Ground beef safety and retail under map conditions

Ground beef is one of the most commonly consumed meat in the USA, due to its relatively low price per pound and its versatility. Ground beef has the capacity to absorb many differing flavors due to exposed fat content throughout the product, and ground beef is able to be shaped into a variety of forms. The change of shape allows versatility that other meat products do not provide to the consumer. What allows ground beef to possess these properties also allows microorganisms to grow and spoil the meat. In comparison with other cuts of beef, ground beef has the highest volume to surface area ratio. The increases surface area, and exposer of fat to air allows spoilage microorganisms to infest the product. This paper reviews a few processes on how to make ground beef safer for consumers, with emphasize on the generally mainstream MAP packaging.

Ground beef is prepared by grinding together trimmings from beef cattle carcasses and larger portions of culled cows that are not considered prime cuts (Gill and Badoni, 2002). The trimmings and larger portions of beef are coarsely ground together and are later finely ground either at either the packaging plant or at the retail outlet (Gill and Badoni, 2002). The combination of trimmings, which include high fat content, and portions of non-prime cuts leads to a complex matrix of cells and microorganisms from the entire carcass. Post mortem myoglobin pH range from between 5. 4 to 5. 8 (Borch, Kant-Muermans, and Blixt, 1996). PH is important in terms of microorganisms for it determines which species can colonize the product. Post mortem beef also contains about 0. 2% glucose and 0. 4% amino acids (Borch, Kant-Muermans, and Blixt, 1996). The amino acid content of beef post mortem is used in part as a fuel source for microorganisms and is consumed at an increased rate with an increased initial microbial load (Jay and Kontou, 1967). Microbial consumption of nutrients like amino acids and glucose lead to a release of volatile metabolites (Ercolini et. al., 2006). The volatile metabolites are a main source of detection of spoilage.

Spoilage has a few possible definitions. The basic definition of spoilage is a change in initial product that is no longer consumable. The moment when a product is spoiled is subjective, but can be affiliated with " changes in color, texture, odor, taste, and microbial counts" (Brooks et. al., 2008). In ground beef specifically, spoilage is characterized by off-odors or off-flavors and can be accompanied with discoloration of the meat or gas production within a sealed package (Borch, Kant-Muermans, and Blixt, 1996). Spoilage of meat can mean that consumers will no longer buy the product, to unnoticed microbial contamination that could lead to health concerns. The point at which beef is spoiled, and cooking cannot provide a safe edible product is of major health concern.

The majority of meat products at retail outlets are packaged and sealed, so that the consumer may visualize the product but may not handle the product directly. The packaging also prevents odors from escaping the meat product. This could lead to the purchase and possible consumption of meat products that have a high microbial load to be a health concern. Microbial spoilage can lead to such odors as putrid, " sulphury", " cheesy", or rancid (Borch, Kant-Muermans, and Blixt, 1996). Some consumers may not detect these odors before consuming the meat product, thus certain procedures were put in place in order to determine when a meat product has a high enough microbial load to be unconsumable. A model was produced that could predict the main microbial growth that could occur on ground beef under a specific temperature (Koutsoumanis et. al., 2006). The mathematical model can predict the shelf life of ground meat dependent on fluctuations in temperature and used *Pseudomonads* as the index due to their high presence on anaerobically stored meat (Koutsoumanis et. al., 2006). A different mathematical model was created to determine shelf life and spoilage of ground beef but incorporated the use of a machine called the electronic nose (Blixt and Borch, 1999). The electronic nose is able to detect volatile compounds that are produced as a biproduct of microbial metabolism (Blixt and Borch, 1999). The electronic nose works as a spoilage predictor due to the accuracy of the model and the results can be obtained in a short amount of time (Blixt and Borch, 1999). The initial microbial load of the ground beef before packaging does influence the rate at which spoilage occurs, with higher initial loads spoiling at a faster rate, which can be recognized by the electronic nose (Blixt and Borch, 1999). An in-depth determination of the specific volatile compounds produced by microorganisms requires a tool known as gas chromatography/mass spectroscopy (GC/MS). The specific volatile compounds determined by GC/MS is then able to be utilized to specify which microorganisms are most likely the source of spoilage in a specific meat product under a specified packaging and temperature conditions (Argyri et. al., 2015). The main volatile compounds that are used to estimate meat spoilage are alcohols, aldehydes, ketones, and esters (Argyri et. al., 2015). Many of the volatile compounds studied contribute to spoilage characteristics, such as odor (Argyri et. al., 2015). GC/MS provided a positive correlation between spoilage characteristics, such as odor, with fluctuations in volatile compounds (Argyri et. al., 2015). The quantity of volatile compounds found within meat products correlates to spoilage of the product, which is due to microbial metabolism (Argyri et. al., 2015). An understanding of the chemical qualities of spoilage can lead to better detection methods and estimators of meat spoilage. This would increase food safety for consumers.

