INTRODUCTION
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The Indian livestock sector, which contributes 20 percent of the agriculture gross domestic product (GDP), is one of the main sources of family income in rural India. India has the largest livestock population in the world. India produces annually 105 million tones of milk, 45,200 million eggs, and 7 million tones of seafood.

India has 55.7 percent (98.7 million) of the world's buffalo population and 15 percent (185 million) of the world's cattle population. India produced around 2.5 million tones of bovine meat in 2007. The bovine meat produced in India is mainly buffalo meat.

The perishable nature of livestock products necessitates the development of a supply chain for hygienic processing, storage and quick transportation. With proper support form researchers and policymakers, the livestock sector could become a driving force for the agricultural economy.

Meat is a rich nutrient matrix that provides a suitable environment for proliferation of meat spoilage microorganisms and common food-borne pathogens, therefore adequate preservation technologies must be applied in order to preserve its safety and quality. Food safety is a top priority for authorities and consumers worldwide.

The preservation of meats, as of most perishable foods, usually is accomplished by a combination of preservative methods. The fact that most meats are very good culture media having high moisture, nearly neutral pH, high in nutrients coupled with the fact that some organisms may be present in the lymph nodes, bones and muscle and contamination with spoilage organisms is almost unavoidable makes the preservation of meats more difficult than that of most kinds of food. Unless cooling is prompt and rapid after slaughter, meat may undergo undesirable changes in appearance and flavor and may support the growth of microorganisms before being processed in some way for its
Long storage at chilling temperatures may allow some increase in numbers of microorganisms. Many factors influence the invasion of tissues by contaminating microorganisms. The greater the load in the gut of the animal, the greater are the chances for invasion of the tissues. The better and more sanitary the bleeding, the better the keeping quality of meat. If the animal is exited, feverish or fatigued, bacteria are more likely to enter the tissues, thus encouraging the spread of bacteria, and changes may take place more readily in the tissue. Rapid cooling will reduce the rate of invasion of the tissues by microorganisms.

To produce wholesome meat, safe to the consumer, it is essential to enforce strict hygienic standards at all stages of meat production. Slaughterhouses or abattoirs need to follow strict scientific design, with the practice of meat hygiene regulations (sanitation, ante-mortem inspection, post-mortem inspection). Prevention of contamination of the carcass and separation of clean and unclean operations is required. All clean operations like dressing of carcass should be separated from unclean operations like cleaning of stomach or guts, so as to prevent contamination of the carcasses.

Strict environmental sanitation control should be adopted to ensure against the contamination of edible products during transportation of the meat from the slaughterhouse to the market and its sale to consumers. It is ideal to transport meat at refrigerated temperatures. Personal hygiene of all those engaged in slaughtering, dressing and handling of the meat and the meat-products is equally important.

Process control systems should limit microbial contamination of meat to as low a practicable level as possible, and prevent subsequent growth to levels that may constitute a hazard. Hazard Analysis Critical Control Point (HACCP), provides a scientific approach to meat safety and wholesomeness throughout the production, processing and distribution of fresh meat, and the HACCP approach should wherever possible, be utilized with other quality assurance procedures.
Chilling and freezing of meat are the common methods of meat preservation to extend shelf-life. It is considered desirable that the temperature of the meat in any part of the carcass should be reduced to below 10°C within 12 hr of slaughter. As a general guide a deep muscle temperature of 6-7°C should be achieved in 28 to 36 hour. Failure to bring down the internal temperature of carcass will result in rapid multiplication of bacteria deep in the meat resulting in off odours and bone taint.

Apart from Good Manufacturing practices (GMP), decontamination technologies may be adapted to ensure meat safety and wholesomeness. Decontamination procedures such as high pressure washes, use of organic acid rinses, hot water rinses, antimicrobial chemicals have been attempted to increase the shelf-life of meats. Gamma radiation and electron beam are promising non-thermal technologies which are being considered at an industrial level for decontamination of meat products. Combinations of decontamination procedures (as in hurdle theory) may be used to improve effectiveness. In the present study, different treatments have been used to reduce microbial numbers on buffalo meat. Different treatments have also been studied to decontaminate Escherichia coli which is a major microbial contaminant on buffalo meat.
REVIEW OF LITERATURE
Status of the meat industry

Meat volume in India largely comprises bovine, cattle and buffalo with mutton and lamb being relatively small segments (figure 1)

Volume Share of Meat in India(Percentage)

As per the last Livestock census, in 2003, there was a growth of 7.5 percent in buffalo during the previous five years. One of the strengths of Indian bovine meat is its competitive price as compared to other sources of animal protein. Livestock, particularly those which have completed their lactation cycles, are used for meat; hence, the cost is competitive.

Production and Consumption

The domestic demand for bovine meat is growing at a lesser rate as compared to production. The current consumption is estimated at approximately 1.9 million
tones. The per capita consumption of 1.6 kilograms per annum in India is one of the lowest in the world.

Figure 2

Source USDA 2007

The low prices of bovine meat in comparison to other meats keep buffalo meat in the diets of the lower-income groups. Certain regions like South India (Kerala) and states in East India, where consumers display a preference for bovine meat, keep the demand high in these regions.

Most of India's bovines are raised in the backyards of farmers, primarily since the farmers need the milk, the cow dung (used as fuel and manure) and the support in other farm-related activities. Either the farmers themselves or farm level traders who collect animals from farmers, take them to auction and sell animals in the weekly livestock market. At the auction, traders buy and supply the animals to the slaughterhouses, where the animals are slaughtered. Slaughterhouses
largely cater to the wet market or the processing units. Modern abattoirs cater mainly to the export market. The supply chain of bovine meat is depicted (figure 3).

Currently, in India, there are more than 4,000 slaughterhouses that are recognized or authorized by local bodies. In addition, a considerable number of animals are slaughtered in unauthorized places. There are about 14 integrated facilities for slaughtering and processing. The other processors use municipal or other slaughterhouses to meet their requirements.

**Market Dynamics**

**Domestic Market**

Key players include Hind Agro, Allana and Al Kabeer. Hind Agro is the only Indian player that has backward linkages with male buffalo calf rearing. Even though buffalo slaughter is allowed in India, it is permitted only when the buffalo
outlives its useful life as a dairy or a draught animal. Most cities in India have banned street side slaughter of animals, in order to ensure animals are slaughtered in authorized slaughterhouses and the meat is sold through licensed wet market shops.

Export Market

Approximately 29 percent of production is exported, primarily to the Philippines, Malaysia, Egypt and a few countries in the Middle East. Indian buffalo meat is witnessing strong demand in international markets due to its lean and near-organic nature.

Export Destination

The major export markets of Indian Buffalo and Lamb Meat are Malaysia, Philippines, UAE, Egypt, Jordan, Iran, Singapore and South Africa. The Sheep meat is destined for markets in UAE, Kuwait, Oman, Bahrain and Qatar.

India is the third largest exporter of bovine meat in the world and currently exports to over 60 countries. In the last few years, there have been increased sales to countries in Africa – including Egypt, Gabon and Angola – the Commonwealth of Independent States (CIS), Iran, Afghanistan, and Saudi Arabia.

The lowering of subsidies in the EU-27 is leading to reduced domestic production, shrinking export and increased dependence on imports. Australia, which is a significant exporter of beef, has been affected by drought, which has impacted herd building. North America’s export capabilities have been affected by occurrences of bovine spongiform encephalopathy (BSE). Brazil, another large exporter, may not be able to raise production in line with growth in export demand. All these reasons provide Indian buffalo meat exports potential to grow significantly.
To exploit the potential of export market there is a need to establish more large abattoirs cum meat processing plants with the latest technology. These plants are environmentally friendly, where all the slaughterhouse byproducts are utilized in the production of meat and bone meal, tallow, bone chips and other value-added products. The plants follow all the SPS measures required by the International Animal Health Code of the World Organization for Animal Health (OIE).

India is becoming a major buffalo meat producing country and will be a main player in the international market with additional establishment of state of the art abattoirs cum meat processing plants. India’s marketing efforts are increasing exports in both traditional and new markets and production of bovine meat is increasing to meet this demand through investments in meat processing capacity. Meat quality is improving due to better animal health management, greater efficiency in animal production and investments in feedlots.

**Key Supply Chain Issues**

**Disease**

In 2001, the news of food and mouth disease (FMD) adversely impacted the Indian meat sector and caused an estimated loss in 2001/02 of USD 95.2 million (INR 4 billion). Since then, the Department of Animal Husbandry has identified three zones which will be free of FMD. These zones cover the main slaughterhouses of the three major buffalo meat exporters in India. These zones, however, still rely on vaccines for ensuring freedom from FMD. To prevent outbreaks of FMD disease, monitoring could be stepped up with improved facilities at livestock markets and slaughterhouses, including testing by veterinarians.

**Infrastructure**

The infrastructure and facilities at most slaughterhouses are inadequate and outdated. The animals are often kept in poor conditions (due to lack of adequate
infrastructure), which violate the defined norms. In order to improve the slaughter conditions, the slaughterhouses need to be modernized and supervision needs to change. This is specially required to provide hygienic meat in the domestic markets as well as to the export markets.

Cold Chain facilities

Most of the meat that is exported from India is in the frozen form. Basic infrastructure like cold chain, plate freezer, air blast freezers, refrigerated transport, cold storage rooms for meat en route to local and international markets exist. However, the infrastructure needs to be further developed.

Rearing of Animals

India does not have large rearing facilities. Due to the small size of farms, aggregation by processors and management of livestock markets becomes difficult. The rearing facilities can facilitate rearing in herds, rather than of individual animals to enable the proper maintenance of health records and the timely vaccination of animals. Globally, the livestock sector is shifting towards contract farming models. Contract farming allows processors to source animals that meet their requirements, while ensuring the farmers have veterinary support and better remuneration.

Taxation

The current taxation system in the meat sector has had a negative impact on the growth of the processing industry. It creates a non-level playing field between wet markets and the processing industry. Currently, there are no taxes levied on wet-market sales. However, sales tax and VAT is levied on meat which is branded and sealed.

Animal Productivity

Indian animal yields are quite low when compared to international averages. Furthermore, there exists a wide variation in meat yields from buffaloes across
different states. As a result, considerable potential exists to increase meat-
production levels through yield-improvement measures. Some breeds could be
developed and marketed as meat breeds. Farmers need to be educated on
modern scientific methods to fatten male buffalo calves, which are often currently
slaughtered or starved when farmers do not find them useful for draught
purposes.

To achieve all of the aforementioned improvements in rearing, animal
productivity and processing methods, and to meet the increasing demand for
animal meat worldwide, India needs to devote more resources to the training of
manpower for the meat industry.

Production growth largely depends on export demand. Export demand from
traditional markets, such as the Philippines, Malaysia, Egypt and a few countries
in the Middle East, could increase demand, which could be met if investments in
meat processing capacity, better animal health management, greater efficiency in
animal production, and feedlots are undertaken. Besides the traditional markets,
new markets in Africa, the CIS and Southeast Asia, will continue to drive export
demand.

The number of head count of buffalo suggests huge production potential. India
could become a low cost supplier of bovine meat to the world. In order to make
these possible, investments need to be made at the ground level to create
infrastructure like modern abattoirs, cold supply chains, quality control
laboratories and animal rearing units. It is also important to ensure, through
better facilities and veterinary support, that production is free from any kind of
disease.
Table 1: Projected requirement of meat production by 2020 (Kondalah N., 2008)

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Meats</th>
<th>Present production (000 tones)</th>
<th>Projected production requirement (000 tones)</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Beef</td>
<td>1334</td>
<td>1440</td>
<td>7.95</td>
</tr>
<tr>
<td>2</td>
<td>Buffalo meat</td>
<td>1488</td>
<td>3552</td>
<td>138.71</td>
</tr>
<tr>
<td>3</td>
<td>Mutton</td>
<td>239</td>
<td>687</td>
<td>65.21</td>
</tr>
<tr>
<td>4</td>
<td>Chevon</td>
<td>475</td>
<td>934</td>
<td>96.63</td>
</tr>
<tr>
<td>5</td>
<td>Pork</td>
<td>503</td>
<td>840</td>
<td>66.99</td>
</tr>
<tr>
<td>6</td>
<td>Poultry meat</td>
<td>2065</td>
<td>3162</td>
<td>53.12</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>6104</strong></td>
<td><strong>10615</strong></td>
<td><strong>73.90</strong></td>
</tr>
</tbody>
</table>

Table 2: Carcass weight of different meat animals (Kg) in different countries (FAO, 2006)

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Countries</th>
<th>Sheep</th>
<th>Goat</th>
<th>Buffalo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>India</td>
<td>12</td>
<td>10</td>
<td>138</td>
</tr>
<tr>
<td>2</td>
<td>Pakistan</td>
<td>17</td>
<td>17</td>
<td>126</td>
</tr>
<tr>
<td>3</td>
<td>Afghanistan</td>
<td>16</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>USA</td>
<td>30</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Australia</td>
<td>20</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>China</td>
<td>15</td>
<td>13</td>
<td>97</td>
</tr>
<tr>
<td>7</td>
<td>Malaysia</td>
<td>15</td>
<td>9</td>
<td>181</td>
</tr>
<tr>
<td>8</td>
<td>Srilanka</td>
<td>20</td>
<td>19</td>
<td>113</td>
</tr>
</tbody>
</table>
Quality control aspects of meat and meat products: Indian has comprehensive legislation as well as a good administrative system to ensure the food safety and quality of the meat production for domestic consumption and export.

Meat Food Products Order 1973 including amendments up to 1994: The order is implemented by Directorate of Marketing and Inspection. It controls production, quality and distribution of raw and processed products. Indian Food processors adopt the standards prescribed by the Bureau of Indian Standards and Meat Products Order, 1973. The second schedule is Sanitary and other requirements to be complied with by a licensee. The third schedule is Hygienic and other requirements to be compiled with by a licensee who also slaughters animals in his factory. The fourth schedule pertains to requirements to be complied with in regard to packing, marking and labeling containers of meat food products.

Meat food products advisory committee: The committee comprises agricultural advisors to the Government of India. The function of the committee is to aid and advice on matters pertaining to meat food products.

Export quality control and inspection Act (1963): This act was promulgated to promote export trade by ensuring exports of international quality products. The Export Inspection Council has been established to ensure compulsory quality control and inspection of various commodities.

