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Outlines of Meat Science & Technology



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2nd Edition

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CHAPTER

Optimizing Shelf-Life of Meat and Meat Products using Innovative Packaging Solutions

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Packaging is the scientific method of containing food products against physical damage, chemical changes and further microbial contamination and to display the product in the most attractive manner for consumer preference. It can be described as a coordinated system of preparing goods for transport, warehousing, logistics, sale and end use. Packaging contains, protects, preserves, transports, informs, and sells. In many countries it is fully integrated into government, institutional, industrial, business and personal use. Packaging fresh meat is carried out to avoid contamination, delay spoilage, permit some enzymatic activity to improve tenderness, reduce weight loss and where applicable, to ensure an oxymyoglobin or cherry-red color in red meats at retail or customer level. When considering processed meat products, factors such as dehydration, lipid oxidation, discoloration and loss of aroma must be taken into account. Traditional food packaging was meant for mechanical supporting of otherwise non-solid food and protecting food from external influences. The shelf life of packaged food depends on both the intrinsic nature of food and extrinsic factors. Intrinsic factors include pH, water activity (a_w), nutrient content, presence of antimicrobial compounds, redox potential, respiratory rate, and the biological structure, whereas extrinsic factors include storage temperature, relative humidity, and the surrounding gas composition.

Vacuum packaging maintains the product in an oxygen deficient environment to achieve its preservative effect. It has the inherent disadvantage of keeping the meat in mechanical strain which may increase drip loss. An alternative to vacuum packaging, with added cost, is modified atmosphere packaging wherein meat and meat products are stored under various gaseous atmospheres to achieve enhanced shelf life. Active packaging is the deliberate incorporation of certain additives into packaging systems (whether loose within the pack,

attached to the inside of packaging material or incorporated within the packaging material itself) with the aim of maintaining or enhancing product quality and shelflife. Principal active packaging systems involve oxygen scavenging, moisture absorption, carbon dioxide and finally antimicrobial systems. These concepts are successfully utilized in the US and Japan but have seen only limited development in Europe. This could be due to legal restrictions, lack of knowledge about both the acceptability of these systems to consumers and their effectiveness in packaging or to their economic and environmental impact. Consumers now look forward to labeling with shelf life dating on the food itself as an assurance of quality, nutrition and safety. Intelligent packaging (sometimes described as smart packaging) is packaging that in some way senses some properties of the food it encloses or indicate history of the environment in which it is kept and is able to inform the manufacturer, retailer and consumer of the state of these properties. Although distinctly different from the concept of active packaging, features of intelligent packaging can be used to check the effectiveness and integrity of active packaging systems.

VACUUM PACKAGING

Vacuum packaging of meat is meant to retard or completely check the oxidative reactions and inhibit the microbial growth by eliminating oxygen. It is widely used to extend the storage life of fresh chilled meats by maintaining an oxygen deficient environment within the pack. The air within the package must be evacuated effectively to almost anoxic levels (less than 500 ppm) to prevent irreversible browning due to low levels of residual oxygen. The exclusion of oxygen from the meat surface as soon as possible, after the breaking of the carcass into primal and subprimal cuts, retains the potential to reoxygenate meat following retail pack display. The application of a vacuum to 0.8–0.9 atmospheres is generally sufficient to produce satisfactory vacuum, so that most potent pathogenic aerobic bacterial growth is inhibited. The oxygen level should be less than 1 percent and carbon dioxide less than 10 percent in vacuum packaged meat. Lactobacillus and Brochothrix thermosphacta are the dominant bacteria in vacuum packaged meat. However, vacuum packaged meat having pH below 5.8 overcomes the danger of Brochothrix thermosphacta. This is due to the longer lag phase of this bacterium in comparison to competitive bacteria and also due to its sensitivity to low pH and temperature.

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Vacuum packages for meat are four basic types. The first one involves use of heat shrinking flexible packaging material around the primal cuts. When exposed to heat it shrinks and increases film thickness, improves mechanical resistance and reduces the drip loss. The second type involves use of preformed plastic bags/pouches made up of polyamide (PA) as the outer layer, while the inner core is polyethylene (PE). Polyamide provides barrier properties and physical strength while polyethylene provides sealing properties. The third type involves use of thermoform trays in line from a base web. Here the product is placed into the tray and then a film web is allowed to cover the tray from a second reel of film followed by pack evacuation and vacuum sealing. The fourth one is called vacuum skin packaging, in which meat is placed in a rigid preformed tray or on the flat surface of a flexible base material followed by heat softening, evacuation and vacuum shrink sealing. This technique is recommended for long term storage of primal and sub primal cuts of buffalo meat. It ensures a shelf life of 8–10 weeks at 00C. Vacuum packaging of lamb and pork is avoided for different reasons. Lamb may have a shelf life of 3 weeks only because of comparatively high pH. However, lambs with ultimate pH less than 5.8 can be vacuum packaged for shipment to distant destinations. Pork starts with a large load of bacteria and pork cuts are reported to have a shelf life of 2 weeks only at 1°C.

