Course Name: Canning Technology and Value Addition in Seafood
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Microbiology and spoilage of canned food P2

Understanding the thermal destruction of microorganisms is one of the important factors in the case of canning. The effect of temperature on the destruction of microorganisms or how the microorganisms overcome the effect of temperature using different mechanisms and which are the different conditions that affect the thermal resistance of the microorganisms and understanding of all these properties is very important because using this information only we can clearly design the thermal sterilization process so that it will impact the target microorganism, the survival of the target microorganisms and it can control the survival of the target microorganism so that we can make sure or we can assure 100% safety of the final product which the consumer is intended to consume.

There are different factors that is going to affect the heat resistance of the microorganism. The main factors are the initial number of spores and time temperature combination. So, these are the factors affecting the heat resistance of the microorganisms. So, in the case of initial number of spores, we already know that which is an indication of the quality of the raw material. So, the higher the number of spores, the more severe the processes need to be designed. So, which in turn results in higher energy requirements, deteriorated nutritional standards and nutritional value, etc. So, initial number of spores is going to be very important. We need to keep the initial number of spores as minimum as possible to make sure that whatever the design process is, which is efficient to check the number of the survivors within the speculative limits.

Age of the spores is also very important factor because if it is a fresh spore, it is less heat resistant and very aged spore or already old spores tends to be more heat resistant than the young spores. Time - temperature combination also is important. If the time temperature combination is not correctly planned for that particular targeted organism in that particular food composition your process is going to shortfall than the required level. So, which results in the survival of the target microorganisms and ultimately results in the spoilage or creation of the biohazard to the consumer. And also, other factors also increase the heat resistance of the microorganisms. Presence of fatty acids for example increases the heat resistance, presence of minerals such as iron and calcium increase the heat resistance, a neutral pH tends to increase the heat resistance of the microorganisms.

The water activity increases the heat resistance decreases the presence of water as we already discussed water is necessary for protein hydrolysis or protein denaturation. And

also, more than 10% of sugar is there which can also affect the heat resistance of the microorganism. Also, phosphate ions can also influence the heat resistance. So, these are some of the factors that is going to affect the heat resistance of the microorganisms. So, how the initial number of spores are going to affect the heat resistance is that because the thermal destruction of microorganisms happens in a logarithmic pattern and logarithmic scale means in each category or each log reduction there is going to be a 90% reduction in the number of survivors.

The initial number of spores shall be determined the final number of surviving spores. Whatever be the initial number in each log reduction, only 90% reduction is possible. If the initial number of spores is a big number or like a larger number of initial number of organisms are there. So, we need to have more log reductions to significantly reduce final number of survivors even though in each log there is 90% reduction. So, this significant increase in log cycles will ultimately result in a very intense process and high time temperature combinations which will deteriorate the final sensory and nutritional quality of the product.

And also, age of the spores as we discussed it is very important because young and moist spores are less heat resistant than old spores because young spores will tend to have a higher water content compared to old spores which can reduce the heat resistance of the young spores. So, maximum heat resistance is found in the spores which has aged around 4 to 8 days. The spores are below these 4 to 8 days it tends to have lesser heat resistance and also soil spores which have survived dehydrated conditions the soil and the spore has reached the food through spoil contamination. The soil spores are tending to have a higher heat resistance than liquid which are found in liquid medium or other medium spores. So, and also time temperature and relationship also very important.

If the time temperature decreases or time decreases or temperature increase it should be like either more time or lesser temperature or a low time and higher temperature. So, that also determines significantly the heat resistance of the microorganisms. This heat resistance of the microorganisms is going to ultimately determine whether the organism is going to survive the conditions or not. If in some cases, organisms manage to survive the processing conditions, these organisms will be capable of further reproduction and they can spoil the food. So, spoilage of canned food is also a significant challenge that has to be faced by the manufacturers.