APEDA: Agricultural and Processed Food Products Export Development Authority (APEDA), Ministry of Commerce, Government of India encourages export of agro and processed food products including meat and meat products. APEDA is engaged in determining the area of operation and its action plan in developing technical and analytical quality assurance capabilities. It also conducts specific training programs for quality management systems such as HACCP, TQM and ISO 9002 series and so on.
The Government of India has laid down standards for export of meat which include standards for abattoirs, processing plants and for various meat products. Registration of abattoirs and meat processing plants is done by the (APEDA). Inspection of the meat processing plants is carried out by a committee as per the standards laid-down. During inspection, focus is given to hygiene and sanitary conditions maintained by the plant, ante-mortem and post-mortem inspections, infrastructure, staff hygiene, laboratory facilities, record maintenance, etc. The registration of the meat processing plant is renewed every year after a detailed plant inspection by the committee.

Prevention of Food Adulteration Act (PFA Act, 1954): This is the basic food act which empowers the Central Government to make rules and amend the existing ones. Central Committee for Food Standards (CCFS) is the main standardization and advisory body to make the food control system effective in terms of science-based approach to develop standards for food and other implementation aspects of the food regulation. Central Committee Food Standards (CCFS) has been constituted at the centre to advise the Central and State Governments on matters related to administration of the act.

Bureau of Indian Standards specifications (BIS) (Certification marks) Act 1952 provides third party assurance/guarantee for the consumers. Under this system BIS issues license to a food manufacturing unit which complies with the specifications laid down in the relevant Indian Standards.

Codex Alimentarius: Codex Alimentarius has now been established as the benchmark for ensuring food safety and consumer protection. F.A.O’s manual of food quality control and food for export has become the standard reference in the improvement of quality of food for national and international trade. Continuous surveillance of product by way of sampling and laboratory analysis is essential to ensure that contaminant levels comply with those prescribed by importing countries.

Halal meat concept: The animals under halal method are slaughtered according to Islamic Law under the supervision and presence of representative of Islamic organizations like Mahakama-E-Sharia and Jamiat-Ulema-I-Hind. According to
the Islamic law for halal meat water is to be offered to the animals before slaughtering. The animal should not be slaughtered in front of the other animals. Thorough bleeding is essential in halal slaughter as the well bled animal carcass/meat has better shelf life due to thorough bleeding.

Almost 93% of Indian Meat exports consist of de-boned and deglanded frozen buffalo meat (and the balance sheep/goat meat). This is a risk free product having pH below 6.0, which is achieved by compulsory chilling of the carcasses after slaughter for minimum 24 hours at temperatures between 2-4 degree C. Organization International Des Epizooties (OIE) Paris has confirmed that international trade in deboned and deglanded frozen meat, prepared in accordance with the guidelines formulated under the Zoo Sanitary Code (International Animal Health Code) ensures that there is no risk of transmission of FMD virus.

Veterinary services: Compulsory ante-mortem inspection of livestock, post-mortem examination of carcasses and microbiological testing of the frozen meat is undertaken by the competent Govt. Veterinary authorities ensuring the use of only healthy livestock for meat processing. Government of India provides comprehensive veterinary health services for livestock. Veterinary health care is provided through facilities like poly-clinics, hospitals, dispensaries and first-aid centers. Control of infectious and contagious diseases of livestock is undertaken by systematic vaccination programs. Epidemiological studies are conducted for monitoring and disease diagnosis. Latest know-how on production of vaccines and immunobiologics is applied for this purpose. There are movement restrictions of livestock in disease outbreak areas and movement regulations of livestock meant for trade. Indian livestock is free from the dreaded Bovine Spongiform Encephalopathy (BSE), commonly known as Mad Cow Disease. Unlike FMD, which does not affect the human beings, meat obtained from BSE infected cattle can cause variant form of Creutzfeldt Jacob Disease (CJD) in humans, which is an incurable and fatal disease.

International scenario includes: WTO (SPS and TBT Agreements) and Codex as a benchmark for international trade in food. Codex Alimentarius Commission is
a commission set up by FAO & WHO jointly, consisting of member countries of
FAO, WHO to recommend international standards on various food items, Codes
of hygiene practices for different foods, maximum residue levels for pesticides,
 veterinary drugs, use of food additives etc., 165 countries are members of
Codex. A number of Subsidiary bodies – General Committees (Horizontal) and
Commodity Committees – which make recommendations on the subjects
assigned to them, milk & milk products committee, meat & poultry products, fruits
& vegetables, oils & fats etc. (General -10, Commodity 13, Task Force-3) exist,
Horizontal Standards relate to use of food additives and their maximum levels,
residues of pesticides and residual veterinary drugs, labeling etc. while vertical
standards relate to quality parameters. Regional co-ordination committees, include
countries from Asia, Europe, Latin America and the Caribbean, Near East, North
America & South West Pacific and Africa. Meetings of Commission and its
subsidiary bodies are held and comments of member countries invited two times
before making a final standard.

Production and export of meat from India commenced in the year 1969. During
the previous 37 years, the quantity of meat exported from India has been
increasing and so also the number of countries to which it is exported.
Scientifically it has been proved that deboned and deglanded (boneless) meat,
having pH below 6, is a risk-free product, wherein no harmful virus, including
FMD virus, can survive.

In the entire Republic of India, not a single livestock has been infected with
Bovine Spongiform Encephalopathy (Mad Cow Disease). In India, it is forbidden
by law to feed meat and bone meal or any other animal by-products to the
animals. Additionally, all livestock in India are also free from Rinderpest.
Moreover, there has not been a single incidence of Contagious Bovine Pleuro
Pneumonia (CBPP) in India during the previous 12 years. The livestock are
reared naturally and there is no practice of utilization of growth promoters,
antibiotics, hormones and other harmful chemicals in the rearing of livestock,
which are fed on natural agricultural crop residues.
According to the current Export and Import Policy of the Government of India, each export consignment is subject to compulsory microbiological and other tests and a comprehensive pre-shipment inspection certificate is issued by the Government laboratory. Each export consignment is accompanied by this health certificate. This certificate also states that meat has been prepared from healthy, disease-free livestock, which are free from contagious and infectious diseases, including foot-and-mouth disease and other diseases. The Health Certificate also confirms that the livestock have been subjected to ante-mortem inspection followed by post-mortem examination and that the meat is fit for human consumption.

India is a member country of Office International Des Epizootic (OIE), Paris and is mandated to report list A and list B animal diseases to the OIE, Paris. These reports are then consolidated and published in the Bulletins issued by the OIE. The OIE in its Zoo Sanitary Code has stipulated guidelines for trade in livestock and livestock products which are recognized as international norms. India follows these guidelines for export of meat.

India has a very elaborate and effective Animal Health Service System for systematic control of livestock diseases. This includes efficient disease diagnostic facilities, nation wide surveillance of various diseases and creation of disease free zones to facilitate export of livestock products. There are 250 disease diagnostic laboratories in the country for quick, accurate and speedy diagnosis of the livestock diseases of which 32 laboratories exist at the State level with ELISA facilities. The disease diagnostic laboratories are fully equipped and manned by specialists of different disciplines. The country has 26 veterinary biological units for production of wide range of vaccines using modern and latest technologies. As a result of various programmes launched by the Govt. of India, the incidence of various livestock diseases has been reduced considerably.

- The livestock in India is reared naturally on green pastures and not stall fed. There is also no recourse to growth promoters (hormones) and is, therefore, not harmful to human beings.
- It is fresh frozen product and stored/transported under a cold chain.
• A small quantity of buffalo meat is exported as fresh chilled meat
• It is considered to be 93% chemically lean and is, therefore, virtually free from fat.
• Indian bovine meat is exported in boneless and deglanded form and is, therefore, free from FMD.
• It is available at very competitive prices.

Marketing, Distribution and Sales: The marketing and distribution of meat industry are well developed and sophisticated in view of WTO regulations and well packed quality products imported to India. Coordinated efforts of meat exporters are necessary to maintain the quality, production, packaging and competitive price of products in international markets.

Meat Export From India

Table no.3

Export Potential: The quantity of meat (MT) exported from India is as follows

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Produced</th>
<th>Meat Produced</th>
<th>Buffalo Meat Produced</th>
<th>Total Export</th>
<th>Meat Export</th>
<th>Export Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-02</td>
<td>8425000</td>
<td>1421000</td>
<td></td>
<td>240989</td>
<td></td>
<td>17%</td>
</tr>
<tr>
<td>2002-03</td>
<td>9622000</td>
<td>1428000</td>
<td></td>
<td>295456</td>
<td></td>
<td>21%</td>
</tr>
<tr>
<td>2003-04</td>
<td>5898000</td>
<td>1443000</td>
<td></td>
<td>338940</td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td>2004-05</td>
<td>5922000</td>
<td>1471000</td>
<td></td>
<td>302280</td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td>2005-06</td>
<td>60912000</td>
<td>1582000</td>
<td></td>
<td>449013</td>
<td></td>
<td>29%</td>
</tr>
</tbody>
</table>

Source: DGFT (2006)
Table no 4

Export of Sheep / Goat Meat from India (MT)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahrain</td>
<td>78.8</td>
<td>127</td>
<td>120</td>
</tr>
<tr>
<td>Jordan</td>
<td>37.5</td>
<td>1124</td>
<td>39</td>
</tr>
<tr>
<td>Kuwait</td>
<td>13.8</td>
<td>126</td>
<td>126</td>
</tr>
<tr>
<td>Oman</td>
<td>672.4</td>
<td>1541</td>
<td>392</td>
</tr>
<tr>
<td>Qatar</td>
<td>464.2</td>
<td>936</td>
<td>1278</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>27.7</td>
<td>1587</td>
<td>4002</td>
</tr>
<tr>
<td>UAE</td>
<td>3340.0</td>
<td>4351</td>
<td>2739</td>
</tr>
<tr>
<td>Others</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL</td>
<td>4,973-00</td>
<td>16,030</td>
<td>8,767</td>
</tr>
</tbody>
</table>

Source: APEDA (2005). Average Price Rs. 89/kg. Average Growth – 45%

There has been restricted import of meat & poultry products to India which is carefully monitored for quality by Ministry of Agriculture, Government of India.

The growth in export of meat from India for the next 10 years is expected to be around 15-25%.

Regulations: Both exporting and importing countries have their own regulations in place. In India, BIS specification are followed and in international markets Codex Alimentarius specification are adhered to. All phyto-sanitary regulations prescribed by Codex are universally practiced.

India exports more than 500,000 MT of meat of which major share is buffalo meat. Indian buffalo meat is witnessing strong demand in international markets.
due to its lean character and its near organic nature. Details of exports in terms of quantity and value of Meat products are given as under:

Table No 5

<table>
<thead>
<tr>
<th>Meat Product</th>
<th>2005-06</th>
<th>2006-07</th>
<th>2007-08</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Qty.</td>
<td>Value</td>
<td>Qty.</td>
</tr>
<tr>
<td>Buffalo Meat</td>
<td>460593.32</td>
<td>263389.33</td>
<td>494506.3</td>
</tr>
<tr>
<td>Sheep/Goat Meat</td>
<td>7272.97</td>
<td>8104.24</td>
<td>5777.52</td>
</tr>
<tr>
<td>Poultry Products</td>
<td>1185279.65</td>
<td>31653.03</td>
<td>711245.87</td>
</tr>
<tr>
<td>Animal casings</td>
<td>1125.82</td>
<td>1751.33</td>
<td>435.98</td>
</tr>
<tr>
<td>Processed Meat</td>
<td>745.35</td>
<td>723.98</td>
<td>860.69</td>
</tr>
</tbody>
</table>

(Qty. in MTs & Value in Rs. Lakh)

Source: APEDA

India is the 6th largest exporter of bovine meat in the world. Indian buffalo meat exports have the potential to grow significantly. Due to emerging health threats of the disease communicable to humans through meat, the meat consumers are more vigilant towards the wholesomeness of the meat and demanding meat and poultry products processed in clean and sanitary environment. In metros and urban areas there are upcoming demands for "convenience items" such as semi cooked, ready to eat, ready to cook meat food products.

Value added Meat & Poultry: The value added meat products in India are as follows:
Mutton Products: Mutton Seekh Kabab, Mutton Kofta, Mutton Shami Kebab, Mutton Samosa and mutton sausages.

Chicken Products: Chicken Salami, Nuggets, Chicken Tandoori, Chicken fingers, Chicken Kababs, Chicken kofta and Shami Kababs and Chicken Sausage.

Some of the important buffalo meat cuts are:

**Hind Quarter:** Knuckle, Tenderloin, Strip Loin. Top Side, Silver Side, Rump and Eye Round.

**Fore Quarter:** Blade, Chuck Tender, Cube Roll and Muscles.

**Mutton:** Mutton is normally exported as chilled carcass. Rarely, there is a demand for assorted mutton cubes in 1 Kg packs (18-20 pieces) in frozen form. There is a good demand for chilled mutton carcass weighing 8 Kgs.

**Dressed Poultry:** At present dress poultry export is negligible in view of low price for the product in international market. If the subsidies enjoyed by the farmers in some advanced countries are reduced by their governments then there will be good chances for dressed poultry of India finding export markets.

**Dressed Chicken Plants:** There are several poultry dressing plants. Some plants have a processing capacity of 50000 birds per day.

**By-Products Industry:** The edible by-products of meat industry are liver, heart, kidneys, brain, tongue and tripe which are generally used for local consumption. The giblet of poultry consists of liver, heart and gizzard. There is some demand of chicken leg for soup. Poultry offal is often processed as by-product meal for feed processing plants. Bone meal, meat cum bone meal and meat meal, tallow and hide & skin are used locally.

**Meat Processing Plants – Location, plant capacity & export growth:** The leading modern abattoir-cum-meat processing plants exporting halal buffalo meat from India are as follows
e Hind Agro Industries Limited, Aligarh, Uttar Pradesh
® Indagro Foods Limited, Unnao, Uttar Pradesh
® Frigorifico Allana Limited, Aurangabad, Maharashtra
® Al-Kabeer Exports Limited, Hyderabad, Andhra Pradesh
® Arabian Exports Limited, Koregaon, Pune, Maharashtra
® MKR Frozen Foods Limited, Nanded, Maharashtra
® Al-Nafees Frozen Foods Limited, Delhi
® Amroon Foods Pvt. Limited, Barabanki, Uttar Pradesh
® Frigerio Conserva Allana Limited, Mourigram, West Bengal

The annual production capacity of few big plants is between 50000 -- 75000 Metric Tones. The meat export growth from India in coming years is expected be around 10-25% annually if congenial conditions prevail.