Vacuum shrink packaging in Cryovac barrier bags may provide a means of storage and transport of frozen carcasses, sides or quarters to overseas destinations. A suitable film for vacuum packaging must have a good mechanical strength and barrier properties, besides making perfect seals Vacuum packaging is done either in laminates or coextruded films.

Some of the typical laminates in use are:

Aluminum foil/Polyethylene	PVDC copolymer film
Polyamide/Polyethylene	Copolymer coated cellulose/PE film
PVDC/Polyester/Polyethylene	Nylon/EVA
Polyester/Polyethylene	

Vacuum packaging is recommended for long term storage of dressed whole or halved poultry because it ensures a shelf life of 5–6 weeks at 2°C. Vacuum packaging reduces the volume of air sealed with meat. The residual oxygen, if any, is quickly consumed by meat. Thus, vacuum packaging provides a good avenue for keeping the product at a better level of quality. The advantages of vacuum packaging can be enumerated as follows:

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1. There is saving of space and energy during storage, transport and distribution.
2. There is no loss in weight.
3. The natural flavor of the product is preserved.
4. The product has better keeping quality.
5. The display of the product is better which help in better marketing and fetching better price.

Vacuum packaged product is stored in a refrigerator at 0–2°C. Storage of chilled meat in gas impermeable packs restricts the growth of *Pseudomonas* sp., thus extending the shelf life of meat. The most common bacteria on stored vacuum packaged poultry meat are the lactic acid bacteria mainly *Lactobacillus* sp. However, a puncture or slit or loose seal in vacuum pack may result in blue or green discoloration. Interestingly, vacuum packaged buffalo meat has been found to have the lower fiber diameter and higher sarcomere length. Thus, vacuum appears to enhance ageing of meat resulting in comparatively tender meat.

MODIFIED ATMOSPHERE PACKAGING (MAP)

Modified atmosphere packaging is an important preservation method for fresh and minimally processed foods. Modified atmosphere packaging encloses food products in high gas barrier materials, where gas environment has been changed once to slow the respiration rate, reduce microbiological growth and retard enzyme spoilage with the final aim of prolonging the shelf life. It is also referred as controlled atmosphere packaging with certain conditions. In controlled atmosphere packaging (CAP) system, the package atmosphere is altered initially and then maintained during the entire period of storage. These techniques are used for a wide range of shelf stable and ready-to-eat chilled foods.

Modified atmosphere combined with low temperature delays the deleterious effects and maintains quality of chilled stored meat for extended periods. The atmosphere inside the package is modified in such a way to extend the shelf life of meat while retaining its color, flavor and weight. The package air can be suitably replaced by gases usually nitrogen, oxygen or carbon dioxide alone or in combination. Different meats have varying modified atmosphere requirements. In red meats, oxygen maintains the much-desired bright red pigment-oxymyoglobin associated with freshness while carbon dioxide inhibits the growth of meat borne microorganisms. The most commonly used

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gas mixture for fresh red meat is high oxygen which is minimum 60–70% and 30–40% carbon dioxide. Buffalo meat and beef need high oxygen content to maintain a bright red color. Pork needs less oxygen due to high fat content. Nitrogen serves as an inert filler to balance a gas mixture. However, its use increases the cost of packaging.

Carbon monoxide is used in very low concentration and gives cherry red color. The sulphur dioxide has inhibitory effect on bacteria in acidic pH and is used in fermented meat products. Argon, an inert noble gas has some antimicrobial activity and is also sometimes utilized in vacuum packaging of meat and meat products. High standards of hygiene and temperature controls are essential prerequisites for the quality and safety of MAP packed meat and meat products. A gaseous atmosphere of 99% carbon dioxide/1% carbon monoxide was found to be best for preserving the desirable pork loin. Pork loins in such MAP obtained the highest consumer acceptance scores after 24 h of storage. Chops from high pH carcasses had comparatively higher color scores and aerobic plate counts and less discoloration. Overall pH was the best indicator of color and microbiological stability.