Main reasons for canned food spoilage is basically pre-process handling is one of the important factors and also under processing is an important factor, post-process contamination and also food container interaction. These are the some of the reasons why this the canned food spoil. Under processing is one of the significant processes and under processing may be due to several reasons, may be due to inadequate thermal process to kill the most significant microorganisms. Thermal process that is applied may

be inadequate, may be due to contamination by highly heat resistant organisms not usually present in the food, a highly heat resistant organism may be contaminated. Unusually high level of contamination by usual contaminant microorganism, large number of initial number of spores.

Faulty retort operations that also is one of the important reasons. Improper working of instruments fixed to the retorts, the instruments may be faulty, the reading by the instruments may or may not be proper. Air inside the retort due to incomplete venting, there is air pockets inside the retort so that whatever food container which are held in that particular air pocket may not receive sufficient heat processing temperatures and also changes in consistency, improper filling with respect to high weight of solid, solid liquid ratio headspace etc. can also result in under processing and also low initial temperature of the product. If it is not properly pre-cooked or blanched properly before canning, the temperature may be considerably low.

For example, if you are using a chilled food product and without increasing the temperature of the chilled product, if you are directly putting into canning process, it may drastically reduce the heat transfer processes and result in under processing. What are the general indications of can spoilages? Can is a packaged food, so the appearance of the can can be a good indicator whether the particular in some cases it can be a good indicator whether the canned food is spoiled or not. Appearance of the can, whether the can is bulged, whether it is leaking, whether it is dented or any rusting is there. These are all red flags that we need to look into the can. These are all indicators of the possible spoilage of the cans.

In the case of bulges, the can ends has to be in concave always. A properly canned food product will have concave ends. If the can ends are even slightly bulging is there, we need to discard that particular can because without opening we may not know that whether it is a microbial bulging or it is like a non-microbial bulging or normal gas production or improper venting because a consumer cannot be sure about what is the reason for that particular bulging. So, bulging has to be treated as a red flag and such cans has to be discarded. There is bulging, it has to be discarded immediately.

The can may have gas buildup inside because bulges definitely there is going to be gas builders. If you try to open also the cans can explode and create problems. So bulged can is always a discarding, it has to be discarded and also if the containers are leaking that means the cans maybe subjected to it may be exposed to post-process spoilage. Leaking means the contents are coming outside the container that means the external atmospheric elements can get inside the can as well. So, there is definitely post-process spoilage can happen.

In the case of leaks also it has to be discarded immediately. This can probably the seal

can be compromised. The compromised seal is also very dangerous and also if there is rust it also needs to be discarded because they can rust indicates either a poor storage conditions or the very old container the age of the container. So, in either case it has to be discarded and also dents are also important because dents are an indication of mishandling of the container, improper handling of the container and because of the dents and that part's mechanical strength of that part is compromised when where the dent has happened and such containers may be some kind of microscopic leakage is already started in this particular region. So, these kinds of external symptoms can be considered as unsafe canned goods.

So, depending upon the type of the bulge, different kinds of bulging are there which can be classified. So, bulge cans are classified into four different categories. The first category is flipper cans. Flipper cans are the pressure inside the can is equal to the atmospheric pressure or the vacuum zero or inside pressure is slightly higher than atmospheric pressure and this excess pressure is equal to resistance of the can. When such a can is hit on the table the can and flips out and becomes convex. When pressure is applied, the can becomes convex where the convex end is pressed it becomes flat again. The reasons for the spoilage are basically under exhausting first stage of hydrogen production first stage of microbial activity pre-processing spoilage of food. So, these can be the reasons. So, this flipper bulging happens that in normal appearance there may not be bulge but if we hit the container or handle the container physically a small bulge can appear and if you apply pressure the bulge will go as well. So, this is an initial bulge so that is why it is called a flipper bulge.