**Buffalo as a source of meat**

India has the largest bovine population in the world. The contribution of livestock to its economy has been estimated to be Rs15000 crores of which the share of meat and meat products is 11.5%. It has been reckoned that the livestock and poultry accounts for 20% of the gross national product.

Meat quality of buffalo is very important from consumer’s point of view. Meat quality is assessed by chemical composition, physical characteristics, microbial profile and sensory evaluation such as colour, taste, texture, juiciness and odour. (Hoda .I. etal, 2002)

Meat is defined as the flesh of animals used as food .In practice this definition is restricted to a few dozen of the 3000 mammalian species; but it is often widened to include, as well as the musculature, organs such as liver and kidney, brain and other edible tissues. The bulk of the meat consumed in India is derived from sheep, goat, buffalo,poultry and pig.
Considerable variability in the eating and keeping quality of meat has always been apparent to the consumer; it has been further emphasized in the last few years by the development of prepackaging methods of display and sale. The view that the variability in the properties of meat might rationally, reflect systematic difference in the composition and condition of the muscular tissue of which it is the post-mortem aspect is gradually being recognized.

An understanding of meat should be based on an appreciation of the fact that muscles are developed and differentiated for definite physiological purposes in response to various intrinsic and extrinsic stimuli.

Livestock has the potential to make immense contribution, direct as well as indirect, towards, alleviating problems of food insecurity, income distribution and poverty. It provides milk, meat, and other edible products that are rich in protein and essential nutrients. About 50 percent of people below poverty line in Asia are associated with livestock, and livestock ownership tends to increase consumption of animal protein. Poor households sell livestock products and live animals for cash income to supplement their livelihood (Taneja V.K. and P.S. Brithal 2003). Livestock ownership is more equally distributed compared to land and thus help improve income distribution and reduce poverty (Adams.R.H. Jr and He,J.J, (1995) Brithal P.S. and Singh M.K., (1995).

Livestock also generates considerable employment for the poor women in the developing Asian countries. Women contribute as much as 70 percent, to the labour required in primary livestock production. The livestock sector therefore present an opportunity to improve livelihood of a large proportion of worlds poor. Growing human population, increasing urbanization and rising per capita income are predicted to double the demand for and supply of livestock products in the developing countries over the next two decades (Delegado etal. 1999). Livestock production is growing faster than any other sub-sector and it is predicted that by 2020, the livestock will produce more than the half of the total global agricultural
output in value terms. The buffalo occupies an important place in livestock economy of Asia.

Buffalo Population

India ranks first in the world buffalo population (96.0 million) and possesses 57.0 percent of the total world population. Major Buffalo producing countries of the world are as follows:

Table No 6 Major Buffalo Producing Countries of the World (Unit: Million heads)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>1990</td>
<td>147.9</td>
<td>162.39</td>
<td>164.9</td>
</tr>
<tr>
<td></td>
<td>1998</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azerbaijan</td>
<td></td>
<td>0.293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bangladesh</td>
<td>0.772</td>
<td>0.850</td>
<td>0.828</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>1.397</td>
<td>1.1</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.023</td>
<td>0.011</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>21.422</td>
<td>22.6</td>
<td>22.6</td>
<td></td>
</tr>
<tr>
<td>Cambodia</td>
<td>0.736</td>
<td>0.71</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>Egypt</td>
<td>2.897</td>
<td>3.15</td>
<td>3.21</td>
<td></td>
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<tr>
<td>Georgia</td>
<td>--</td>
<td>0.01</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>78.320</td>
<td>91.78</td>
<td>93.8</td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>3.335</td>
<td>2.86</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
<td>Iran</td>
<td>0.44</td>
<td>0.47</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Iraq</td>
<td>0.140</td>
<td>0.06</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>0.112</td>
<td>0.17</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>--</td>
<td>0.10</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Laos</td>
<td>1.072</td>
<td>1.92</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.205</td>
<td>0.15</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Myanmar</td>
<td>2.061</td>
<td>2.39</td>
<td>2.44</td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>3.012</td>
<td>3.40</td>
<td>3.50</td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>17.373</td>
<td>22.00</td>
<td>22.70</td>
<td></td>
</tr>
<tr>
<td>Philippines</td>
<td>2.765</td>
<td>3.00</td>
<td>3.02</td>
<td></td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>0.958</td>
<td>0.72</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>5.094</td>
<td>2.20</td>
<td>2.10</td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>0.429</td>
<td>0.19</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Vietnam</td>
<td>2.84</td>
<td>2.91</td>
<td>2.89</td>
<td></td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>0.021</td>
<td>0.016</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

Source: FAO Production year book 2000
Riverine and Swamp buffaloes are two major types of buffaloes. The riverine (Bubalus bubalis) are primarily developed for milk and secondarily for meat and draught. The swamp buffaloes (Bubalus carabanensis) have been developed primarily for draught, while milk and meat are secondary. The riverine buffaloes are found in India and swamp type are found in east of India. Buffaloes in Europe and Latin America are Mediterranean type.

Acharya R.M and Bhat P.N. (1988) classified Indian buffaloes on the basis of well defined characters and categorized them into five groups as follows:

Table No 7: Group, Breed and Breeding Tract of Buffalo in India

<table>
<thead>
<tr>
<th>Group</th>
<th>Breed</th>
<th>Breeding Tract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murrah type</td>
<td>Murrah</td>
<td>Rohtak, Jind, Hisar, Bhiwani, Sonepat.</td>
</tr>
<tr>
<td></td>
<td>Nili Ravi</td>
<td>Ferozepur distt. in Punjab</td>
</tr>
<tr>
<td>Gujarat</td>
<td>Surti</td>
<td>Kaira and Baroda distt.</td>
</tr>
<tr>
<td></td>
<td>Jaffarabadi</td>
<td>Kutuch, Junagarh and Jamnagar districts</td>
</tr>
<tr>
<td></td>
<td>Mehsana</td>
<td>Mehsana, Sabarkantha and Banaskantha districts</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>Bhadawari</td>
<td>Bhadawari estate, Bah tehsil in Agra distt, Gwalior and Etawah districts.</td>
</tr>
<tr>
<td></td>
<td>Tarai</td>
<td>Tarai region of Uttaranchal and UP</td>
</tr>
<tr>
<td>Central India</td>
<td>Nagpuri</td>
<td>Nagpur, Akola and Amravati districts of Maharashtra</td>
</tr>
<tr>
<td></td>
<td>Pandharpuri</td>
<td>South Maharashtra, West Andhra Pradesh and North Karnataka.</td>
</tr>
<tr>
<td></td>
<td>Parlakhemundi</td>
<td>Ganjam, Koraput and Plateau region of Orissa.</td>
</tr>
<tr>
<td></td>
<td>Kalahandi</td>
<td>Hilly region of Andhra Pradesh and Orissa.</td>
</tr>
<tr>
<td></td>
<td>Sambalpur</td>
<td>Biiaspur district</td>
</tr>
<tr>
<td>South India</td>
<td>Toda</td>
<td>Nilgiri hills</td>
</tr>
<tr>
<td></td>
<td>South Kanara</td>
<td>West coast in Kerala</td>
</tr>
</tbody>
</table>
Murrah and Nili Ravi breeds are predominant in North India and are famous for milk and for meat after their productive life is over after 12 to 15 years of age. The other breeds of buffaloes are found in Gujarat, Uttar Pradesh, Central India and South India.

There has been increase in buffalo meat production in almost all the countries except Indonesia, Iran, Malaysia and Sri Lanka. India is the largest producer of buffalo meat accounting for 50 percent (1.4 million tons) of world’s production. It is followed by Pakistan (0.46 MT) and China (0.25 MT). In Europe and Latin America, Argentina is the largest meat producer.

Table No 8: Growth in Buffalo Meat Production in some selected Asian Countries

<table>
<thead>
<tr>
<th>Countries</th>
<th>1981 No. Slaughtered (000)</th>
<th>Meat produced (000 mt)</th>
<th>1998 No. Slaughtered (000)</th>
<th>Meat produced (000 mt)</th>
<th>Growth in meat production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>11,811</td>
<td>1,542</td>
<td>20,955</td>
<td>2,956</td>
<td>91.6</td>
</tr>
<tr>
<td>Asia</td>
<td>10,803</td>
<td>1,409</td>
<td>19,461</td>
<td>2,722</td>
<td>93.2</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>25</td>
<td>2</td>
<td>46</td>
<td>4</td>
<td>100.0</td>
</tr>
<tr>
<td>Cambodia</td>
<td>774</td>
<td>72</td>
<td>2,407</td>
<td>242</td>
<td>236.0</td>
</tr>
<tr>
<td>China</td>
<td>5,969</td>
<td>824</td>
<td>10,169</td>
<td>1,403</td>
<td>70.2</td>
</tr>
<tr>
<td>India</td>
<td>264</td>
<td>92</td>
<td>313</td>
<td>53</td>
<td>-43.3</td>
</tr>
<tr>
<td>Indonesia</td>
<td>48</td>
<td>7</td>
<td>70</td>
<td>11</td>
<td>-42.8</td>
</tr>
<tr>
<td>Iran</td>
<td>39</td>
<td>7</td>
<td>14</td>
<td>2</td>
<td>-42.8</td>
</tr>
<tr>
<td>Malaysia</td>
<td>103</td>
<td>18</td>
<td>148</td>
<td>20</td>
<td>22.8</td>
</tr>
<tr>
<td>Myanmar</td>
<td>2,157</td>
<td>188</td>
<td>4,400</td>
<td>603</td>
<td>273.0</td>
</tr>
<tr>
<td>Pakistan</td>
<td>166</td>
<td>28</td>
<td>269</td>
<td>51</td>
<td>82.1</td>
</tr>
<tr>
<td>Philippines</td>
<td>74</td>
<td>8</td>
<td>36</td>
<td>4</td>
<td>-100.0</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>290</td>
<td>11</td>
<td>270</td>
<td>68</td>
<td>60.9</td>
</tr>
<tr>
<td>Thailand</td>
<td>290</td>
<td>62</td>
<td>488</td>
<td>105</td>
<td>69.4</td>
</tr>
</tbody>
</table>

The contribution of livestock sector in National Economy is increasing year by year. In 2002 -- 2003, the contribution of the sector in National GDP was 5.39. The value of output from livestock sector was Rs.1,56,080 crores at current prices, out of which milk and milk products was Rs. 1,07,544 crores, of meat it was Rs. 24,876 crores (Sirajuddin Qureshi and S.K. Ranjhan 2005). There has been an increase in buffalo population during the last two decades in Asia (34.0 percent and The World (35.0 percent). Meat production is estimated at 5:9 million tones standing fifth in rank in the world’s meat production. Buffalo in India contributes about 30 percent of meat production. The contribution by cattle, sheep, goat, pig and poultry are 31, 5, 10 and 13 percent respectively.

Table No 9: Trends in per capita milk and meat consumption in selected Asian countries, 1991-2000

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>16.1</td>
<td>16.0</td>
<td>2.8</td>
<td>3.2</td>
</tr>
<tr>
<td>Myanmar</td>
<td>11.3</td>
<td>19.6</td>
<td>6.1</td>
<td>9.4</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>34.9</td>
<td>41.9</td>
<td>3.2</td>
<td>5.4</td>
</tr>
<tr>
<td>India</td>
<td>63.1</td>
<td>81.2</td>
<td>4.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Indonesia</td>
<td>5.0</td>
<td>7.7</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Laos</td>
<td>1.6</td>
<td>4.1</td>
<td>11.1</td>
<td>15.5</td>
</tr>
<tr>
<td>Malaysia</td>
<td>50.1</td>
<td>54.0</td>
<td>37.9</td>
<td>52.1</td>
</tr>
<tr>
<td>Nepal</td>
<td>48.2</td>
<td>50.0</td>
<td>10.3</td>
<td>10.5</td>
</tr>
<tr>
<td>Pakistan</td>
<td>117.4</td>
<td>156.8</td>
<td>12.1</td>
<td>12.7</td>
</tr>
<tr>
<td>Philippines</td>
<td>18.4</td>
<td>23.1</td>
<td>18.1</td>
<td>27.3</td>
</tr>
<tr>
<td>Thailand</td>
<td>14.3</td>
<td>21.3</td>
<td>21.3</td>
<td>24.6</td>
</tr>
<tr>
<td>Vietnam</td>
<td>2.1</td>
<td>4.7</td>
<td>16.0</td>
<td>24.7</td>
</tr>
<tr>
<td>China</td>
<td>7.6</td>
<td>11.1</td>
<td>25.9</td>
<td>50.5</td>
</tr>
<tr>
<td>South Asia</td>
<td>63.7</td>
<td>82.2</td>
<td>5.2</td>
<td>5.4</td>
</tr>
<tr>
<td>E &amp; SE Asia</td>
<td>12.1</td>
<td>16.3</td>
<td>14.8</td>
<td>19.9</td>
</tr>
<tr>
<td>Asia</td>
<td>37.3</td>
<td>48.7</td>
<td>17.0</td>
<td>26.7</td>
</tr>
<tr>
<td>World</td>
<td>96.3</td>
<td>94.4</td>
<td>33.6</td>
<td>38.5</td>
</tr>
</tbody>
</table>

Source: calculated from FAOSTAT
Table 10 The trend in Livestock production and Meat production in India
Livestock census—2003 is as follows:-

<table>
<thead>
<tr>
<th>Livestock Species</th>
<th>Population in (Million) (%)</th>
<th>Animal Slaughtered (Million) (%)</th>
<th>Percent Slaughtered</th>
<th>Carcass weight (kg)</th>
<th>Meat production (million Tones)</th>
<th>Share in total meat production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>189.1</td>
<td>14.2</td>
<td>7.9</td>
<td>103</td>
<td>1.49</td>
<td>31.1</td>
</tr>
<tr>
<td>Buffalo</td>
<td>96.0</td>
<td>10.3</td>
<td>10.0</td>
<td>138</td>
<td>1.58</td>
<td>30.5</td>
</tr>
<tr>
<td>Sheep</td>
<td>40.1</td>
<td>19.2</td>
<td>47.9</td>
<td>12</td>
<td>0.25</td>
<td>4.9</td>
</tr>
<tr>
<td>Goats</td>
<td>124.0</td>
<td>47.0</td>
<td>37.9</td>
<td>10</td>
<td>0.57</td>
<td>10.0</td>
</tr>
<tr>
<td>Pigs</td>
<td>18.0</td>
<td>16.0</td>
<td>88.9</td>
<td>31</td>
<td>0.60</td>
<td>10.0</td>
</tr>
<tr>
<td>Poultry</td>
<td>1106.0</td>
<td>604.0</td>
<td>73.6</td>
<td>0.8</td>
<td>1.60</td>
<td>13.4</td>
</tr>
<tr>
<td>Total</td>
<td>6.09</td>
<td>100</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Per capita consumption

Per capita consumption of milk and meat in Asia though has been increasing fast, their consumption levels are below the global average. Between 1991 and 2000, per capita milk consumption increased from 37 to 49 kg and meat consumption 17 to 27 kg in Asia. The global consumption of milk declined from 96 kg to 94 kg and per capita meat consumption grew from 34 to 39 kg. The meat consumption in India was 4.6 kg, China 50.5 kg, Malaysia 52.1, Asia 26.7 kg and World 38.5 kg.
Unproductive buffaloes which are surplus are normally slaughtered for local consumption and surplus for export. There is scope to rare 10 million male buffalo calves per year which otherwise are neglected and die can be salvaged for meat production by fattening.

