ABSTRACT

India is producing twice the amount of protein than the actual requirement; even then, the 2/3\textsuperscript{rd} of the population is suffering from protein deficiency. This is because of heavy losses during storage, processing and distribution. Meat in this reference is vitally important to the Indian people. It provides all the necessary nutrients required for growth and development and hence, it is highly valued for our nutrition, their diet being deficient in the first class proteins, which could be easily obtained from meat. Therefore, from economic, nutritional and public health point of view, the meat processing is of considerable importance to the nation and deserves more attention that it has been receiving in the industrial progress of the country. People are changing their traditional food habits and consequently the demand for meat and meat products is increasing.

A study of live stock population in India shows that with this 205 millions cattle and 90 million buffalo, India ranks first in the world possesses about 50 percent of world buffalo population. India with the world's largest livestock population has estimated meat production of 4.59 million tonnes only. Buffalo meat contributes about 85 percent of total meat being exported from our country. Many of the European countries have started giving due attention to buffalo meat production. Countries like Italy and Bulgaria have initiated planned efforts while in Brazil it has been taken as an industry termed as Black Gold Industry.

Generally the buffalo meat is coarse and tough as it is produced form old and unproductive animals. Such tough meat can be profitably utilized for the development of various comminuted meat products. Ground meat tends to become brown and rancid more rapidly than
whole muscle retail cuts. Such changes are due to pigment and lipid oxidation. Lipid oxidation in meats leads to the development of off-flavour, loss of colour and nutritive value. The production of meat varies considerably from location depending upon a number of factors such as livestock population, method of rearing and management, the availability of suitable fodders, climate, concentration of meat eating communities in an area and finally restrictions imposed on the slaughter of certain animals.

*Rigor mortis* is a temporal process occurring during the time course of post-mortem glycolysis and is characterized by progressive stiffening of the muscle. The rate of post-mortem glycolysis and the extent to which it occurs have implications for muscle food quality. As anaerobic glycolysis proceeds from the point of slaughter to rigor mortis, changes occur in the muscle. The production of $H^+$ leads to more acidic condition in decreased pH of muscle tissue.

For meat selection in a retail supermarket, consumers generally evaluate the sensory properties in terms of colour, surface characteristics, size and shape. The effect of meat colour on acceptance of red meat is well established. The raw meat has a weak, salty and serum like flavour while the true meaty flavour develops during cooking. Meat is an excellent source of iron and this is a nutritional benefit.

Texture is the most important palatability factor that affects the acceptability of meat. Consumers use textural attributes to determine both acceptability and quality. Many consumers define quality in terms of texture i.e. tenderness and juiciness, with more tender and juicy meat considered to have higher quality.
pH is the quality attribute most commonly measured in fresh meat. It affects technological ability, keeping ability and most sensory traits. The ultimate pH attained by the meat has important effects on other properties of the meat. Meat with a high pH is darker in colour than normal, slimy to touch and does not allow salt of curing pickle to penetrate readily.

Reduction in microbial load by either keeping in refrigerated temperature or treating with different ways of preservation like curing, curing with antioxidants and smoking can enhance the hygienic status of meat, provide extended shelf-life, increase consumer acceptability and further improve the export of buffalo meat. Meat proteins are good source of carbon and nitrogen that are essential for microbial growth. Investigations show that smaller butcher shops have poor record of hygiene, and that infection is entering the food chain through faecal contamination on slaughter lines.

Several simple methods have been investigated for reducing the initial microbial load on meat, such as use of water spray, hot water dips, organic acid dips and use of chlorinated water for washing the carcass.

Food lipids oxidation is considered to be risk factors for human health. Some lipid oxidation products and few cholesterol oxides in particular, are considered altherogenic agents and appear to have mutagenic, carcinogenic and cytotoxic properties. Lipid oxidation is one of the primary causes of deterioration in the quality of meat and meat products during storage leading to the development off-flavour, loss of colour and texture and decrease in nutritive value.
Ascorbic acid is a strong reducing agent. It is used as a biological antioxidant to stabilize meat colour by way of pre-slaughter injection in animals, exogenous addition in ground beef, dip treatments of surface application of beefsteaks.

