Therefore reducing the pH and a minimum salt concentration of 3.5% will scale down the water activity to a level insufficient for the bacterial growth making ambiance unfavorable for the microbes (Gould, 1999) making it difficult for the injured cells to germinate and produce lethal toxins (Smith et al., 1990). Keeping in view this concern the thermal process employed in sous-vide technology should ensure that cold point receives heat sufficient

for a time period to kill the vegetative bacterial cells preventing its germination. Hence the heat treatment adopted should be satisfactory enough so that cold point receive at least 90°C which need to be maintained for 10 min to inactivate the bacterial vegetative cells (Díaz et al., 2008). In addition to the basic time-temperature combinations, alternative hurdles like acidic pH and addition of spices should also be integrated into the process. In sous-vide not only pathogens but food spoilers too are a major threat to the security of the product (Gonz et al., 2005). Utilization of mild heat in sous vide also leave the enzymes active which can be detrimental for the sous-vide product especially the lysozyme which has been found aiding the germination process of the damaged or injured cell. When lysozyme seeps into the damaged cell it hydrates it causing the injured cells to germinate and produce lethal toxins (Peck & Stringer, 2005). Generally, the shelf life of the sous vide is 6 to 42 days depending upon the composition and nutritional value of the food (Garc & Gonzalezfandos, 2004). The prime asset of sous vide is it offers fresh alike products without the addition of preservatives and low heat treatment ensuring sustained quality of nutrients (fats, proteins, vitamins, amino acids, minerals) (Meynier & Mottram, 1995).

Most research on sous-vide focus upon the pathogenic group of flora and controlling measures to prevent the possible contamination (Borch & Arinder, 2002). The main health risk of these products is the mesophilic anaerobic lethal toxin spore former, *Clostridium botulinum* (Betts & Gaze, 1995) as hermetically sealed pouch provide anaerobic condition providing hospitable ambiance to this group of microbe along with another set of microbes like *Bacillus* (Borch & Arinder, 2002). An alternative to this, another group of deadly pathogens like *Listeria* (Nyati, 2000; Rybka-Rodgers, 2001), *Salmonella* (Peck & Stringer, 2005) and *E. coli* (Can, 2011) also possess a big threat to the safety of these cook chilled products. Among the wide variety of bacterial flora posing threat to the sous-vide, lactic acid bacteria tends to be the most important cause of spoilage which in turn lead to off- odors and off flavors to the product (Borch et al., 1996). Not only bacteria are considered as a potential danger but molds and yeast having a wide tolerance, possess a big threat to the sous-vide products as they can flourish well even under the refrigerated conditions (Nyati, 2000). SVCC's sensory attributes has also been analysed in various studies indicating wide group of bacterial

flora can flourish if there is temperature abuse in the cold chain (Nyati, 2000; Simpson et al., 1994; Vaudagna et al., 2002); changes in the sensory attributes like sheer force, texture, juiciness, freshness of the products has been compared to conventional cooked products where these sous-vide products are found to lead the race with retaining most of the fresh like parameters for a long time based on the composition of the raw material used (García-Segovia et al., 2007; Vaudagna et al., 2002).

Conclusion

Sous-vide an emerging food preservation technology with series of advantages and a few doubts need thorough research work as indicated in many papers because SVCC process is not enough for shelf life extension and therefore any misconduct of cold storage temperature can cause the germination of the lethal bacterial spores, focus has been emphasized over the incorporation of various hurdles in the form reducing the pH, water activity (aW), addition of various seasoning, spices creating inhospitable conditions due to its antibacterial properties to upsurge the safety of these cook-chill vacuumed products (Díaz et al., 2008). Most of the research on sous-vide is confined to microbiology and more studies are required for the diversity in the nutritional and sensory qualities attributed to these products in contrast with the conventional cooking techniques (Rhodehamel, 1992). The nutritional aspects of sous-vide also obligate the need of efforts to investigate the consequence of this process on nutrients existing in the product. To ensure total quality management of the sous-vide products HACCP (hazard analysis and critical control point), GMP (good manufacturing practices) and code of practice consolidation need to be employed in the whole production process (Schellekens, 1996). Along with these regulations, standardization in terms of time-temperature is needed for different products relying on the composition of the product to certify the complete safety of the product so that any lag in the cold chain does not affect the quality of the product considerably (Schellekens, 1996). With recent analysis, irradiation (Shamsuzzaman et al., 1992) and spices incorporated as hurdles give very promising results to this technology. Lack of hygienic processing and quality assurance will escalate the chances of re-infection in case temperature is not maintained properly. Flawless risk management system, plant-process layout, efficient

expertise for handling the production, dissemination, and marketing of the product from the time of collection of raw material till it reaches the customers. Contemporary advancement for safeguarding the product quality by using starter bacterial cultures, bacteriocins and enzymes has great future potential. During the complete process of sous vide production, utmost care should be maintained for guarantying the safety and quality of the sous vide products.

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