Buffalo meat is similar to beef with regard to structure, chemical composition, nutritive value, palatability under the same age, nutrition and management practice. Differences are found in the distribution of fat connective tissue. In buffalo carcass fat accumulates more under the skin and on the walls of body cavities less between the muscles and still less within the muscles – less marbling. The surface of larger cuts are rather coarse. The structure of meat derived from older animals has a coarse appearance than the same cuts from younger animals.

Buffalo meat is more reddish brown, coarse fibres than beef. The odour of buffalo meat resembles to that of musk and the fat is strikingly white and is drier and less sticky than in beef.

Table No 11: Characteristics of Various meats available in market

<table>
<thead>
<tr>
<th>Meat</th>
<th>Colour</th>
<th>Fat Consistency</th>
<th>Normal colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>Red</td>
<td>Fairly firm</td>
<td>Creamy white</td>
</tr>
<tr>
<td>Buffalo meat</td>
<td>Dark Red</td>
<td>Firm</td>
<td>Pure white</td>
</tr>
<tr>
<td>Camel meat</td>
<td>Red</td>
<td>Fairly firm</td>
<td>Pale yellow</td>
</tr>
<tr>
<td>Sheep &amp; goat meat</td>
<td>Light red</td>
<td>Very firm</td>
<td>Pure white</td>
</tr>
<tr>
<td>Pork</td>
<td>Light red</td>
<td>Very soft</td>
<td>Grey white</td>
</tr>
<tr>
<td>Horse flesh</td>
<td>Dark red</td>
<td>Soft</td>
<td>White or yellow</td>
</tr>
</tbody>
</table>

Agarwal 1964,
Rheological properties of buffalo meat is superior to beef, only juiciness is less. Water binding capacity is not significantly different. Buffalo meat has more uniform clear red colour but a lower reflectivity than that of beef. The dry matter, protein and lipid contents are little lower in buffalo meat and ash content is the same (Matassine, D., Romita A. et al (1976)).

Buffalo meat is lean with low fat as can be seen in table below:

**Table No 12: Proximate composition of longissimus dorsi muscle**

<table>
<thead>
<tr>
<th>Components</th>
<th>Young</th>
<th>Old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>77.8</td>
<td>79.6</td>
</tr>
<tr>
<td>Protein</td>
<td>19.1</td>
<td>17.8</td>
</tr>
<tr>
<td>Fat</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Ash</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>


Slaughter and dressing of animals

The slaughter and dressing of livestock may be carried out either on the rail or on the slaughter floor. The storage life of meat depends on conditions during slaughter and dressing, much depends on initial bacterial loads. On-the-rail dressing is more clean and hygienic compared to slaughter floor dressing because the operations are carried out above the ground level. A uniform approach to dressing technique in all the countries is not possible due to climatic conditions, stage of development, social differences and religious practices.

In general, during slaughter and dressing of animals, the following are essential:

- Humane Slaughter which refers to stunning of animal either by mechanical, chemical or electric method prior to bleeding.
Proper inspection through ante and post-mortem examination to ensure the health of the animal before and after slaughtering.

Complete bleeding to prevent growth of microorganisms and to improve the appearance of carcass.

Hygienic evisceration and dressing to obtain good quality meat.

Class of animals for slaughter and method of killing

This includes buffalo, sheep and goat, camel and poultry. Slaughter of Sheep and goats have no religious taboos compared to cattle and pigs. Poultry meat is acceptable to many due to low price compared to other meats and lesser chances of adulteration with other meat. Beef, veal, pork, lamb (mutton), goat (chevon) are known as red meat where as poultry meat is known as white meat. In India Halal method for Muslim and Jhatka method for Sikh are more prevalent than other methods of slaughter. Pithing and stunning is not allowed in Halal method.

Preparation of animals to be slaughtered are carried out as follows:

- Removal of feed on the previous evening for slaughter because empty stomach and intestines prevents carcass contamination and ease for evisceration
- Provision for enough water for drinking for animals clears the gastro-intestinal tract, is a humane method and improves quality of meat.
- Ante-mortem inspection to eliminate diseased and unhealthy animals
- Spraying of hooves, legs and underside of abdomen to remove dust, dirt and filth from the body
- Excitement is prevented because stress reduces glycogen content in muscles and thus pH higher than 6.0 prevents setting of meat (rigormortis) i.e. lowering of meat quality.

The modern abattoir layout is as follows keeping in view humane method of slaughter and hygienic, wholesome and safe meat for consumers
Details of abattoir layout is as follows:

Stock yard: for collection and marketing of live-stock in a large number.

- Lairage: to keep 2 to 3 days stock for slaughter.
- Stunning: to make the animals unconscious before killing.
- Slaughter: for killing and bleeding
- Dressing of carcass: to remove hide and skin.
- Inspection of carcass/organs: to detect healthy & unhealthy animals.
Chilling (optional): for setting up of meat.
- Cutting deboning and packaging and dispatch: to produce value added products.
- Quality control: to set up in house quality control laboratory for testing.

Provision is made for:
- Blood collection: for edible and inedible use
- Skin storage: for marketing
- Tripary: for edible purpose
- Condemn carcass: place to hold rejected carcass/organs
- Rendering: converting disease condemned carcass and parts by high temperature processing for animal feed/fertilizer.

The staff facilities include:

Veterinary Doctor's Chamber – to supervise work

- Change room: to change work uniform
- Utility block: general purpose block normally close to abattoir
- Office rooms: located in utility block

Dressing yield and carcass composition are given (Table 14). It appears that 30-40% of the live weight consists of muscular tissue. The proportion of muscle and bone decreases and fat increases as the animals grows older. Meat tends to become tougher with increase in connective tissue content of muscles. Lean meat becomes darker and intensity of flavour tend to increase with increase in age of animals. All these changes affect eating quality of meat. The state of bone and cartilage development is used as an indication of maturity of a carcass and its meat. Growth of bone, muscle and fat takes place in three phases. In the very young animal the skeleton grows more rapidly, and in the next phase muscle growth predominates to support the skeleton, and in the third phase the rate of fat growth reaches a maximum.
Table no 13: Dressing percentage and composition of carcass

<table>
<thead>
<tr>
<th>Species</th>
<th>Dressing %</th>
<th>Composition of carcass</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Meat %</td>
<td>Fat %</td>
<td>Bone %</td>
<td>Skin %</td>
</tr>
<tr>
<td>Buffalo</td>
<td>43-54</td>
<td>65-70</td>
<td>5-10</td>
<td>20-24</td>
<td>-</td>
</tr>
<tr>
<td>Sheep</td>
<td>40-50</td>
<td>55-67</td>
<td>3-8</td>
<td>20-30</td>
<td>-</td>
</tr>
<tr>
<td>Goat</td>
<td>43-52</td>
<td>55-65</td>
<td>3-6</td>
<td>20-32</td>
<td>-</td>
</tr>
<tr>
<td>Pig</td>
<td>70-75</td>
<td>40-50</td>
<td>30-40</td>
<td>10-15</td>
<td>-</td>
</tr>
<tr>
<td>Poultry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broilers</td>
<td>70</td>
<td>52</td>
<td>6</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>Hen</td>
<td>65</td>
<td>37</td>
<td>12</td>
<td>40</td>
<td>11</td>
</tr>
<tr>
<td>Duck</td>
<td>65</td>
<td>34</td>
<td>18</td>
<td>38</td>
<td>10</td>
</tr>
</tbody>
</table>


Edible Meat-by-products

Edible by product forms 20 to 30 percent of the live weight and 5 to 6 percent for chicken. The following table provide by products yield base on live weight.
Table no 14: By-Products Yield

<table>
<thead>
<tr>
<th>By-Products</th>
<th>Percentage of live weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beef</td>
</tr>
<tr>
<td>Cheeks</td>
<td>0.32</td>
</tr>
<tr>
<td>Blood</td>
<td>2.4-6</td>
</tr>
<tr>
<td>Blood, dried</td>
<td>0.7</td>
</tr>
<tr>
<td>Brain</td>
<td>0.08-0.1</td>
</tr>
<tr>
<td>Chitlings</td>
<td>0.06</td>
</tr>
<tr>
<td>Cracklings</td>
<td>3.0</td>
</tr>
<tr>
<td>Edible kill fat</td>
<td>1-7</td>
</tr>
<tr>
<td>Feet</td>
<td>1.9-2.1</td>
</tr>
<tr>
<td>Gizzard</td>
<td></td>
</tr>
<tr>
<td>Hanging tender</td>
<td>0.19</td>
</tr>
<tr>
<td>Head and cheek meat</td>
<td>0.32-0.4</td>
</tr>
<tr>
<td>Heart</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Intestines</td>
<td></td>
</tr>
<tr>
<td>Kidney</td>
<td>0.07-0.2</td>
</tr>
<tr>
<td>Lips</td>
<td>0.1</td>
</tr>
<tr>
<td>Liver</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>Lungs</td>
<td>0.4-0.8</td>
</tr>
<tr>
<td>Pancreas</td>
<td>0.06</td>
</tr>
<tr>
<td>Rennet</td>
<td>0.23</td>
</tr>
<tr>
<td>Skirt</td>
<td>0.2-0.3</td>
</tr>
<tr>
<td>Spinal cord</td>
<td>0.03</td>
</tr>
<tr>
<td>Spleen</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>Sweetbread</td>
<td>0.03-0.05</td>
</tr>
<tr>
<td>Heart</td>
<td>0.02</td>
</tr>
<tr>
<td>Neck</td>
<td>0.02</td>
</tr>
<tr>
<td>Tail</td>
<td>0.1-0.25</td>
</tr>
<tr>
<td>Tongue</td>
<td>0.25-0.5</td>
</tr>
<tr>
<td>Tripe</td>
<td>0.75-2.0</td>
</tr>
<tr>
<td>Bible</td>
<td>0.18</td>
</tr>
<tr>
<td>Plain</td>
<td>0.6</td>
</tr>
<tr>
<td>Honeycomb</td>
<td>0.1</td>
</tr>
<tr>
<td>Weasand</td>
<td>0.04-0.09</td>
</tr>
<tr>
<td>Rendered edible fat</td>
<td>2-11</td>
</tr>
</tbody>
</table>

The degree of fatness and age at slaughter affect the proximate composition meat from fattened buffaloes, compared to meat of lean animals, which has slightly lower value for moisture, slightly lower value for protein and total ash and higher value for fat as shown in the following table.
Table No 15: Chemical composition and nutritive value of buffalo meat

<table>
<thead>
<tr>
<th>Class and Fatness</th>
<th>Water Percentage</th>
<th>Protein</th>
<th>Fat</th>
<th>Ash</th>
<th>Calories Kg</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffalo meat Fat</td>
<td>64.42 19.18 15.40 1.00</td>
<td>2556</td>
<td></td>
<td></td>
<td></td>
<td>Kurbanov, et al 1961</td>
</tr>
<tr>
<td>Medium</td>
<td>68.87 20.15 9.60 1.03</td>
<td>2080</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean</td>
<td>73.35 22.40 1.55 1.08</td>
<td>1386</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buffalo calf Meat*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed by buffalo Milk</td>
<td>71.68 21.41 5.83 1.04</td>
<td>*1400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed by cow Milk</td>
<td>73.15 20.37 5.35 1.01</td>
<td>*1300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Rounded values for calories per kg are calculated on the basis of 4 cal (gm of proteins and carbohydrate and 9 cal per gm of fat).

**Conditions of chilling deboning, freezing and storage:** After the slaughter the carcass is kept in chilling room before being transferred for deboning. The deep bone temperature is +7 C when deboning takes place and the pH level of the carcass is lower than 6.0. After deboning and packaging, the meat is frozen in plate freezer/blast freezer at -40 C. The packed frozen meat is kept at -18 C in a cold storage until the time of shipping.

**Packaging and freezing:** The different parts of the carcass are trimmed during deboning. The deboned meat is poly packed cut wise and is sent for freezing. The buffalo carcass is separated into two halves namely hindquarter and forequarter. Hindquarter contains knuckle, tenderloin, striploin, topside, silverside, rump and eye round while forequarter contains blade, chuck tender, cuberole and meat. The packed meat is put in the carton and is also tagged in
inner and outer cartons showing the type of cuts and name and place of production and date of production. Mutton carcass is usually exported in chilled condition. However mutton cuts are normally frozen in packs, each containing 20 pieces in one kg pack.

Figure no 5: Carcass cuts from buffalo

Source: Information bulletin of Hind Agro Industries Limited, New Delhi

GRADING OF MEAT

Grading of meat according to IS2537:1995, the beef and buffalo carcass is graded on the basis of:

Conformation

The term conformation refers to the general build, form, shape, contour or outline of the carcass, side or cuts. The most desired conformation is the one which
shall yield the greatest quantity of edible meat. Superior conformation implies short necks and shanks, deep plump rounds, thick backs with full loins, and well-fleshed ribs and smooth shoulders. This is in contrast to ranginess and angularity. In other words, the most desirable cuts, including the loin, rib, round or leg, and chuck and shoulder, have shapely and full muscles and a large proportion of edible meat to bone. Terms expressive of poor conformation are narrow, shallow, angular, prominent hips (hippy), hollow loins, long-necked, and lacking in plumpness and uniformly.