The use of polyphosphate in meat and meat products of beef, pork and chicken has been increasing due to their beneficial effect in improving the functionality of meat and the palatability and storage of meat products. Regardless of its origin, smoking, like curing of meat has been practiced since the beginning of recorded history. Curing and smoking of meat are closely interrelated and are often practiced together, that is cured meat is commonly smoked. The chemical components most commonly found in wood smoke include phenols, organic acids, alcohols, carbonyls, hydrocarbons, and some gaseous compounds such as carbon dioxide, carbon monoxide, oxygen, nitrogen and nitrogen oxide. The primary purpose of food preservation is to prevent food from spoilage. The modern meat industry is based on efficient refrigeration. If longer periods are required, then freezing the meat will extend the storage periods into years. Overall the studies indicated that the meat may be slightly more tender after freezing. The preservative action of refrigeration is based on the prevention of multiplication harmful bacteria, yeasts and moulds by the artificial lowering of temperature. All food preservation methods especially refrigerated or frozen storage are directed to inhibit or decrease the rate of the various reactions responsible for food deterioration.

The development of meatpacking during the last 20 years has brought about major changes in the pattern of its distribution and marketing. The most fundamental function of packaging is to contain and utilize the product in to sizes and cuts required for the market.
Packaging must have both high strength and integrity. Packaging must allow the meat product to be produced and distributed efficiently and economically. The primary function of meat package to prevent contamination is easily accomplished with the range of plastic materials available today. The introduction of vacuum packaging for the distribution and storage of chilled beef has been hailed as the greatest innovation in meat handling during the last 25 years. The intention of MAP has generally been to preserve the fresh meat colour and to prevent an aerobic spoilage by using high concentration of O₂ (50-100%) along with 15-50% CO₂ to restrict the growth of Pseudomonas and related bacteria.

Keeping above stated points in mind the present study was conducted in the Department of Post Harvest Engg. and Technology of A.M.U. Aligarh to investigate the effects of smoking, curing and antioxidant treatments individually and in combinations on various physico chemical, microbiological and textural properties of raw buffalo meat. The effects of packaging material and storage condition on shelf life of buffalo meat was also investigated. The proximate composition of raw buffalo meat was found to be protein 19±1%, fat 10±1%, moisture content 70±3%, and ash content 2±1%. During experimentation it was found that raw meat developed optimum level and desirable characteristics of smoking i.e. glossy surface finish, blooming of colour and tenderization of tissues and uniform dehydration nearly after 8 hours of continuous smoking at 50-60°C temperature while cured as well as cured with antioxidants treated samples took 9 hours of smoking in achieving the same desirable characteristics described earlier. Initially, pH of raw buffalo meat was 5.84. Decreasing trends of pH was observed during further storage. It
was found that pH of raw meat packed in HDPE bags and Al-foils stored at 0°C reached to a value of 5.11 and 5.01 respectively after 40 days in each case.

Logarithmic value of TPC per gram of raw buffalo meat samples was 4.29. After 40 days of storage it went to 5.97 & 6.91 for HDPE and Al-foil packed at -4°C. The meat sample had desirable colour, texture and aroma. The colour started fading with storage. Smoking considerably reduced the microbial population in raw meat. Logarithmic value of TPC per gram just after smoking was found to be 4.20 and pH increased up to 6.14, thus the increase in pH was by 0.3 units over raw meat. During storage colour was not entirely lost even after reaching spoilage condition. This was perhaps due to the surface coating of smoke on meat.