Now, another kind of bulging is called Springer. The Springer happens and if the inside pressure is more than in the case of flipper one end of the can remains permanently convex and if this end is pressed down the other end flips out. The reason for the spoilage is the same as the flipper because the Springer is an advanced form of flipper where the bulge is always permanent at either one of the ends is always bulged. So, if you apply pressure in one end, other ends flip out. This Springer is a higher form of flipper and also other swellings are known as soft swells are there. So, they are permanently convex can and pressed by finger it get depressed but when the pressure is removed it regains original bulge. It is also a permanent kind of bulge but it is a soft bulge. A soft swell, because if you apply pressure, the bulge can be removed but if you release the pressure again the bulge reappears. So that there is the final stage of swell is hard swell, they are permanently convex ends and do not get depressed due to pressure by fingers. Soft and hard swells are due to high pressure gases more hydrogen production or advanced bacterial reaction. So, these are the reasons for hard swell. These are the four different stages or different kinds of swellings in the can container. The swelling is considered as one of the most obvious indicators the bulged cans. It can be bacterial spoilage or chemical reaction or any kind of gas production is there.

If you open the container, appearance of the contents is important also, the odor is also very important. Any off flavor any off odor comes that also has to be considered but if there is bulging the container needs to be discarded immediately because a bulged container should not be tried to be opened because it can cause spilling out of the contents of the container. If the can is not bulged that is also not an indicator of a fresh can because there are also different kinds of spoilage which happen without gas production as well. You cannot be sure about the spoilage until you open the container. Once you open the container, we need to check the appearance of the content whether the contents are broken, mushy cloudy etc. and also odor also is a very good indicator. There are different kinds of non-microbial swells as well. There are different foods which react with metal containers; the sulfur is there the sulfur containing amino acids are there which can react with the ions and also this kind of food metal interaction is more in acidic foods. The poor internal occurring is the main reason of this kind of interactions.

It is basically harmless, but a consumer cannot differentiate between a hydrogen swell and a clostridium swell. Swelling is always considered as dangerous because it can be a chemical swell, a non-microbial swell like hydrogen production but it can also be a clostridium swell that it may be due to carbon dioxide or H2S production. In the case of high sugar foods molasses are formed they undergo fermentation; production of CO2 and swelling can be formed and also over filling can also create in small sized cans or larger lid area wise cans like sardine cans this kind of over-filling can result in bulging and also low internal vacuum because if the vacuum exhausting is not properly done the pressure difference in high altitudes can create the small kind of non-microbial swells in the can containers. Hydrogen swells are one of the most important non-microbial swells that can happen inside the can container. The most important chemical spoilage of canned food is the hydrogen swell.

We can say like that the hydrogen gas is formed by the action of the acid or food on the iron base of the can between the acidic nature of the food and the iron content of the container. This spoilage usually occurs in high acid canned foods such as apples, cedar, strawberries etc. Hydrogen swelling is favored by different conditions such as increasing acidity of the food, increasing temperature of the food, imperfection in the tinning and lacquering of the interior of the container, poor exhaust in the can and also due to the presence of soluble sulfur and phosphorus compounds. These conditions can favor the production of hydrogen gas.

There is also incipient spoilage or pre-process contamination and also there is another spoilage known as leaker spoilage or post-process contamination. Product is sometimes

held too long after blanching or canning before retorting. This may be due to power failure to a breakdown of machinery or to the slow accumulation of sufficient cans to fill a retort. The bacterial growth which occurs may cause little obvious spoilage. Spoilage due to contamination after processing or leaker spoilage as it is more commonly called may occur as a result of basically seam damage, contaminated cooling water or pressure drop during cooling.