In general, the ideal MAP gas mix. for various meat and meat products can be summarized as follows:

Raw red meat	70% O_2, 20% CO_2, 10% N_2
Raw pork	80% CO_2, 20% N_2 or even 100% CO_2
Raw dressed poultry	40% CO_2, 60% N_2 or 50% CO_2, 50% N_2
MDPM	20–30% CO_2, 0–10% O_2, 70-75% N_2
Cured meats	10–15% CO_2, 85–90 %N_2
Raw offal	80% O_2, 20% CO_2
Combination products	30% CO_2, 70% N_2

ACTIVE PACKAGING

Active packaging has been defined as packaging, which changes the condition of the packaged food to extend shelflife or to improve safety or sensory properties, while maintaining the quality of packaged food. Packaging may be termed as active when it performs some desired role in food preservation other than providing an inert barrier to external conditions. The development of a whole range of active packaging systems, some of which may have applications in both new and existing food products, is fairly new. Active packaging includes additives or freshness enhancers that can participate in a host of packaging applications and by so doing, enhance the preservation function of the primary packaging system. Active packaging is one of

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the innovative food packaging concepts that have been introduced as a response to the continuous changes in current consumer demands and market trends. Major active packaging techniques are concerned with substances that absorb oxygen, moisture, carbon dioxide, flavors/odors and those which release carbon dioxide, ethylene antimicrobial agents, antioxidants and flavors.

Oxygen Scavengers

High levels of oxygen present in food packages may facilitate microbial growth, off flavors and off odors development, color changes and nutritional losses, thereby causing significant reduction in the shelf life of foods. Although oxygen sensitive foods can be packaged under MAP or vacuum conditions, such techniques do not always facilitate the complete removal of oxygen. Therefore, control of oxygen levels in food packages is important to limit the rate of such deteriorative and spoilage reactions in foods.

Oxygen absorbing systems provide an alternative to vacuum and gas flushing technologies as a means of improving product quality and shelf life. Using an oxygen scavenger, which absorbs the residual oxygen after packaging, quality changes in oxygen sensitive foods can often be minimized. Oxygen absorbers can also be a complement of vacuum packaging to avoid photo-oxidation phenomena, in particular for sliced delicatessen products. Indeed, presentations in small packages with a transparent cover to show the food product are more and more appreciated. However, if oxygen traces are still present when the package is put on the shelf, the photo-oxidation phenomena start to take effect, leading to a rapid discoloration of the meat. Existing oxygen scavenging technologies utilize one or more of the following concepts: iron powder oxidation, ascorbic acid oxidation, photosensitive dye oxidation, enzymatic oxidation (e.g., glucose oxidase and alcohol oxidase), and unsaturated fatty acids (e.g., oleic or linolenic acid) rice extract or immobilized yeast on a solid substrate. Structurally, the oxygen scavenging component of a package can take the form of a sachet, label, film (incorporation of scavenging agent into the packaging film), card, closure liner or concentrate. Ageless® (Mitsubishi Gas Chemical Co., Japan) is the most common oxygen scavenging system based on iron oxidation. The sachets are designed to reduce oxygen levels to less than 1%. Iron based oxygen scavenger along with catalysts have been successfully used in sliced, cooked and cured meats.

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Carbon Dioxide Scavengers and Emitters

The function of carbon dioxide within a packaging environment is to suppress microbial growth. Therefore, a carbon dioxide generating system can be viewed as a technique complimentary to oxygen scavenging. Since the permeability of carbon dioxide is 3–5 times higher than that of oxygen in most plastic films, it must be continuously produced to maintain the desired concentration within the package. High carbon dioxide levels (10–80%) are desirable for foods such as meat and poultry in order to inhibit surface microbial growth and extend shelf life. The advantages of carbon dioxide are that it acts on all the food inside the packaging and does not require contact between the food and package, whereas the disadvantage is that it changes the color of meat.

CO_2 may be used in conjunction with oxygen scavengers to maintain an atmosphere that is favorable for the preservation of certain products. In the case of fishery products, fresh and processed meats, cheeses, and baked goods, a high concentration of carbon dioxide in the atmosphere of the package is advantageous because it maintains the organoleptic properties of the products and exerts a bacteriostatic effect. Collapse of the package or development of a partial vacuum may also be a problem for food packed with oxygen absorbers. To overcome this problem, the dual action of oxygen absorber/emitter of carbon dioxide absorbs oxygen and generates an equivalent volume of carbon dioxide. Ageless® G and FreshPax exert dual effects as they have the ability to absorb oxygen and emit carbon dioxide. Freshilizer® is another CO_2-releasing product used to extend the shelflife of fresh meat. This innovative package consists of a tray with a perforated false bottom in which a porous sachet containing sodium bicarbonate/ascorbate is deposited. When exudates from meat come in contact with the sachet, it releases carbon dioxide, so that the carbon dioxide absorbed by the meat is replaced continuously. Carbon dioxide absorbers (sachets), consisting of either calcium hydroxide and sodium hydroxide, or potassium hydroxide, calcium oxide and silica gel, may be used to remove carbon dioxide during storage in order to prevent bursting of the package. Food applications include their use in packs of fresh meat, dehydrated poultry products and beef jerky.