Ground beef like most edible consumer products does contain as minimal amount as possible microorganisms. All edible consumer products contain somewhere on it microbial life, which is a source of spoilage. The microorganisms grow and reproduce under favorable conditions and use organic compounds that comprise the meat as s food source. Over several days stored ground beef microbial diversity lessens, with only a few genera dominating (Jay, Vilai, and Hughes, 2003). There are a few microorganisms that outcompete others in refrigerated packaged environments with limited exposure to outside influences (Jay, Vilai, and Hughes, 2003). Due to refrigeration practices for meat products, psychotropic Gram-negative bacterium, including *Pseudomonads* outcompeted other microorganisms and result in spoilage (Jay, Vilai, and Hughes, 2003). The parameters of the environment that would limit certain species of microbes originally found in ground beef would be the decrease in pH, a specific temperature range from refrigeration, and specific chemical compounds that microbes can use as a fuel source.

It was only in the past two decades that a maximum microbial load on a meat product could be utilized (Borch et. al., 1996). Under refrigeration temperatures regardless of species, the maximum microbial load on ground beef is 10^7-10^9 cfu/cm^2 (Borch et. al., 1996). CFU stands for colony forming unit. The load of bacteria in the first few days however does not guarantee that spoilage can be detected by the consumer, due to the fact that not all microbes produce volatile compounds that are associated with spoilage (Borch et. al., 1996). Once the microbial load is 10^7 cfu/cm^2 or higher, there is a notable odor regardless of the microbes that are colonizing the ground beef (Stern et. al., 1992). The initial microbial load of the ground beef does affect the rate at which the product will spoil, with higher microbial counts initially significantly lowering the shelf life (Stern et. al., 1992). The dominate microorganisms that contribute to spoilage characteristics in refrigerated and packaged ground beef are *Pseudomonas, Brochothrix, Enterobacteriaceae* , lactic acid bacteria (LAB), and a few others (Ercolini et. al., 2006). These bacteria are able to utilize organic compounds that comprise ground beef, such as amino acids, glucose, and proteins (Ercolini et. al., 2006). The colonization of ground beef by these specific bacterium leads to a reduction in other possibly more harmful bacterial colonization. It was proposed that not all of the LAB bacterium try to be eradicated so that it would act as a buffer against more harmful bacteria, such as *Escherichia coli* O157: H7 from colonizing the ground beef (Vold et. al., 2000). The background flora of ground beef inhibits other microbes from colonizing the beef product and lower the health risks (Vold et. al., 2000). If it were possible to eradicate the entire initial microbial load in ground beef, there would be nothing but outside extrinsic factors to limit the microorganisms that could colonize the meat product. It is a major health concern that consumers are not consuming spoiled beef, but that the microbes that are present will not cause a health concern.