Finish

The term finish refers to the quality, amount, colour and distribution of fat. Indications are that fat, within certain limits, increases palatability including juiciness, tenderness and flavour of the meat; it also adds to the general attractiveness of the carcass, side or cut. The best finish implies abundant marbling (intermingling of fat with lean) and a smooth and even covering of firm fat over most of the exterior surface of the rib, etc. The fat should be firm and creamy-white for beef and white for buffalo in colour. In fairly heavy carcasses, deposits of fat are found around the kidney, the flank and brisket. These are indications of degree of finish. Excessive fat means waste and, therefore, is as undesirable as inadequate finish. Intramuscular fat is the fat distributed between the muscles and is desirable unless it is too excessive. Marbling is the liberal distribution of fat between the muscle fibres or within the muscle. It is the marbling that gives to the muscle the streaked appearance. In buffalo meat the tenderness as produced by marbling in beef is generally absent. This is the fat most desired in beef and buffalo meat, but it is dependent to a certain extent to the quantity of the intramuscular fat and outside covering.

Quality

The term refers to the factors which affect the palatability, characteristics of cooked meat, such as colour, flavour, tenderness and juiciness. In general, the indications of quality are Red porous bone as contrasted with hard, white and
flinty bone. Uniformity of the carcass, Uniformity of finish, ample marbling, Fine texture of muscles, evidenced by smooth and velvety appearance, Bright luster of the cut surface and Firmness of lean which means freedom from watery appearance and also freedom from dry appearance.

High quality beef/buffalo meat has a smooth covering of firm, creamy-white fat for beef or white fat for buffalo meat evenly distributed over the exterior. The lean should be uniform and bright. The colour may range from pale-red to deep blood red. It is well-marbled with fat. The texture of the lean is firm, velvety in appearance and fine in grain. However, the buffalo meat is comparatively coarser-grained than beef due to muscle fibres being thicker and seldom interspersed with fat. The bones in young animals are reddish and porous; and in older animals, white and flinty.

- Low quality is indicated by soft or oily fat, dark coloured lean, coarse appearance, hard bone and poor or no marbling.

- A prime carcass combines the highest degree of conformation, quality and finish consistent with palatability.

Generally, the percentage of dressed mass in buffaloes is always lower in comparison to the dressed mass of beef cattle due to the former’s bulky abdomen, large thick bone, massive head, thick hide, and rather poorly developed rump.

Zoonoses

Zoonoses are those diseases and infections which are naturally transmitted between vertebrate animals and man. Workers in slaughter houses have more risk in acquiring zoonoses. More than 300 zoonotic disease have been recorded which include Bacterial zoonoses, Viral zoonoses, Mycotic zoonoses, Parasitic zoonoses, Foodborne disease. Zoonoses may be acquired through the following,

- Direct contact with diseased animals/infected material.
- Consumption of contaminated meat, water, and milk etc.
- Inhalation of infectious organisms.
- Vectors.

Accidental inoculation of pathogen through breach on skin.

The Zoonoses through meat are transmitted by two main modes

(i) Infection and intoxication due to exogenous (human and environmental) contamination of meat and manufactured meat products.

During the course of rearing, transportation, slaughtering, dehiding, skinning, dressing and processing, infective agents are transferred from animals to man through meat handler, equipment and instruments.

(ii) Endogenous animal infections are transmissible to man by meat. The animal themselves are the reservoir of food poisoning organism e.g. anthrax, brucellosis, tuberculosis etc. Salmonellosis occurs more because of the consumption of contaminated poultry meat. Campylobacter jejuni has also been found in poultry meat causing food poisoning.

Some of the Zoonotic diseases prevalent in India are:

1. Rabies
2. Japanese encephalitis
3. Kyasanur forest disease (KFD)
4. Influenza
5. Salmonellosis
6. Brucellosis
7. Anthrax
8. Taeniasis
9. Echinococcosis
10. Guineaworm
11. Tuberculosis
12. Leishmaniasis
13. Scrub Typhus
14. Toxoplasmosis
15. Weil's disease
16. Indian Typhus
17. Q-fever
18. Haemorrhagic fever
19. Tetanus
20. Borreliasis
21. Influenza
Zoonotic diseases are prevalent in India from earlier days. Economic loss due to Brucellosis in terms of annual income from cattle and buffalo is more than Rs 240 million. Mycotoxicosis – fungal toxin produced by Aspergillus, Fusarium, and Penicillium contaminate food of man and animals. This results in damage to liver, kidneys, lungs and also is carcinogenic. Thus effect of toxin on human health and animal productivity is enormous.

**Decontamination techniques**

Many decontamination methods of fresh meats and poultry have been investigated. Some of these rely on washing carcasses or meat cuts with high-pressure water sprays (Cabedo et al. 1996, Zhongping et al. 1998); chlorinated water or chlorine dioxide-generating systems (Unda and Molins, 1989); solutions of organic acids and their salts (Smulders and Woolthius 1985, Mendoca et al. 1989a, Castillo et al. 1998); solutions of various antimicrobial agents such as short-chain fatty acids (Quartey-Papafio et al. 1980); and potassium sorbate alone or combined with other chemicals (Mendoca et al. 1989b). Gaseous decontamination treatments such as ozonation have also been tested (Sheldon and Brown 1986).

Novel physical decontamination treatments based on ultra-high-temperature, ultra-short-time pasteurization of meat surfaces are under development, but their efficacy on highly contaminated spots and crevices in chicken or beef carcasses or parts remains to be proved (Morgan et al. 1996, Nutsch et al. 1998). Other physical decontamination treatments for meat that may prove to be useful in the future, such as high hydrostatic pressure (Ananth et al. 1998) and pulsed electric fields (Pothakamury et al. 1996), are still in early development stage.

**Pathogen Reduction**

Foodborne illness remains a serious problem. In the United States, it is estimated that foodborne disease caused by pathogenic bacteria may cause as many as 9000 deaths, and 6.5 million to 33 million cases of diarrheal disease. Meat and poultry are primary sources of foodborne illness worldwide.
Bacterial contamination of beef carcasses is an unavoidable consequence of processing cattle into meat. This contamination can come from processing equipment, workers, and the environment, but the primary source is the animal. The hide, hooves, intestinal contents, and milk can harbour large numbers of bacteria, some of which are pathogenic. Therefore, all such visible contamination must be removed from the surfaces of beef carcasses.

**Antimicrobial Interventions in the Slaughter Process**

There are numerous anti-microbial interventions being utilized in slaughter processes. The most commonly used interventions and their effectiveness as shown in scientific studies are described below. Anti-microbial interventions are not a substitute for sanitary dressing procedures.

**Beef Slaughter Interventions**

Until recent years, knife trimming and carcass washing with plain water have been the primary means by which the industry addressed meat contaminants. However, the occurrence of foodborne disease outbreaks and scientific advances over the years have shown that trimming and washing alone will not accomplish the level of food safety that regulators and consumers expect from meat products. In response to food safety concerns, the industry and scientific community, with encouragement from Food Safety Inspective Service U.S.A (FSIS), have introduced as follows. Numerous antimicrobial interventions in the beef slaughter process are practiced.

**Steam Vacuum System**

Steam vacuum systems are designed to remove small visible spots of contamination from carcass surfaces. The steam vacuum is a hand-held apparatus that uses a hot water spray (185 degrees F.) in a vacuum nozzle, with steam sprayed above and below the vacuum head. The hot water sprayed onto a
carcass kills 90% or more of the bacteria and detaches contamination such as ingesta and faeces, which is then vacuumed off. The following bulleted items may be considered as guidelines for the use of the steam vacuum system. Establishments may develop alternate parameters and should have supporting documentation to validate the use of such parameters.

**Carcass Washes Followed by Organic Acid Rinses**

After hide removal, the carcass may be subjected to a pre-evisceration wash and subsequent organic acid rinse. The use of a carcass spray immediately after hide removal serves to remove bacteria before they have the opportunity to attach to the carcass surface and begin growing. The subsequent organic acid rinse then provides a significant kill step for any bacteria that remain on the carcass surface. This intervention is also applied after the slaughter process is complete and before the carcasses enter the cooler. The organic acids commonly used are acetic and lactic, although citric acid is also approved for this purpose. The concentration of the organic acid is between 1.5 and 2.5 percent and it may be used as a mist, fog, or a small droplet rinse.

**Other Antimicrobial Chemicals**

Some other chemicals utilized as an anti-microbial rinse in beef slaughter include the following:

* Acidified Sodium Chlorite (Sanova ®) – has been shown to have a significant kill rate for *E. coli*, *Listeria*, *Campylobacter*, *Salmonella*, and other bacteria. Applied at ambient temperature by spray at 500- 1200 ppm; it is being used in several establishments across the country.

* Lactoferrin – Applied as a spray in a 1% solution as a final step of the slaughter process. Lactoferrin has been shown to be effective against more than 30 foodborne pathogens, including *E. coli*, *Salmonella*, and *Listeria*.  

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Hot water Rinses

High temperature water (>160 degree F.) sprayed on the carcass as the last step prior to chilling has been shown to be effective in reducing the numbers of E. coli and Salmonella.

Steam Pasteurization

Steam pasteurization is a process where carcasses are placed in a slightly pressurized, closed chamber at room temperature and sprayed with steam that blankets and condenses over the entire carcass.

The surface temperature of the carcass is raised to 185 degrees F. which results in the killing of 95-99 percent of all bacteria. Carcasses are then sprayed with cold water which reduces the surface temperature of the carcasses to approximately 60 degrees F. The rapid procedure prevents discoloration and a "cooked look" to the carcasses. The steam pasteurization system is an efficient automated technology which kills a large percentage of bacteria on carcass surfaces and greatly reduces the risk of enteric pathogens such as E. coli and Salmonella in the meat supply.

Multiple Hurdle Approach

Studies have shown that it is more effective to use the "multiple hurdle" approach to pathogen control rather than relying on any one intervention. Using the "multiple hurdle approach," an establishment will utilize multiple interventions at various steps in the slaughter process to achieve maximum reduction of bacterial numbers on the carcass. For example, an establishment may use the steam vacuum at multiple locations as the hide is removed; rinse the carcass with water followed by an anti-microbial spray prior to evisceration and after evisceration wash the carcass with water, followed by steam pasteurization and rinsed again with an anti-microbial spray.
Thermal Organic Rinse (TOR)

Thermal Organic Rinse (TOR) utilizes organic acid heated to 131 degrees F. provides the most effective documented anti-microbial performance. TOR has been documented by independent university researches as providing bacteria reduction of 99.9999 percent when used as part of the company's "multiple hurdle" intervention.

TOR provides one more shield against potential contamination with *E. coli*, *Listeria*, *Salmonella*, or *Campylobacter*.

Meat Quality

The quality of meat produced in the existing traditional systems in India is far from satisfactory. Thus there is a need to bring improvements in infrastructural facilities and training of operators in hygienic meat production. Few modern abattoirs that exist are facing the problems related to maintenance. Export houses (buffalo processing units) have modern abattoirs and follow scientific method of handling of meat. CFTRI has developed abattoir models for hygienic processing of buffalo meat.

The need for hygienic meat production has gained importance due to awareness among consumers world over about the health risks associated with microbial contamination of meat. Development of hygienic processing systems is always a challenging problem for providing safe and wholesome meat to the consumers. Understanding of meat food chain is important to improve the microbiological status of buffalo meat (Narasimha Rao 1998). Application of Hazard Analysis Critical Control Point System (HACCP) and hygienic and sanitary measures are crucial during processing of buffalo. The hygienic measures followed include abattoir clan up operation, processing on overhead rail, careful removal of skin and viscera, closure of oesophagus, rectum, and washing the carcasses with spray of water. Studies were conducted at CFTRI on hygienic processing of buffalo carcass in modern abattoir and microbiological quality was assessed. The studies revealed low microbial profile in meat processed in a modern abattoir as
compared to traditional units (Yashoda et al. 2000). The meat cuts obtained from hygienically processed carcasses had a shelf life of six days as against three days for those obtained from traditional slaughter unit. The minced meat from hygienically prepared carcass had a shelf life of four days as against one day for those obtained for local slaughter unit.

Table 16: Shelf-life of meat at various storage temperatures

<table>
<thead>
<tr>
<th>Product</th>
<th>Storage Temp.</th>
<th>Shelf Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat Product-cuts</td>
<td>4±1°C</td>
<td>5 days</td>
</tr>
<tr>
<td></td>
<td>-12°C</td>
<td>8 months</td>
</tr>
<tr>
<td></td>
<td>-18°C</td>
<td>18 months</td>
</tr>
<tr>
<td>Minced Meat</td>
<td>4±1°C</td>
<td>3 days</td>
</tr>
<tr>
<td></td>
<td>-12°C</td>
<td>6 months</td>
</tr>
<tr>
<td></td>
<td>-18°C</td>
<td>10 months</td>
</tr>
<tr>
<td>Poultry</td>
<td>4±1°C</td>
<td>4 days</td>
</tr>
<tr>
<td></td>
<td>-12°C</td>
<td>9 months</td>
</tr>
<tr>
<td></td>
<td>-18°C</td>
<td>18 months</td>
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<tr>
<td>Cooked Products</td>
<td>2±4°C</td>
<td>15 days</td>
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<td>-12°C</td>
<td>6 months</td>
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<td>-18°C</td>
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Source: International Institute of Refrigeration, Paris

CONTROL OF MICROORGANISMS IN FOOD

1. Control of Access (cleaning and sanitation)
2. Control by Physical Removal
3. Control by Heat
4. Control by Low Temperature
5. Control by Reduced Water activity
6. Control by Low pH and Organic Acids
7. Control by Modified Atmosphere (or Reducing O-R Potential)
8. Control by Antimicrobial Preservatives
9. Control by Irradiation
10. Control by Novel Processing Technologies
11. Control by a combination of methods (Hurdle Concept)

ANTIMICROBIALS

Antimicrobials are used to prevent or inhibit the growth of microorganisms. They play a major role in prolonging the shelf-life of foods. Nowadays, consumers expect all foods to be available all year round and to have a fairly long shelf-life. In dietary behavior, however, risks from microbial contamination are often overlooked.

As far as food safety from a microbiological viewpoint is concerned, some advances have been made without calling in the help of additives. These involve the application of certain packaging and processing methods. Nevertheless, the use of chemical antimicrobials is indispensable for safe food handling.

Contamination of animal carcasses during slaughtering procedures is undesirable, but unavoidable in the conversion of live animals to meat for consumption. Dickson J.S. et al 1992. Throughout the slaughter and fabrication processes, bacterial populations are spread among carcasses by slaughter/fabricating instruments, plant workers, cutting tables and the processing environment.