Moisture Absorbers

The main purpose of liquid water control is to lower the water activity of the product, thereby suppressing microbial growth. Several companies

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manufacture drip absorbent sheets or pads such as Cryovac® Dri-Loc® (Sealed Air Corporation, USA), Thermarite® or Peaksorb® (Australia), Toppan (Japan) and Fresh-R-Paxe (Maxwell Chase Technologies, LLC, USA) for liquid control in high water activity foods such as meat and poultry. These systems consist of a super absorbent polymer located between two layers of a microporous or nonwoven polymer like polyvinyl acetate blanket. Such sheets are used as drip-absorbing pads placed under whole chickens or chicken cuts.

Chlorine Dioxide Generators

Chlorine dioxide can exist in gaseous, liquid or solid state. Its efficiency against bacteria, fungi and viruses can be delivered from a solid state, called Microspheres (Bernard Technologies, USA), through the interaction of moisture to produce a controlled and sustained release of chlorine dioxide in gaseous form. According to the company, no residue is left, nor is the food product contained in the packaging tainted in any way. Sustained and controlled release of chlorine dioxide is related to exposure to humidity greater than 80% and light. The result is a high activity against a broad spectrum of microorganisms including actively growing vegetative cells and spores. Microsphere powder can be delivered from sachets previously incorporated in the packaging. The sustained and controlled release of chlorine dioxide from the Microspheres can be varied from peak delivery of 1 ppm–100 ppm for periods of days to 6 weeks. Applications for this technology are just beginning to unfold in the food industry to reduce food safety risks for meat, poultry, fish and dairy products.

Preservative Releasers/Antimicrobial Packaging

Microbial contamination and subsequent growth reduces the shelf life of foods and increases the risk of food borne illness. Traditional methods of preserving foods from the effect of microbial growth include thermal processing, drying, freezing, refrigeration, irradiation, MAP and addition of antimicrobial agents or salts. However, some of these techniques cannot be applied to food products such as fresh meats. Antimicrobial packaging is a promising form of active packaging especially for meat products. Incorporation of bactericidal agents into meat formulations may result in partial inactivation of the active compounds by meat constituents and therefore exert a limited effect on surface microflora. Antimicrobial food packaging materials have to extend the lag phase and reduce the growth phase of

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microorganisms in order to extend shelf life and to maintain product quality and safety.

The classes of antimicrobials listed range from acid anhydride, alcohol, bacteriocins, chelators, enzymes, organic acids and polysaccharides. Antimicrobial packages have had relatively few commercial successes except in Japan where Ag-substituted zeolite is the most common antimicrobial agent incorporated into plastics. Ag-ions inhibit a range of metabolic enzymes and have strong antimicrobial activity. Antimicrobial films can be classified into two types: those that contain an antimicrobial agent which migrates to the surface of the food and, those which are effective against surface growth of microorganisms without migration. Besides these flavor/odor absorbers like cellulose triacetate, citric acid, activated carbon, etc., have applications in poultry and fish.

INTELLIGENT PACKAGING

Intelligent packaging systems are those that contain an external or internal indicator or sensor to provide information regarding aspects of history of package and/or quality of packaged food. Intelligent packaging has been defined as packaging systems which monitor the condition of packaged foods to give information about the quality of the packaged food during transport and storage. Smart packaging devices, which may be an integral component or inherent property of a foodstuff's packaging, can be used to monitor a plethora of food pack attributes. It refers to packaging that senses and signals or informs. The headspace of food packages undergoes changes in their composition over time. Devices capable for identifying, quantifying, and/or reporting changes in the atmosphere within the package, the temperatures during transfer and storage and the microbiological quality of food provide valuable information both to the final consumer and producer and/or marketer about the effectiveness of the conservation strategies used in the marketing chain.