A process of packaging was put in place that would decrease the microbial load, increase shelf life, and decrease sources of possible contamination. The type of packaging is called MAP, modified atmosphere packaging, which is where the gas composition within the package differences from the air (Brooks et. al., 2008). MAP lengths the shelf life of ground beef by inhibiting microbial growth and prolonging desirable physical characteristics, such as a red color from oxymyoglobin, without masking indicators of spoilage (Hunt et. al., 2004). In comparison of traditional packaging with MAP, the microbial load over time is significantly reduced in MAP (Argryi et. al., 2015). At the time of packaging or before retail, ground beef is exposed to air in order to convert deoxymyoglobin to oxymyoglobin, which produces that characteristic red color that consumers associated with freshness (Hunt et. al., 2004). The main gas in MAP packaging is either oxygen or carbon monoxide. MAP comprised mainly of oxygen produce a more desirable red coloring that lasts a longer period of time, but MAP comprised mainly of carbon monoxide had a significant decrease in odor production over time (Brooks et. al., 2008). High oxygen MAP has the potential to increase the rate of spoilage due to the gas composition with in the packaging and metabolic pathways microbes use (Vihavainen and Björkroth, 2007). If a product will sell quickly high oxygen MAP might be preferable, but if a product has to last over a longer period of time either due to retail or travel, high carbon monoxide MAP would be preferable. Carbon monoxide MAP produces a paler red coloring than high oxygen MAP (Hunt et. al., 2004). The carbon monoxide decreases aerobic microbial growth significantly, but it might not be as desired by consumers.

Using high carbon monoxide MAP the average refrigerated self-life is seven to ten days (Vihavainen and Björkroth, 2007). Regardless of packaging ground beef products are show spoilage characteristics and should not be consumed due to health concern after 14 days of storage (Ercolini et. al., 2006). Microbial loads are subjective to the beef carcasses used, the microbial load at time of processing and packaging, and can vary depending upon extrinsic factors, such as temperature (Ercolini et. al., 2006). Fluctuations in temperature as meat is processes, packaged, and sold at retail store is highly likely. Meat products need to be below a certain temperature in order to inhibit microbial growth. Temperatures above 10°C are considered abuse due to the fact that microbes increase at a dramatic rate and decrease the shelf life of the product exponentially (Koutsoumanis et. al., 2006). Since abuse temperatures are considered dangerous to public health, ground beef is supposed to be maintained at 2°C throughout the manufacturing process and should be displayed at retail outlets at 4°C maximum (Gill and Badoni, 2002). Variance in temperature is constantly monitored because of the detrimental effect meat products reaching abuse temperatures can have on public health and loss of marketable products.

It is desirable to decrease the microbes present in meat products and rate of spoilage, while increasing marketability. In large cuts of beef, the outside of the carcass undergoes hot water pasteurization in order to eliminate any microbes that are on the surface of the meat (Gill, Bryant, and Badoni, 2001). The idea of pasteurization in order to decrease the microbial load was applied to ground beef. It was found that the rate of spoilage did not decrease a significant amount from pasteurization and the majority of the time consumers could not detect a noticeable difference in pasteurized versus unpasteurized meat (Gill and Badoni, 2002). There are some consumers that notice that pasteurized meat is paler in color, especially the longer the product is stored, which decreases the marketability of the ground beef (Gill and Badoni, 2002). In relation to spoilage the process of pasteurization has little to no effect, but it does decrease the quantity of spore-bearing microbes present (Gill, Bryant, and Badoni, 2001). Certain manufacturing plants and slaughterhouses have an increased risk of spore-bearing microbes contaminating the product due to individualized manufacturing processes or the plant environment itself. Pasteurization is able to significantly decrease the quantity of spore-bearing microbes, such as *E. coli* and coliforms, from ground beef by treatment with 85°C water for 45 seconds (Gill, Bryant, and Badoni, 2001). Pasteurized meat decreases the count of certain microorganisms from the meat, but since it does not affect the rate of spoilage it could be considered unnecessary in many cases. There is one market where a decrease in spore-bearing microbes that can withstand low temperatures, and where slight bleaching would not be considered unusual, which is frozen hamburger patties (Gill, Bryant, and Badoni, 2001). When ground beef is frozen the risk of spore-bearing microbes spoiling the meat is a greater risk than refrigerated ground beef. The process of pasteurization would be beneficial in frozen ground beef products.