Study on curing of raw buffalo meat was also conducted. It was found that cured meat improved in pH by 0.04 units over controlled meat samples. The cured meat samples were packed in HDPE & Al foils and kept for storage study at 0°C and -4°C. From the results of storage study, it was found that the logarithmic value of TPC per gram started increasing slowly and the cured meat samples were found to be in spoiled condition after 50 & 40 days for HDPE bags & Al foil packaging respectively at 0°C and samples at -4°C has shelf-life 60 & 50 days respectively for HDPE & Al foils. Combined treatment of curing and smoking was also taken for study to see the effect on pH of raw buffalo meat. There was considerable improvement in pH of cured and smoked meat samples over raw buffalo meat. Improvement in pH is indicative of meat quality and extension of shelf life during refrigerated storage. There was slow increment in microbial population after 50 days. Logarithmic value of TPC per gram for HDPE and Al
foil packed samples were found to be 6.68 and 7.91 respectively at 0°C storage while the value of logarithmic value of TPC per gram for the counter part samples stored at -4°C were 5.82 and 6.81 respectively. The shelf-life determination was based on sensory characteristics and microbial characteristics. Two antioxidants Sodium Ascorbate and Sodium Hexa Meta Phosphate (SHMP) were chosen for treatments in combination with meat curing. In the first combination, curing was combined with Sodium Ascorbate and its additional effect was studied over control and cured meat. pH values of the curing combined with Sodium Ascorbate treated meat sample improved to 5.91 as compared to 5.84 and 5.88 for control and cured meat.

The shelf life of sample under both packaging material was found to be 60 & 70 days respectively. Sodium Ascorbate has positive effect on sensory characteristics of meat. Particularly the combined treatment improved odour and colour of meat. Curing in combination with Sodium Ascorbate and smoking had improved the pH meat samples to 6.54. pH value of combined treatment was better as compared to all previous samples. Curing and smoking in combination with antioxidants lead to increment in keeping quality of meat. This treatment caused sufficient reduction in microbial population. The storage study at -4°C of meat samples in both packaging material Al foil and HDPE revealed that the shelf life of samples were 70 and 90 days and corresponding values of logarithmic value of TPC per gram was found to be 5.41 & 6.08 respectively. It was found that curing in combination with antioxidant (SHMP) brought significant improvement in the colour, texture and odour as well as pH and reduced the growth of microbial population.
pH values of the curing combined with SHMP treatment improved to 5.98 as compared to 5.84, 5.88 and 5.91 for control, cured and cured with Sodium Ascorbate samples respectively. The shelf life at 0°C in both packaging material were 60 and 70 days while its counter part sample stored at –4°C had shelf life of 80 and 90 days. The corresponding values of logarithmic value of TPC per gram were 6.81, 7.27 and 7.24 and 6.89 respectively.

Curing in combination with SHMP followed by smoking improved the samples pH to 6.78. It was better as compared to all previous samples. The combined treatment of curing with SHMP followed by smoking caused sufficient reduction in microbial population in comparison to all treatments, which were taken in the present study. Shelf life of the samples under –4°C storage condition was found to be 120 days and corresponding values of logarithmic value of TDC per gram were found to be 7.44 and 5.86 respectively at 0°C & -4°C. For sensory characteristics, it was found that the present combination i.e. smoked with cured and SHMP treated meat samples had better sensory scores in comparison to all samples taken in present study.

Textural analysis of raw buffalo meat was conducted within 24 hours of refrigerated storage conditions at 0°C and -4°C at regular intervals of 20, 40 and 60 days under different packaging material i.e. Al foil & HDPE bags. It was found that the mean peak force measuring hardness of raw buffalo meat was 11547.4 g when analysis was made for buffalo meat on second day. The sample was packed in Al foil and kept for storage at 0°C. Texture analysis of cured buffalo meat was also conducted after treatment and during refrigerated storage condition at 0°C and -4°C under different packaging materials viz, Al foil and
HDPE bags. It was found that the positive mean peak force measuring the hardness of cured samples on very first observation within 24 hrs of storage were 16680.7 g 20926.2 g for samples packed in Al foil and HDPE bags at -4°C. The increased values of mean positive peak forces is due to the treatment of curing solution and storage temperature i.e. – 4°C. Storage temperature at -4°C produced hardness in the meat samples, which caused increment in positive peak forces, while storage at 0°C, did not increase hardness as such.