Common antimicrobial food additives are benzoic acid and benzoates, sorbic acid and sorbates, short-chain organic acids (acetic acid, lactic acid, propionic acid, citric acid), parabens (alkyl esters of p-hydroxybenzoic acid), sulfite, and nitrite. Most of these substances are believed to be safe for application in food. They are easily excreted and metabolized by both animal and man. An exception
should be made for one of them, namely nitrite. The intake of nitrite can lead to the formation of nitrosamines, which are well-known carcinogens.

The inhibitory effect of Sodium acid pyrophosphate and Sodium lactate in raw buffalo meat mince stored at 4°C for 16 days and 37°C for 36 h against *Listeria monocytogenes* was carried out by Pawar et al (2002). Minced meat was evaluated for physicochemical (pH, extract release volume) and microbiological (mesophiles, psychrophiles, *Listeria* sp) qualities. Addition of Sodium acid pyrophosphate (0.5%) to meat mince significantly (P< 0.05) inhibited *L. monocytogenes* after day 10 of storage at 4°C but favoured the growth of the pathogen at 37°C. A mixture of Sodium acid pyrophosphate (0.5%) and Sodium lactate (2.5%) significantly (P< 0.05) reduced the count of the pathogen at both the storage temperatures. This combination of food grade preservatives could be used as effective listeriostatic in minced meat stored at 4°C as well as at 37°C.

Sodium diacetate alone can be used to delay growth of *L. monocytogenes* in turkey, and an additional level of safety can be achieved using diacetate in combination with sodium lactate and pediocin. (Schlyter JH et al, 1993)

D.D. Pawar et al (2001) also studied the survivability of pathogenic *Listeria Monocytogenes* against Nisin and its combination with Sodium chloride in raw buffalo meat mince. Nisin (Ambicin N) was used alone at concentrations of 400,800 and 1200 IU/g and in combination with 2% sodium chloride in raw buffalo mince stored at 4°C for 16 days and 37°C for 36 h. Initial microbial analysis of meat mince revealed pH, extract release volume, mesophiles and psychrophiles count as 5.76, 49, 33x10^4 and 15x10^4 cfu/g of meat, respectively. All the combinations of preservatives inhibited the count of *L. monocytogenes* significantly (P< 0.05) at both the storage temperatures when compared to the control. Addition of 2% sodium chloride increased the efficacy of nisin against *L. monocytogenes* in all the three combinations. The degree of inhibition was more at higher concentration of nisin and lower temperature. pH in treatment groups remained significantly lower than the control groups at 4°C (P< 0.01) and
37 °C (P< 0.05). Results indicated that the combination of food grade preservatives could be an effective listeriostatic in minced meat.

RADIATION TREATMENT

Food irradiation is a process in which gamma rays or electrons are used to disinfect, preserve or sterilize food. The most common source is Cobalt-60, a radioactive isotope that emits gamma rays as it decays. Irradiation could be applied judiciously where conventional methods are inadequate, uneconomical or pose potential health risk. It can be used as a complimentary process with many existing procedures.

Irradiation has a multipurpose role in the processing and conservation of foods. Application of radiation at different doses serves four different purposes in preservation and safety, namely

- Destruction of spoilage microbes
- Elimination of pathogens and parasites
- Inhibition of sprouting
- Eradication of insects

Radiation processing is an important emerging technology for strengthening food security, improving food hygiene and overcoming quarantine barriers in international trade. The technology is being increasingly adopted worldwide both by the developed and developing countries. Foods processed by radiation is claimed to be safe, wholesome and nutritionally adequate.

Food and Agricultural Organisation (FAO), World Health Organisation (WHO), International Atomic Energy Agency (IAEA) and Codex Alimentarius Commission (CAC), have affirmed safety of foods processed by radiation. The agreements on sanitary and phytosanitary (SPS) practice and technical barriers to trade (TBT) under the World Trade Organisation (WTO) has provided a distinct incentive to the adoption of irradiation as an SPS measure in international trade.
under the principle of equivalence. (Arun sharma, 2000) Thus irradiation has been recommended to overcome quarantine barriers and to hygienize products for international trade.

Ionizing radiation can be an effective step in a HACCP program to kill enteric pathogens associated with meat and poultry products. (Thayer D.W., 1996)

Radappertization (10-50 kGy) is the application of doses of ionizing radiation sufficient to reduce the number of viable organisms (excluding viruses) to such an extent that few (if any) are detectable in the treated food by any recognized method, and no spoilage or toxicity of microbial origin is subsequently detectable, irrespective of the duration or conditions of storage (provided no recontamination occurs). It is analogous to thermal sterilization as understood in the canning industry.

Radicidation (2.5-10 kGy) involves doses of ionizing radiation sufficient to reduce the number of viable, specific, non-spore-forming pathogenic microorganisms (other than viruses) so that none are detectable in the treated food when it is examined by any standard method. Radicidation eliminates parasites such as Trichinae and cysticerci in pork and, very importantly, Salmonella organisms in poultry and red meat.

Radurization (1-3 kGy) is the term applied to a dose of ionizing radiation sufficient to enhance keeping quality by causing a substantial reduction in the numbers of viable, specific spoilage organisms. It is equivalent to pasteurization and it is thus essential to employ refrigeration during subsequent storage.

The objectives of meat and poultry irradiation are essentially inactivation of parasites and bacteria. The process may be targeted toward one microorganism or group of microorganisms or encompass a wide variety of organisms. Specific radiation doses can be applied for parasite inactivation or destruction, for elimination of pathogenic bacteria, for reduction in numbers of spoilage microorganisms to attain extended shelf life, and for elimination of bacterial
spores to achieve product shelf stability (Kampelmacher 1983, Henon 1983, Murano 1995, IAEA 1996, Lee et al. 1996, Loaharanu 1996). The highly effective antiparasitic and bactericidal properties of ionizing radiation, along with the fact that this form of energy can be applied to meats and poultry with only a negligible increase in temperature and without major product alterations, make it an ideal process for decontamination of muscle foods (IAEA 1996). Depending on the applied dose from lower to higher levels, the irradiation process allows the production of parasite free, longer-lasting, pathogen free, or sterile meats and poultry.

Combinations of irradiation and other food processing techniques such as modified atmosphere packaging (MAP), Refrigeration, freezing and cooking have great potential for improving the quality and safety of fresh and processed meats and poultry. To a large extent, combination treatments involving irradiation would benefit from the fact that irradiation renders surviving contaminating microorganisms sensitive to other sources of external stress. In addition, radiation injured microorganisms often exhibit impaired or more demanding recovery mechanisms before being able to resume normal growth (Farkas 1987). Hence, combinations of irradiation and other conventional food preservation techniques often have synergistic antimicrobial effects. This is not limited to postirradiation treatment but include preirradiation combinations as well (e.g., heating before irradiation). Tesson and Rocchi (1987) reviewed the benefits of combining food irradiation and low temperatures; while irradiation provides antibacterial activity in foods with minimum changes in temperature, low storage temperatures postirradiation delay enzymatic activity and other chemical reactions. According to these authors, irradiation at 4 KGy causes temperature changes of only 1.9, 2.7 and 4.2°C in ice, meat and aluminium packaging material respectively.

Possible antibacterial and chemical synergism between irradiation and food additives has been examined. A combination treatment involving radiation treatment at 2.5 kGy and the addition of lactic acid to pH 5 was developed by (Niemand et al. 1983) to extend the shelf life of refrigerated (4°C) minced beef packaged aerobically or under vacuum. Irradiation completely eliminated
Enterobacteriaceae and Brochothrix thermospacta, and reduced anaerobic and lactic acid bacteria by $\log_{10} 4.8/g$ and $3.4/g$. Total aerobic microorganisms were reduced in numbers from $\log_{10} 6.18/g$ to $\log_{10} 1.78/g$, which resulted in aerobic shelf life greater than 9 days and anaerobic shelf life of more than 21 days for treated beef against only 1 day for untreated samples. When the pH of the meat was adjusted to a value of 5.0 with lactic acid before or after irradiation, an aerobic shelf life of 11 days and more than 21 days of anaerobic shelf life were attainable.

Safety problems associated with meats and poultry are not limited to fresh products, for which cross-contamination from raw to cooked foods and mishandling of cooked products at the consumer and institutional levels are to blame in many outbreaks of food poisoning (Bryan 1988). Ready-to-eat, precooked, often nitrile-free, microwave-ready meat and poultry products sold unfrozen, including some products referred to as “sous vide”, also may pose threat to public health (Buchanan 1986, Prabhu et al. 1988). The potential hazard that these products pose originate not only from the common occurrence of temperature abuse and mishandling by retailers and especially by consumers (Scott 1998), but also from the very nature of the products (Lechowich 1988, Unda et al. 1991). Adequate and continuous refrigeration temperatures are essential to minimize botulism hazard in such products. On the other hand, and ironically, long shelf life at above-freezing temperatures have been known to provide adequate conditions for growth of *Listeria monocytogenes* in precooked meat and poultry products contaminated with this pathogen (Molins R.A 2001).

Radicidation process for eradicating *Salmonella* and *Staphylococcus* from pork meat products was developed by Alur M.D. et al. (1998). In the study processed meat products including pork salami, luncheon meat, ham and cocktail sausages maintained at sub zero temperature in retail cold storage were found to possess counts of mesophilic aerobes, *Staphylococcus* and *Salmonella* counts in the ranges of $10^6$-$10^7$ and $10^4$-$10^5$ and 10-100 cfu/g respectively when these aprocessed meat products were subjected to a gamma radiation dose of 2.5 kGy, under cryogenic condition, counts of mesophilic aerobes and *Staphylococcus* of the samples were reduced by 3-4 log cycles. At the same time
products were completely free from *Salmonella*. Inoculated pack studies indicated that gamma radiation dose of 4 kGy would suffice to eliminate *Salmonella* completely even in the case of samples, which were artificially inoculated with a heavy initial inoculum of $10^6$ cfu/g.

Effects of intensity and processing time of 254 nm UV irradiation on *Listeria monocytogenes*, *Escherichia coli* 0157:H7 and *Salmonella typhimurium* were investigated. Intensities measured at 5.08, 10.1, 515.2, and 20.3 cm from the light source were 1000, 500, 250, and 150 µW/cm², respectively. Intensities of 250 or 500 µW/cm² reduced all suspended pathogen cells in peptone water about 5 log cycles after 2 min and completely inactivated *Listeria monocytogenes* and *E. coli* 0157:H7 after 3 min by reductions of 8.39 and 8.64 log cycles, respectively. Intensities of 250 or 500 µW/cm² also reduced (P < 0.05) the tested pathogens inoculated on stainless steel (SS) chips, and *E. coli* 0157:H7 was completely destroyed at 500 µW/cm² for 3 min. After UV treatment for 3 min at 500 µW/cm², all selected pathogens on chicken meat with or without skin showed reduction ranges from 0.36 to 1.28 log cycles. Results demonstrated that UV irradiation could effectively decrease pathogens in peptone water and on SS but it was less effective on chicken meat.

The effect of gamma irradiation (1.0 kGy) and high hydrostatic pressure (200 Mpa for 30 min), either alone or in combination on the shelf-life of lamb mince meat at 0-3°C was studied by Pushpa Paul et al (1997). Untreated control samples initially had total microbial counts of $10^5$ cfu/g, $10^2$ of coliforms and $10^4$ cfu/g of *Staphylococcus* species. Coliforms were eliminated by all the treatments. *Staphylococcus* species however, were reduced only by 1 log cycle when treated with irradiation alone and high pressure alone. These species were a mixture of mannitol-fermenting and mannitol-nonfermenting strains. In sample, subjected to the combination treatment, *Staphylococcus* species appeared only after 3 weeks of storage and all were mannitol-nonfermenting. On the basis of microbiological and sensory quality, the shelf-life of the control sample was less than 1 week. All
treated meat samples had a shelf-life of 3 weeks, but only combination treated samples were free from potentially pathogenic *Staphylococcus* species.

The potential for high pressure processing (HPP) to kill *E. coli* 0157 in two RTE meats (Hungarian salami and all beef salami) was investigated. The RTE meats were inoculated with a five-strain cocktail of *E. coli* 0157, vacuum packed and then pressure treated at 600 MPa with a hold time of 3 minutes. Samples were stored at 15°C for 28 days. HPP initially reduced *E. coli* numbers on both RTE meats by greater than 4 logCFU/g. (Gill, Alexander and Ramaswamy, Hosahalli O.S., 2008)

A number of ready-to-use shelf-stable intermediate-moisture (IM) spiced mutton spiced chicken products were developed by Sweetie R. Kannan et al (2002) with a combination of hurdles (reduced moisture, vacuum packing and irradiation). The water activity of the products was reduced to about 0.80 either by grilling or by hot-air drying. These IM products were vacuum packed and subjected to gamma radiation processing at 0 to 10 kGy. Microbiological analysis revealed a radiation dose-dependent reduction in total viable counts and in numbers of *Staphylococcus* species. IM meat products that did not undergo radiation treatment showed visible mold growth within 2 months. The products subjected to irradiation at 10 K Gy showed an absence of viable microorganisms and also retained high sensory acceptability for up to 9 months at ambient temperatures.

A number of ready-to-use shelf-stable meat products have been developed by using a combination of hurdles (irradiation, reduced water activity and vacuum packing). The effectiveness of these hurdles in preventing the growth of *Clostridium sporogenes*, *Staphylococcus aureus* and *Bacillus cereus* in these products was tested by S.P. Chawla and R. Chander (2004). Radiation sensitivity (*D* sub 10 values) of *S. aureus*, *C. sporogenes* and *B. cereus* in intermediate moisture (IM) mutton kababs were found to be 0.36, 3.0 and 0.9 K Gy respectively. Radiation treatment (2.5 K Gy) resulted in complete elimination of inoculated \(10^6\) cfu of *S. aureus* and *B. cereus* but not of *C. sporogenes*. The water activity (\(a_w\)) of 0.85 and vacuum packaging of products prevented the growth of all three
organisms inoculated into these samples during 3 months of storage at room temperature. Irradiation usefully inactivated yeast and molds which otherwise grow in the kababs after 2 months of storage. The studies demonstrated that a combination of the above hurdles result in microbiologically safe and shelf-stable meat products.