Another form of possible sterilization of ground beef proposed was high-pressure (HP) destruction kinetics since high-pressure in conjunction with high heat can eradicate spore-bearing microbes in other food products (Zhu et. al., 2008). When ground beef reaches abuse temperatures there is the possibility that *Clostridium* could revert from the spore stage to the vegetative stage and cause severe health risks if consumed (Kalchayanand et. al., 1989). Spoilage by *Clostridium* is characterized by excessive amount of odor producing sludge, decomposition of myoglobin, and production of gas within a sealed environment (Kalchayanand et. al., 1989). Spore-bearing microbes are generally a public health concern because they are able to survive under adverse conditions. Ground beef in particular can be challenging to eliminate spores because the high surface to volume ratio and higher fat content than other meat products leads to a semi-protective environment for the spores (Zhu et. al., 2008). HP heating provides a safe way to decrease spore counts in ground beef without changing the properties of the meat that makes it marketable to consumers (Zhu et. al., 2008).

Pasteurization and HP are not the only forms of microbial load reduction being used at the moment, irradiation has become a process that increases food safety. Irradiation at low doses of 2. 2 to 2. 4 kGy has been shown to increase the shelf life of ground beef products by up to 14 days (Gamage et. al., 1997). In another study the shelf life of irradiated beef is increase up to 55 days of storage under 4°C, which is dramatically longer than any other form of storage discussed so far (Murano, Murano, and Olson, 1998). This is due to irradiation minimizing microbial growth by damaging structures such as DNA (Gamage et. al., 1997). Immediately after irradiation the microbial count showed a 2-log reduction (Gamage et. al., 1997; Murano, Murano, and Olson, 1998). The storage packaging after irradiation, such as air or vacuum can affect the product (Murano, Murano, and Olson, 1998). There are adverse effects to the meat if stored under vacuum after irradiation, such as off-texture and color (Murano, Murano, and Olson, 1998). Irradiation does change the flavor profile by making the ground beef " juicier", and if stored under air conditions has a dark red color profile (Murano, Murano, and Olson, 1998). Irradiation has shown to be effective in increasing shelf-life of ground beef products but may not be as marketable due to consumers weariness about the use of radiation on food products.

There are other more consumer acceptable ways to reduce microbial counts. Lactates are naturally present in meat, and sodium lactate has shown an antimicrobial effect by delaying microbial growth and reproduction (Shallam and Samejima, 2004). This is a more natural alternative to increase shelf life because if growth and reproduction are delayed then microbes are not creating as high a quantity of volatile compounds. Sodium lactate has been used as an effective means to extend shelf life of meat stored under and aerobic environment, such as certain MAP conditions (Shallam and Samejima, 2004). Lactate although naturally present in meat is a metabolite produced by some microbes, and if present at a high rate when not used as an additive can be a sign of high microbial colonization (Lambropoulou, Drosinos, and Nychas, 1996). There are several processes that can reduce the microbial load in ground beef and extend shelf-life.

Ground beef is a meat product that is consumed in large quantities annually. It is of economic importance that food safety is maintained, while providing a desirable and marketable product. There are several techniques used to determine when beef is spoiled, such as an electronic nose, GC/MS, and mathematical models. The bacteria that can be found in ground beef is diverse with a few dominating as the beef spoils (Jay, Vilai, and Hughes, 2003). The genera or species that causes spoilage depends on extrinsic factors such as temperature, packaging atmosphere, and sterilization procedures. MAP is used by most retailers to provide a fresh product that is desirable in color, texture, and taste without masking microbial colonization or spoilage. There are several techniques to sterilize ground beef, but there is controversy in using some microbes as an inhibitory boundary against health risk microorganisms (Vold et. al., 2000). Ground beef is popular product that must be handled carefully otherwise all of the hard work that is put into safety and marketability will be ruined.

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