Textural analysis of curing with antioxidant Sodium Ascorbate treated meat sample were conducted during refrigerated storage temperatures at 0°C & -4°C. The peak forces for samples stored at 0°C for Al-foil and HDPE bags were 15338.6g and 17079.9g, while its counterpart samples stored at -4°C had peak force values 22261.0g and 23356.5g respectively. Further textural analysis showed that the hardness started decreasing, but slowly in comparison to previous samples, packed in either Al-foil or HDPE bags at refrigerated storage temperature 0°C & -4°C. It was also observed that cured meat samples treated with Sodium Ascorbate had higher positive mean peak values at every observation in comparison to the raw and simply cured meat samples. In the case of SHMP treated meat samples, it has higher positive peak force values in comparison to raw, cured and S. A. treated samples. The peak force values for SHMP treated meat samples stored at 0°C and packed in Al-foil and HDPE bags were 16358.6g and 19208.2g, while its counterpart samples stored at -4°C had peak force value 22261.0g and 25381.0g respectively on the very first observation within the 24 hrs of storage. Treatment of SHMP improved the texture and meat samples became more compact as compared to raw meat.
samples. The low temperature of $-4^\circ\text{C}$ added more hardness and extended shelf life.

All treated samples were treated with smoke also. Smoking caused dehydration. It is evident from the all textural graphs that the mean positive peak forces increased due to dehydration and partial cooking effect as compared to only non-smoked raw & treated meat samples. Positive peak force values for samples on the very first observation within the 24 hrs of storage at $0^\circ\text{C}$ packed in Al-foil and HDPE were 12396.6g and 13488.2g for raw smoked, 15773.7g and 19336.2g for cured smoked, 20989.7g and 21040.4g for cured, sodium ascorbate treated and smoked, 21009.7g and 23168.7g for cured, SHMP treated and smoked samples. While its counterpart samples stored at $-4^\circ\text{C}$ had peak force values 13728.4g and 15536.2g for raw smoked, 16754.9g and 21748.7g for cured smoked, 21298.0g and 23168.6g for cured, SA treated and smoked and 214.7.8 g and 29418.7g for cured, SHMP treated and smoked samples respectively.

The samples were kept for storage study and on 20, 40, 60, 80, and 100 day the texture analysis was conducted. It was found that as usual the samples started loosening its texture with the increasing storage period. But the peak force showed that the softening in texture was little bit slow for smoked sample as compared to raw & treated samples. Smoking caused the partial denaturation and dehydration effect on meat, which was the cause of increment of positive mean peak force for smoked meat samples.

The smoking of raw meat created many qualitative changes in raw meat. Smoking of meat is very effective device to preserve the meat. The combined treatment of smoking and antioxidants like Poly phosphate (SHMP) was found to be most successful in improving the
colour, texture and aroma of meat. The shelf-life of meat given combined treatment was 120 days under refrigerated condition. Smoking led to development of a layer of formed sward compounds by thermal decomposition of hard wood. These compounds are phenols, poly phenols, carbonyl compounds and organic acids. Among these compounds some are antimicrobial, some are antioxidants and some are effective in colour and flavor development. The phenol and aldehyde condensation during smoking helped in formation of resins, which added to glossy finished surface to the raw and treated meats. There was considerable reduction in moisture, increment in pH, improvement in colour, texture and odour after smoking. Dehydration effect, antimicrobial and antioxidant properties of smoke were considered to be the responsible factors for the extension of shelf lives of smoked samples. It was observed that curing followed by smoking considerably increased pH and also improved colour, texture and odour of meat.

The samples cured and treated with SHMP and finally smoked were found to be the best as far as quality (physico-chemical properties and textural properties) & shelf life is concerned. There was greater improvement in pH as compared to the individual treatments or any other combination thereof. The samples improved in colour, texture and odour and had maximum score for colour, texture and odour. The storage study established that this sample i.e. samples treated with SHMP and finally smoked has greatest shelf life during storage.

Study on effect of packaging materials on raw and treated meat samples suggested that packaging material played an important role in improving meat quality during storage. The most suitable packaging material for raw and treated meat was found to be HDPE as compared to
Al-foil. The controlled oxygen supply helps in maintaining the colour of meat. The packaging material HDPE therefore allowed the permeation of required oxygen for maintaining the colour of meat. HDPE showed better performance as compared to Al foil in maintaining physico-chemical, microbiological, sensory and textural characteristics of meat samples. This was due to the barrier properties and better sealability of HDPE films as compared to Al foils, which is being used as a wrapping not packing with seal.

As far as storage temperature is concerned, it is very much evident from this work and has been supported by many previous researchers that lower storage temperature increases the shelf life.