As we discussed, *Clostridium botulinum* is one of the most target microorganisms or pathogenic target toxin producing microorganisms of canning technology. It is also called as reference microorganism and another reference spoilage reference microorganism is the *Geobacillus stearothermophilus. Clostridium botulinum* is basically a gram positive, obligate anaerobic, rod-shaped spore forming bacteria that produces a toxin called botulinum with characteristic neurotoxicity which causes a neuro paralytic food toxicity called botulism. Some strains of Clostridium *baratii* and *Clostridium butyricum* also produces botulinum neurotoxins but they are not common as *Clostridium botulinum*. Botulinum is basically most potent toxin known to human mankind. It is natural or synthetic with a lethal dose of 1.3 to 2.1 nanogram per kilogram in humans which is bring out lethality at those low levels. So, strains of *Clostridium botulinum* are separated into seven types; A to G types are there based on the serological specificity of the neurotoxin produced. There are human botulism including foodborne, wound and infant botulism is associated with the types A, B, E and very rarely F. Type C and D cause botulism in animals. To date, there is no direct evidence linking type G to any diseases. According to the serological specificity the *Clostridium botulinum* will show specific anti-toxic reactions. Type A and B are most common type of variety. They are the main source of such A and B strains are basically soil and they affect the food through soil contamination. They are also most heat resistant among the Clostridium varieties.

Type B is basically aquatic source and is important one of the important in the seafood and most common cases are home canning because in the home canning, strict observations are not made in the case of time temperature combinations and etc. Previously home canning was the major source of botulism. As we told there are different strains like A, B, C, D, E, F, G strains of *Clostridium botulinum*. Their optimum temperature is around 26 to 28 ˚C with ideal temperature of 35 ˚C and B, E, F and as well as A, C, D are proteolytic in nature. Based on the source of the botulism from which source the botulism is happening also the phenomena can be divided different categories.

For foodborne botulism, is generally happening from the canning industry. Infant botulism is generally botulism associated with honey and bone botulism is also there associated with drug use such as heroin and A and B strains are basically you also use for buttocks in injection in the case of cosmetics and also *Clostridium botulinum* is also used

as an agent in the bioterrorism as well. This also indicates the significance of *Clostridium botulinum* as a food safety hazard. So certain conditions can be followed for preventing the incidence of *Clostridium botulinum*. The growth of the *Clostridium botulinum* can be prevented the acidity of the food is managed below 4.2 pH. Botulism is a neurological disorder created by the ingestion of a botulin toxin. So, there are different kinds of signs and symptoms of botulism. Different kinds of symptoms like facial nerve paralysis, double vision, dry mouth and throat, slurred speech, different kinds of muscle weaknesses, nausea and vomiting and also abdominal dysfunction, coronary complications. These are normal symptoms that usually that we observe when somebody is intoxicated with botulin toxin. So, if we are following certain conditions, we can prevent the botulin risk actually.

It is basically the pH is one of the regulating factors that we can control the occurrence of botulin. Growth can be prevented if the product naturally or by design has a higher acidic value like below 4.2 is the pH range that we are looking for and also the water activity should be low like low water activity will also like you know reduce the risk of botulin toxin and a high concentration of sodium chloride that is also is going to help you. High sodium chloride foods also pose less risk in the case of botulin toxin. An inhibitory concentration of sodium nitrate also or other preservatives can also give a preventive action towards the presence of this toxin or to lower more of these conditions in combination. These conditions in combination can also be provided. The refrigeration will not prevent actually the growth of toxin the growth of the *Clostridium botulinum* as well as the toxin formation but by non-proteolytic strains unless the temperature is precisely controlled and kept below 3 ˚C. The pH and the temperatures are it's going to be the key factors in controlling the growth and proliferation of *Clostridium botulinum*. So, the pH needs to maintain below 4.2 and the temperature has also to be maintained below 3 ˚C. These two conditions are very crucial. Other than botulism or the toxic related spoilage or pathogenic conditions created by *Clostridium botulinum* another kind of spoilage that is caused by a bacterium by a thermophilic bacteria called *Geobacillus stearothermophilus* is called as flat sour spoilage. Actually, *Geobacillus stearothermophilus* and *Bacillus coagulans* are the chief flat sour thermophiles found in canned foods. So, *Bacillus coagulans* is a problem particularly in canned foods exposed to temperatures in the range from 40 to above the pasteurization temperature 40 or above to 60 ˚C and the pH values are on 4.3 and 4.8. *Geobacillus stearothermophilus* is the primary cause of thermophilic spoilage in low acid canned foods because it will grow in the pH range from 5.4 to above neutral pH that is 7. So *Geobacillus stearothermophilus* type organisms sometimes may grow at temperatures as low as 37 ˚C but never below 30 ˚C. So that these are the conditions in which this kind of flat sour producing organisms can survive. If we are maintaining the temperature like or we are quickly passing this temperature when the cooling process is conducted without providing these organisms a chance to proliferate this kind of flat sour spoilage conditions can be prevented. The