The effect of gamma irradiation on the survival of pathogens in Kwamegi, a traditional Korean semidried seafood was studied by Chawla S.P. et al (2003). The effectiveness of the hurdles low wateractivity and low temperature in preventing the growth of Staphylococcus aureus, Bacillus cereus, Salmonella typhimurium and Escherichia coli and the efficacy of irradiation treatment in eliminating these bacteria from Kwamegi using inoculated pack studies was examined. Radiation sensitivity of S.aureus, B.cereus, Sammonella typhimurium and E.coli in Kwamegi was investigated. D$_{10}$ values of these organisms in Kwamegi were 590 ± 13.6, 640 ± 14.9, 560 ± 45.4 and 550 ± 8.6 K Gy, respectively. The growth of all four test organisms inoculated into these foods during 4 weeks of storage at an ambient winter temperature (ranging from -5°C to +5°C) was recorded. All four pathogens (inoculated at $10^5$ cfu/g) were eliminated by irradiation at 4 K Gy. These studies unequivocally demonstrate that irradiation, with a combination of low water activity and low temperature, results in microbiologically safe Kwamegi.

**SPICES**

In recent years, the growing demand for novel products that are safe, natural and fresh-like, is stimulating the research into new processing methods to improve microbiological quality of foods and beverages. Spices, condiments and plant extracts, besides their role as flavorings and seasonings, present strong medicinal, preservative and antioxidant properties and thus contribute to overall safety and preservation of food products (Zaika LL 1988).

These natural ingredients of plant origin appeal to the consumer due to the odour and taste they give to foods and beverages. Cinnamon effectively inactivates
bacteria, yeasts and mold (Smith-Palmer et al. 1988). It contains cinnamaldehyde and eugenol as major antimicrobial compounds. Smith-Palmer et al. investigated the effect of some plant essential oils on *E. coli*, and reported that cinnamon was one of the most inhibitory.

Rhee et al. (2003) found mustard to have high inhibitory activity on *E. coli*, but in acidic products. Clove and cinnamon showed strong activity towards *E. coli* and *B. cereus*, but relatively less towards *S. aureus* at 0.5% and 1% concentrations. The potent antimicrobial activity of clove and cinnamon can be predominantly attributed to eugenol and cinnamaldehyde. These are the phenolic components of clove and cinnamon, which render them effective against the tested microorganisms.

Cinnamon powder was examined for antilisteric activity in meat and cheese by Vrinda Menon et al. (2002). It exhibited bacteriostatic action on *L. monocytogenes* in both the foods. Foods treated with 6% cinnamon showed 1-2 log_{10} less Listeria counts g^{-1} than in the untreated controls on holding the foods at 30 °C for 7 days and at 7°C for 15 days. Treatment with 3% cinnamon also slowed down the growth of the microorganism significantly in meat but to a lesser extent in cheese at 30°C. The activity of 3% cinnamon, however, was not appreciable in meat and cheese at 7°C.

Eugenol and pimento extract significantly inhibited the growth of *Aeromonas hydrophila* and *Listeria monocytogenes* in refrigerated cooked beef.

These results suggest that plant extracts might be useful as an antimicrobial in cooked ready-to-eat meat. (Hao et al.)

**BACTERIOCIN**

The development of new technologies that allow food spoilage control, including nonthermal processes as well as natural antimicrobial agents like bacteriocins, are of considerable interest to the food industry. The bacteriocin nisin, a 3.5 KDa peptide produced by *Lactococcus lactis subsp. lactis*, is used in many countries...
for a number of applications involving the inhibition of gram-positive bacteria. Delves Broughton J. (1990).

Nisin is effective only against gram-negative bacteria at high-level doses, which are not commercially feasible. The resistance of the gram-negative bacteria is due to the protective outer membrane that forms the outermost layer of the cell envelope, functioning as an efficient barrier against hydrophilic solutes and macromolecules like nisin. Nisin produces pores in the cytoplasmic membrane, causing the leakage of intracellular material and the osmotic imbalance of the target cell. The use of nisin in combination with other stress factors like water activity depression, pH and technologies leading to the permeability of the outer membrane could broaden the use of nisin in controlling gram-negative bacteria. The effect of nisin combined with pulsed electric fields [PEF] and water activity reduction by sodium chloride (NaCl) on the inactivation of E.Coli in simulated milk ultra filtrate media was studied by Terebiznik M, et al (2002). They found that decreasing water activity to 0.95 and applying PEF at 5 KV/ Cm (a nonlethal intensity when no other hurdle is used) with the further addition of nisin (1,200 IU/ml) resulted in a 5-log cycle reduction of the bacterial population.

Yasmina Barboza de Martinez et al (2002) studied the combined effects of Lactic acid and Nisin solution in reducing levels of microbiological contamination in Red Meat Carcasses. Results indicated that the highest prevalence of aerobic plate counts, total coliforms and Escherichia coli was found in the neck site after splitting, and the lowest level of microbial contamination was found after skinning. Washing with water did not significantly reduce the bacterial load. The largest reduction in aerobic plate counts, total coliforms and E. Coli occurred on carcasses treated with a mixture of nisin and lactic acid. A mixture of nisin and lactic acid can be applied to beef carcasses through spray washing and can reduce bacterial populations by 2 log units.

Jeong-In-Lee et al (2002) studied the Synergistic effect of Nisin and heat treatment on the growth of Escherichia coli 0157:H7. A combination of nisin and heat treatment was found to inhibit Escherichia coli 0157:H7 effectively. After organisms were heated at 50, 52.5 and 55°C for 5, 10 and 15 min, respectively,
Nisin was incorporated into the plates of *E. coli* 0157:H7 at 0, 25, 50 and 100 IU/ml. The concentration of 100 IU/ml nisin significantly inhibited the growth of *E. coli* 0157:H7 heated at 50 and 52.5°C for 15 minutes. Nisin treatment at 100 IU/ml after 6 hours incubation resulted in the elimination of *E. coli* 0157:H7 heated at 55°C for 10 and 15 min.

**High hydrostatic pressure (HHP).**

Several types of control methods are effective in preventing or minimizing microbial contamination of product and inhibiting the growth of or destroying microbial contaminants. Very intense water pressure such as that which would be felt at extreme ocean depths is known as High hydrostatic pressure (HHP). HHP has recently been used as a non-thermal processing technique (not involving high temperatures, such as cooking or pasteurization) to control pathogens in food products.

A study conducted by Means, W.J. etal (2003) implied that high hydrostatic pressure treatment of 50,000 psi for 5 min at 50°C in conjunction with bacteriocins of lactic acid bacteria, would be effective in eliminating the threat of *Salmonella* that may arise due to post-heat contamination during processing of low-heat processed meat products such as vacuum packaged frankfurters, stored at refrigeration temperatures.

**Escherichia coli**

The GI tract of most warm-blooded animals is colonized by *E. coli* within hours or a few days after birth. The bacterium is ingested in foods or water or obtained directly from other individuals handling the infant. The human bowel is usually colonized within 40 hours of birth. E. coli can adhere to the mucus overlying the large intestine. Once established, an E. coli strain may persist for months or years. Resident strains shift over a long period (weeks to months), and more rapidly after enteric infection or antimicrobial chemotherapy that perturbs the normal flora. The basis for these shifts and the ecology of Escherichia coli in the intestine of humans are poorly understood despite the vast amount of information
on almost every other aspect of the organism's existence. The entire DNA base sequence of the E. coli genome has been known since 1997.

E. coli is the head of the large bacterial family, Enterobacteriaceae, the enteric bacteria, which are facultative anaerobic Gram-negative rods that live in the intestinal tracts of animals in health and disease. The Enterobacteriaceae are among the most important bacteria medically. A number of genera within the family are human intestinal pathogens (e.g. Salmonella, Shigella, Yersinia). Several others are normal colonists of the human gastrointestinal tract (e.g. Escherichia, Enterobacter, Klebsiella), but these bacteria, as well, may occasionally be associated with diseases of humans.

The Enterobacteriaceae are distinguished from the Pseudomonadaceae in a number of ways known reflexively to competent microbiologists. The pseudomonads are respiratory, never fermentative, oxidase-positive, and motile by means of polar flagella. The enterics ferment glucose producing acid and gas, are typically oxidase-negative, and when motile, produce peritrichous flagella.

Physiologically, E. coli is versatile and well-adapted to its characteristic habitats. It can grow in media with glucose as the sole organic constituent. Wild-type E. coli has no growth factor requirements, and metabolically it can transform glucose into all of the macromolecular components that make up the cell. The bacterium can grow in the presence or absence of O₂. Under anaerobic conditions it will grow by means of fermentations, producing characteristic "mixed acids and gas" as end products. However, it can also grow by means by anaerobic respiration, since it is able to utilize NO₃, NO₂ or furmarate as final electron acceptors for respiratory electron transport processes. In part, this adapts E. coli to its intestinal (anaerobic) and its extra intestinal (aerobic or anaerobic) habitats.

E. coli can respond to environmental signals such as chemicals, pH, temperature, osmolarity, etc., in a number of very remarkable ways considering it is a single-caused organism. For example, it can sense the presence or absence or chemicals and gases in its environment and swim towards or away from them. Or
it can stop swimming and grow febrile that will specifically attach it to a cell or surface receptor. In response to change in temperature and osmolarity, it can vary the pore diameter of its outer membrane porins to accommodate larger molecules (nutrients) or to exclude inhibitory substances. With its complex mechanisms for regulation of metabolism the bacterium can survey the chemical contents its environment in advance of synthesizing any enzymes necessary to use these compounds. It does not wastefully produce enzymes for synthesis of metabolites if they are available as nutrients in the environment.

E. coli is a consistent inhabitant of the human intestinal tract, and it is the predominant facultative organism in the human GI tract; however, it makes up a very small proportion of the total bacterial content. The anaerobic Bacteroides species in the bowel outnumber E. coli by at least 20:1; however, the regular presence of E. coli in the human intestine and faeces has led to tracking the bacterium in nature as an indicator of faecal pollution and water contamination. As such, it is taken to mean that, wherever, E. coli is found; there may be faecal contamination by intestinal parasites of humans.

The chief microbiological concerns associated with products at refrigeration temperature centers around two types of microorganisms psychrotrophic and mesophilic pathogens that could grow during extended refrigerated storage or temperature abuse. Psychrotophs are bacteria, yeasts and molds that grow, although slowly, at refrigeration temperatures (below 7°C) but grow optimally at temperatures above refrigeration, eg 25-30°C. Their maximum growth temperatures are 30-35°C ( Olson and Nottingham, 1980). Mesophilic pathogens could survive under refrigeration and grow during any temperature abuse of the food. Mesophiles grow well between 20-45°C with optimum growth between 30-40°C. The potential for psychrotrophic spoilage microorganisms to grow during the extended refrigerated storage period and decrease organoleptic quality or spoil the food product is also a concern.

A few serotypes and strains of E.Coli, a facultative anaerobe that is part of the normal microflora of the intestinal tract of humans and most warm blooded
animals can cause illness although they are not considered true psychrotrophs, some of these strains can grow at 6.9°C and below. Pathogenic E.Coli are categorized into six groups enteropathogenic, enteroinvasive, enterotoxigenic, enterohemorrhagic (EHEC) enteroaggregative and diffusely adherent. Foods involved in outbreaks caused by pathogenic E.Coli include meat, poultry, fish, vegetables, apple cider, raw milk, Brie and camembert cheese, water, radish and alfalfa sprouts. Some strains of E.Coli including some EHEC strains, are acid tolerant a complex phenomenon that is growth phase dependent and inducible acid tolerance may persist for extended periods at refrigeration (Buchanan and Doyle, 1997).

The complete removal of oxygen, or the presence of reducing substances, may increase the radiation resistance of E.coli threefold(Niven,1958). It has been suggested that it would seem more practicable to combine an irradiation dosage which is lower than normally necessary to achieve sterility with another process(e.g. refrigeration, vacuum packaging, antibiotics, curing, heating) Lawrie R.A,(1991).The bactericidal effects of combined processes are more than additive, for one treatment generally increases sensitivity to another. (Ingram,1959)

A study carried out by Genevieve A.Barkocy Gallagher(2002) etal confirmed that storage temperatures at or below 4°C are very important for limiting the growth of any E.coli 0157:H7 in ground beef and that freezing at -20°C cannot be expected to eliminate the organism in this product. This study also demonstrates that there are small differences in the abilities of various E.coli 0157 strains(Isolate 55AC1,114AC1,131AC1,237AC1,299AB3,ATCC 43895) to survive and sometimes grow in fresh ground beef at cold storage temperatures, but overall these differences do not appear to be meaningful.
MATERIALS AND METHODS
MATERIALS AND METHODS

1. Procurement of Meat
2. Chemical analysis
3. Microbiological analysis
4. Different treatments in the Lab
5. Shelf life studies

Procurement of Meat

20 Samples of Buffalo meat of around 10 years of age was procured from retail markets in Delhi. The Sampling was done and brought to the laboratory in accordance with IS/ISO 3100-1: 1991 Meat and Meat Products – Method of Sampling, BIS Specifications.

The Colour of the fresh meat samples were red with normal meaty odour. The temperature of the meat at ambient temperature was in the range of 28 to 30°C. The samples of 1 kg each were collected in sterile polyethylene bags and brought to the laboratory in insulated containers within one hour after collection and analysed for proximate composition and microbial load.

20 samples of frozen buffalo meat were procured from a hygienic abbatoir. The samples had been quick frozen in plate freezers at -40 °C having a storage temperature of -18 °C. The samples of meat were analyzed for proximate composition and microbial load in accordance to BIS specifications.

Chemical analysis

The samples were analysed for the following parameters.

1. Determination of total fat content was done in accordance to IS:5960 Part III, 1970.
2. Determination of Moisture content was done in accordance to IS:5960 Part V, 1971.
3. Estimation of Protein was done in accordance to IS 5960(Part 1):1996
Microbiological analysis

The microbiological analysis was done for the following parameters:

1. Total Plate Count was done in accordance to IS: 5402.
2. Yeast and Mold count: The presence of yeasts and molds in meat may occur due to cross-contamination, inadequate hygienic practices and storage at improper temperature and humidity. Yeast and Molds were estimated in accordance to IS: 5403-1999.
3. Detection of Escherichia coli was carried out in accordance with IS:5887 (PT.I) 1976.
4. Detection of Staphylococcus aureus was carried out as per IS:5887 (PT II) 1976.
5. Detection of Salmonella was carried out in accordance to IS:5887 (Pt III) 1999.

Media used for the microbiological analyses were from Himedia, India. Microbiological analyses of the samples included the determination of total plate count (TPC) using plate count agar (30°C for 48h). Selective and differential media used were McConkey agar and Eosine Methylene Blue agar (37°C for 48h) for E.coli. Baird Parker agar(37°C for 48 h) was used for detection of Staphylococcus species. For detection of Salmonella, selective enrichment was carried out in selenite cystine broth and then plated on bismuth sulfite agar (37°C for 48h). For Yeast and molds, Potato dextrose agar was used.

Different treatments

Preparation of meat samples

Buffalo meat was procured from a hygienic abattoir. To minimize the initial numbers of resident microflora, 2 to 3mm of the meat surface was aseptically trimmed off. The lean meat was aseptically cut into 11×10 ×1cm. To further reduce the initial numbers of microflora, each side of meat surface was exposed
at a distance of 15 to 20 cm to UV light (30 watts, UV lamp) for 15 minutes in a laminar flow hood before each experiment.

**Bacterial culture**

E. coli ATCC 10536 and MTCC 739 were used. The cultures were maintained in Brain heart infusion agar slants (Himedia), stored at 4°C and transferred to a fresh slant once per month.

**Preparation of inoculum**

Bacterial cells were propagated on brain heart infusion agar and incubated at 37°C for 24 hours. After incubation cells were suspended in sterile saline (0.85% NaCl). The bacterial growth was quantified and adjusted to give counts of approximately 10^6 CFU/ml of the bacterial suspension.

**Treatment solutions**

Disodium EDTA (Qualigens) was added to distilled water for final concentrations of 1% and 2%. It was then filter sterilized through 0.22μm membrane filter.

Sodium acetate (S.D. fine chemical , Ltd) was added to distilled water for final concentrations of 0.5% and 2%. It was then filter sterilized through 0.22μm membrane filter.

Cinnamic aldehyde and Eugenol (S.H.Kelkar and co Ltd) were added at concentrations of 0.6% and 0.2% and 0.6% on the meat respectively.

**Radiation treatment:** The radiation treatment was carried out in a gamma chamber at 2kGy by maintaining temperature of the sample at 5°C. The gamma chamber had a dose rate of 3.52K Gy/hour. The control was also maintained at 5°C.
Inoculation of meat samples with E.coli and decontamination treatments

All experiments (4 replications) were aseptically performed in a laminar flowhood. For inoculation the meat surface was treated with approximately \(10^6\) CFU/ml of E.coli. The bacteria was spread uniformly over the surface with a sterile glass spreader. The inoculated samples were allowed to stand undisturbed for 15 minutes to enable attachment of bacterial cells. Then each surface was individually treated with treatment solutions for 5 minutes and individually heat sealed in Polyethylene bags. The samples were then stored at 4°C for further studies.

Microbial counts

The samples were examined for microbial counts on 0, 3, 7 days and the values averaged. The treated meat samples were individually stomached for 2 minutes. (Seward stomacher 80, LAB system). E.coli was enumerated by using Eosine Methylene Blue (EMB agar)/Mac Conkey agar (MCA Plates) incubated at 37°C for 48 hours.

Determination of total fat content was done in accordance to IS : 5960 [Part III] – 1970 as follows:-

PROCEDURE

- Preparation of Sample – Proceed from a representative sample of at least 200 g. Render the sample uniform by passing it at least twice through the meat mincer and mixing. Keep it in a completely filled airtight container and store it in such a way that deterioration and change in composition are prevented. Analyze the sample as soon as possible, but in any case within 24 hours.

- Weigh 3 to 5 g of the minced sample to the nearest 0.001 g into the 300-ml conical flask. Dry the flask of the extraction apparatus, provided with some boiling chips, for one hour at 103 ± 2°C in the drying oven, allow the flask to cool to room temperature in the desiccator and weigh to the nearest 0.001 g.
Add to the test portion 50 ml of the hydrochloric acid and cover the conical flask with a clock glass. Heat the conical flask on an asbestos wire gauze by means of a gas burner until the contents begin to boil. Continue boiling with a small flame for one hour and shake occasionally. Add 150 ml of hot water. Moisten a fluted filter paper held in a glass funnel with water and pour the hot contents from the flask on to the filter. Wash the flask and the clock glass thoroughly three times with hot water and dry in the oven. Wash the filter with hot water until the washings do not affect the colour of the blue litmus paper. Put the filter paper on the clock glass or Petri dish and dry for 1 hour in the oven at 103 ± 2°C. Allow to cool. Roll up the filter paper and insert it into the extraction thimble. Remove any traces of fat from the clock glass or Petri dish, using cotton wool moistened with the extraction solvent, and also transfer the cotton wool to the thimble. Place the thimble in the extraction apparatus. The paper should be handled either with tongs that can be rinsed or with paper cover slips on the fingers. Pour the extraction solvent into the dried flask of the extraction apparatus. Wash the inside of the conical flask used for the disintegration with hydrochloric acid, and the covering clock glass, with a portion of the extraction solvent and add it to the extraction flask. The total solvent quantity should be one-and-a-half to two times the capacity of the extraction tube of the apparatus. Fit the flask to the extraction apparatus. Heat the extraction flask for 4 hours on the heated sand-bath or water-bath. After extraction, take the flask containing the liquid from the extraction apparatus and distill off the solvent using the heated sand-bath or water-bath. Evaporate the last traces of the solvent on the water-bath, using air blowing, if desired. Dry the extraction flask for 1 hour in the drying oven at 103 ± 2°C and, after allowing to cool to the room temperature in the desiccator, weigh to the nearest 0.001 g. Repeat this process until the results of two successive weighings do not differ by more than 0.1 percent of the sample weighted. Verify the completion of the extraction by taking a second extraction flask and extracting for a further period of 1 hour with a fresh portion of the solvent. The increase in weight should not exceed 0.1 percent of the weight of the sample. Carry but two determinations on the same prepared sample.
CALCULATION

The total fat content of the sample, percent by weight, is equal to:

\[
\frac{W_2 - W_1}{100 X W_0}
\]

where

- \(W_2\) = weight in g, of the flask with the dried fat;
- \(W_1\) = weight, in g, of the empty extraction flask with boiling chips; and
- \(W_0\) = weight, in g, of the test portion.

Take the result as the average of the two determinations.

- The difference between the results of two determinations carried out simultaneously or in rapid succession by the same analyst should not be greater than 0.5 g of total fat per 100 g of sample.

Determination of Moisture Content was done in accordance to IS : 5960 [Part V] – 1971.

PROCEDURE

- **Preparation of Sample** – Proceed with a representative sample of at least 200 g. Render the sample uniform by passing it at least twice through the meat mincer and mixing. Keep it in a completely filled, air-tight container and store in such a way that the deterioration and change in composition are prevented. Analyze the sample, as soon as possible, but in any case within 24 hours.

- **Test Portion** – Dry the dish, containing a quantity of sand three or four times the mass of the test portion and the glass rod for 30 minutes in the oven at 103 ± 2°C.

- Allow the dish with its contents to cool in the desiccator to room temperature and weigh to the nearest 0.001 g.
• Transfer 5 to 10 g of the prepared sample to the dish and weigh the dish again to the nearest 0.001 g.

• **Determination** – Add 5 to 10 ml of ethanol, depending on the mass of the test portion, and mix the mass by means of the glass rod.

• Place the dish on the water-bath regulated at a temperature between 60°C and 80°C in order to avoid the ejection of particles, and heat until the ethanol has evaporated, stirring occasionally.

• Heat the dish and contents for 2 hours in the drying oven regulated at 103 ± 2°C. Remove the dish from the oven and place it in the desiccator.

Allow the dish to cool to room temperature and weight it to the nearest 0.001 g.

• Repeat the operations described above until the results of two successive weighings, separated by 1 hour’s heating, do not differ by more than 0.1 percent of the sample weight.

Carry out two determinations on the name prepared sample.

**CALCULATION**

Moisture content, as a percentage by weight, is equal to:

\[
\frac{(W_2 - W_1) \times 100}{W_1 - W_0}
\]

where

\( W_1 \) = weight in g, of the dish containing the test portion, rod and sand, before drying;

\( W_2 \) = weight, in g, of the dish containing the test portion, rod and sand, after drying; and

\( W_0 \) = weight, in g, of the dish, rod and sand.
Calculate the arithmetic mean of the two determinations if the requirement of 2.6 is satisfied. Report the result rounded to one decimal place.

**Repeatability** – The difference between the results of two determination carried out simultaneously or in rapid succession by the same analyst should not be greater than 0.5 g of moisture per 100 g of sample.

**Sampling of Meat** was done in accordance to the Indian Standard IS | ISO 3100-1 : 1991

**METHODS OF SAMPLING**

In General Samples shall be taken as follow:

A distinction is made between sampling procedures for the following categories of products:

(a) consignments or lots of meat or meat products prepared or packed as individual units of any size (for example sausages, vacuum-packed minced meat, sliced sausages, canned cooked ham, or meat in pieces not exceeding 2 kg in mass.
(b) carcasses, cuts of carcasses, or cured meat in pieces exceeding 2 kg in mass (for example bacon joints, sides of bacon, fresh or frozen joints of meat, fresh or frozen boneless meat, beef sides or quarters, pork side lamb carcasses, venison) and mechanically separated meat or dried meat.

**Equipment and containers for sampling units intended for chemical analysis.**

The sampling equipment and sampling unit containers shall be dry and clean, and shall not influence the chemical composition of the product.
Equipment and containers for sampling units intended for sensory examination.

The sampling equipment and sampling unit containers shall be dry and clean, and shall not impart any flavour or odour to the product.

Equipment and containers for sampling units intended for microbiological examination and for other purposes (for example biological, parasitological, serological, histological or toxicological examination and for incubation tests)

The sampling equipment and sampling unit containers shall be clean and sterile, and shall not influence the micro flora of the product.

If necessary sterilization of sampling equipment and sampling unit containers shall be performed by one of the following methods:

a) Wet sterilization at not less than 121°C for not less than 20 min.
b) Dry sterilization at not less than 170°C for not less than 1 h, using an oven with efficient air circulation to ensure that the stated temperature is maintained in all parts of the oven.

If the use of either method a) or method b) is impossible, and if the equipment is to be used immediately after sterilization, one of the following methods may be used:

c) Exposure to steam at 100°C for 1 h.
d) Immersion in 96% (V/V) ethanol and flaming to burn off the ethanol.
e) Exposure to a hydrocarbon (e.g. propane or butane) torch flame so that all working surfaces contact the flame.

Thus, in general samples shall be taken as follows:

a) Surface sampling units (for example for the detection of coliforms or salmonella) shall be taken by wiping over the entire meat unit (or selected areas) with large moist swabs or (for making microbiological counts) by
defining areas using a template and excising or, in the case of frozen meat, scraping those areas;

b) Excised secondary sampling units having a mass between 500 g and 1 kg for chemical or microbiological examination in the laboratory shall be taken, wherever possible, form an existing cut surface and in such a way as to cause minimum damage;

Transport and storage of sampling units

Sampling units shall be sent to the laboratory as quickly as possible after sampling, during which time they shall be maintained at the temperature at which the product concerned should be stored. However, in the case of products that are refrigerated, transport the sampling units.

a) At 0 °C to 2 °C if it is expected that they will be examined within 24 h.
or
b) Frozen at a temperature not exceeding -24°C, in other cases; however, samples that are to be subjected to physical or sensory tests shall not in general be frozen.

Take precautions to prevent exposure of the sampling units to direct sunlight during transport. Sampling units shall arrive in the laboratory in an undamaged state and with undisturbed seals.

Estimation of Protein was done in accordance to IS 5960(Part 1):1996

PROCEDURE

Proceed with a representative sample of at least 200g. Make the sample homogeneous by passing it at least twice through the meat mincer and mixing. Keep it in a completely filled air-tight closed container and store it in such a way that deterioration and change in composition are prevented. Analyse the sample as soon as possible, but in any case within 24 hours.
Place a few boiling regulators into the Kjeldahl flask, then add about 15 g of anhydrous potassium sulphate and 0.5 g of copper sulphate. Weigh to the nearest 0.001 g about 2 g of prepared sample on a grease-proof paper. Transfer the grease-proof paper and the test portion to the Kjeldahl flask.

Add to the Kjeldahl flask 25 ml of sulphuric acid. Mix by gently swirling the liquid. Place the flask in an inclined position on the heating device. At first, heat the flask gently until the foaming has ceased and the contents have become completely liquefied. Then digest by boiling vigorously occasionally rotating the flask, until the liquid has become completely clear and of a light blue-green colour; keep the liquid boiling for another 1½ hours.

The total digestion time should not be less than 2 hours. Take care that no condensed liquid runs down the exterior of the flask. Prevent the escape of too much sulphuric acid caused by overheating during the digestion, because this results in loss of nitrogen.

Cool to about 40°C add cautiously about 50 ml of water. Mix and allow to cool. Pour into a conical flask, of capacity about 500 ml, 50 ml of the boric acid solution from a measuring cylinder, add few drops of methylene blue indicator solution, mix and place the flask under the condenser of the distillation apparatus so that the outlet of the adapter dips into the liquid.

Treat the contents of the flask for distillation. Cautiously dilute the contents of the Kjeldahl flask with about 300 ml of water and swirl. After about 15 minutes add 100 ml of sodium hydroxide (330 g of NaOH per 1000 ml solution) carefully down the neck of the flask by means of a measuring cylinder. Immediately attach the flask to the splash-head of the distillation apparatus. Gently swirl the flask to mix the contents.

Continue the distillation until 250 ml of distillate has been collected. Make sure that the distillate is cooled effectively. Titrate the contents of the conical flask with
0.1 N Hydrochloric acid solution. Carry out two determinations on the same prepared sample.

Carry out a blank test by the same procedure described taking a piece of greaseproof paper only.

**CALCULATION**

The nitrogen content, as a percentage by weight of the sample, is equal to:

\[
\frac{1.4(V_1-V_0)N}{W}
\]

Where

- \(V_1\) = volume in ml of hydrochloric acid solution required for the test;
- \(V_0\) = volume in ml of hydrochloric acid solution required for the blank test;
- \(N\) = normality of hydrochloric acid solution; and
- \(W\) = weight, in g, of the test.

Take the result as the average of the results of the two determinations.

To convert nitrogen to protein a factor of 6.25 is used.

**Statistical analysis**

T-test and one way Anova was performed using SPSS Software.