terminology called flat sour created because flat means there is no gas production. The containers will be flat that there won't be any bulging and also the sour taste is created by the acid produced by the bacteria. So that is why the spoilage is known as flat sour spoilage. It's caused mainly by slow cooling process as we have already discussed. Why this low cooling process creates a condition for this flat sour spoilage is that it gives more time in optimum thermophilic growth range that is around 45 to 55 ˚C around 55 ˚C to be optimum.

More and more time is spent at this temperature any thermophilic this flat sour forming bacteria and bacterial spores have managed to survive this condition are present in the food. In these slow cooling conditions, this bacterial spore can proliferate at a larger rate and also low hygienic handling is also one of the reasons because this the main source of this thermophilic flat sour causing organisms the soil, different kinds of spices and other ingredients. So, the quality of the raw material is also very important. As they are more heat resistant than *Clostridium botulinum,* this normal processing conditions which are designed to target *Clostridium botulinum* will not work. If the raw material quality is not good there is a higher chance that this kind of thermophilic flat sour spoiling organism spores can survive the conditions and they will eventually create a spoilage a post-process spoilage.

Another kind of common spoilage that we see in the can products is a sulfide blackening or iron sulfide blackening is also known as iron sulfide blackening. Though the cans are coated with sulfur resistant lacquer any imperfection in the lacquer coating during its manufacture or subsequent reforming or any scratches during handling expose the tin layer and the trimethyl amine present in marine products dissolve tin layer exposing iron. This is the main reason for how this tin layer getting exposed. Sulfur containing components of marine products chemically react with iron to form black iron sulfide causing black discoloration on the inner can surface. Mostly, this reaction is under alkaline conditions and when less fresh or spoiled materials are used. Uniform lacquering of can, its careful handling and use of parchment paper by packing can minimize this problem. This problem occurs because the interaction of food with the iron in the can material. That is why it's called iron sulfide because seafood is highly rich in iron, the sulfur containing amino acids. If the lacquer is not proper in marine products because it's having TMA can dissolve tin layer this kind of chemical processes that is happening will expose the steel base of the container and steel is basically iron. So, that iron in the steel can interact with the sulfide in the food product or the seafood.
The iron sulfide is basically black in color, it's not toxic or it does not create any ingestion related problems but it will crucially affect the appearance of the food. These black patches are going to be a deterrent for the consumers and it will affect the consumer acceptability also.

Another common spoilage that found in the can products is known as curd or adhesion. The curd is nothing but salt soluble coagulated proteins or precipitated protein and often found at the top of canned salmon or mackerel. This problem is more in fish canned in a natural style without pre-cooking. The curd may adhere to can surface and the lacquer may get peeled off when the curd is removed. The reasons for curd formation are use of less fresh fish, inadequate brining and pre-cooking. This can be prevented by cold blanching of fish or brining in 10 to 15 percentage brine for 20 to 30 minutes and subsequent washing. This curd or adhesion can be provided by proper pre-processing steps like blanching and pre-cooking and also using good quality raw material. So that this kind of spoilage will not occur.

Another common type of spoilage that we found is a honeycombing. This honeycombing is basically honeycomb like patterns are created over the meat canned meat. It occurs in mostly in canned tuna processed from stale raw material. Raw material quality is one of the main issues of this honeycombing phenomenon. Meat in the can resembles a honeycomb. Usage of fresh raw material and slow thawing of frozen tuna without rough handling can minimize this problem. This happens when the steam escapes. So, when the protein denatures because of the staled raw material, will create the denaturation of the protein, coagulation of protein and through this liquid coagulated protein the steam will escape. When the processing is done, the steam will escape through this coagulated protein creating a small pore like structures. It will basically look like a honeycomb. That is why it is called honeycombing.

Another major spoilage seen especially in crustaceans especially crab like creatures is called blue discoloration. This is mostly associated with crab meat. Meats from parts of the body having poor blood circulation than the legs, claw etc are prone to this kind of spoilage. Such meat shows high degree of blue discoloration. A kind of blue coloration is formed over the meat. The hemocyanin in the crab hemolyms react with sulfur compounds especially during heat processing to produce blue copper sulfide. That is what finally creates a blue discoloration over the meat and that is why it is known as blue discoloration or blue spoilage. This is evident when copper in meat is more than two milligrams per 100 grams. If the copper in the meat in the hemocyanin is more than two milligrams per 100 grams that concentration there is more chance of blue discoloration. The problem can be minimized by thorough bleeding of crab while dressing so that the copper level is reduced to less than two milligram percentage. Other methods of minimizing this problem are use of chelating agents in brine, maintenance of proper acidity in the can etc. Maintaining these conditions, we can minimize the formation of blue color. So, mostly the copper content is going to decide so that proper bleeding etc. if we are following and minimizing the copper content below two milligram per 100 gram. So, this can reduce the chance of blue discoloration in the canned crab meat preparations.

Another common kind of spoilage that we found is retort burns. Retort burn it is usually associated with canned shellfish like clam mussels or oysters. This is due to insufficient filling medium to cover the meat completely. So, retort burn means we already discussed that liquid medium is filled inside canned containers inside the metal containers and different canned products to provide a uniform heating medium other than the flavor and other properties. It is also to provide a uniform heating medium. What happens is that if sufficient liquid is not filled in the container some part of the meat pieces is going to be get exposed through the headspace. So, what happens is that those part will get overheated and overcooked and will be darker in color compared to other part of the meat which is actually submerged within the liquid medium. This is called as retort burn.

Another kind of spoilage known as case hardening is also observed. Surface of fish meat gets dehydrated and hard cover is formed on the surface of the meat caused by high heat process and too quick heating process. When the rate of heating is higher because of many reasons the fish gets dehydrated so far. So, if you are especially in the case of dry packs where no liquid is added and fried fish is added to different containers in such conditions if the heating process is at an accelerated rate this kind of case hardenings may occur.

One of the most important spoilages that is observed among the canned products is known as struvite formation. Some canned marine products such as brine packed shrimp, crab or tuna shows the presence of some glass like crystals. These crystals are made up of magnesium ammonium phosphate hexa hydrate. There is a chemical name for that crystals. These crystals form when the pH of meat is more than 6.8. So, towards the neutral pH this kind of crystals of magnesium ammonium phosphate hexa hydrate is formed. Struvite is basically it is a harmless colorless odorless transparent chemical. However, the large crystals appear as if they are broken glass pieces which are disliked by the consumer. However, if the product is cooled rapidly small crystals are formed and they go unnoticed.

The cooling is also very important. The formation of these crystals may be prevented by the addition of chelating agents such as sodium hexametaphosphate or EDTA. So, these chelating agents can also remove this kind of magnesium, ammonium phosphorous and phosphorous such components and prevent the formation of the crystals. And another form is like other than adding chelating agents make sure that rapid cooling takes place because the rapid cooling what happens is only small crystals are formed which gets unnoticed but if it is a slow cooling process the larger crystals of struvite can may get formed. Use of hard water stale raw material and presence of magnesium in salt used in canning are responsible for the formation of these crystals. These are the major issues that results in the formation of struvite.