Basically, there are two types of intelligent packaging: one based on measuring the condition of the package on the outside, the other measuring directly the quality of the food product, i.e., inside the packaging. In the latter case, there is direct contact with the food or with the headspace and there is always the need for a marker indicative of the quality and/or safety of the packed food. Examples include time-temperature indicators (TTI), gas leakage indicators, ripeness indicators, toxin indicators, biosensors, and radio frequency

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identification. Although distinctly different from the concept of active packaging, features of intelligent packaging can be used to check the effectiveness and integrity of active packaging systems.

Indicators

Time-Temperature Indicators

The best-before date printed on food packaging is only an indicative value and does not take into account possible fluctuations in temperature that food may suffer during storage. The best-before date must therefore be within the shelflife of the food to ensure that food is safe to consume. They fall into two types: visual indicators or radio frequency identification (RFID) tags. The basic idea underlying visual indicators is that the quality of food deteriorates more rapidly at higher temperatures because chemical reactions, biochemical reactions, and microbial growth are speeded up. The indicators change color in response to cumulative exposure to temperature to point at probable loss of shelflife. The main mechanisms of action include enzymatic reactions, polymerization, or chemical diffusion. These products are used to monitor exposure to unsuitable temperatures during transport and storage and are an indication of quality for the producer because they ensure that the product reaches the consumer in optimal conditions. It is important that the indication is irreversible.

Freshness Indicators

The information provided by intelligent packaging systems on the quality of meat products may be either indirect (i.e., changes in packaging oxygen concentration may imply quality deterioration through established correlation) or direct. Freshness indicators provide direct product quality information resulting from microbial growth or chemical changes within a food product **(Fig. 36.1)**. Microbiological quality may be determined through reactions between indicators included within the package and microbial growth metabolites. The chemical detection of spoilage of foods and the chemical changes in meat during storage provide the basis for which freshness indicators may be developed based on target metabolites associated with microbiologically induced deterioration.

Changes in the concentration of organic acids such as n-butyrate, L-lactic acid, D-lactate and acetic acid during storage offer potential as indicator metabolites for a number of meat products. Biogenic

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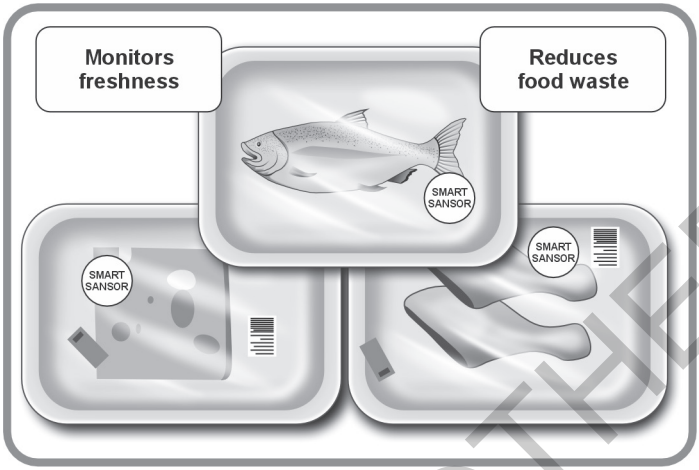

Fig. 36.1: Freshness indicators.

amines such as histamine, putrescine, tyramine and cadaverine have been implicated as indicators of meat product decomposition. Carbon dioxide produced during microbial growth can in many instances be indicative of quality deterioration. Hydrogen sulphide, a breakdown product of cysteine, with intense off-flavors and low threshold levels is produced during the spoilage of meat and poultry by a number of bacterial species.

Sensors

A sensor is defined as a device used to detect, locate or quantify energy or matter, giving a signal for the detection or measurement of a physical or chemical property to which the device responds.

Gas Sensors

Gas sensors are devices that respond reversibly and quantitatively to the presence of a gas by changing the physical parameters of the sensor and are monitored by an external device. Systems presently available for gas detection include amperometric oxygen sensors, potentiometric carbon dioxide sensors, metal oxide semiconductor field effect transistors, organic conducting polymers and piezoelectric crystal sensors. In recent years, a number of instruments and materials for optical oxygen sensing have been described. Such sensors are usually comprised of a solid-state

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material, which operate on the principle of luminescence quenching or absorbance changes caused by direct contact with the food. These systems provide a noninvasive technique for gas analysis through translucent materials and as such are potentially suitable for intelligent packaging applications.

Fluorescence-based Oxygen Sensors

Fluorescence-based oxygen sensors represent the most advanced and promising systems to date for remote measurement of headspace gases in packaged meat products. The active component of a fluorescence-based oxygen sensor normally consists of a long-delay fluorescent or phosphorescent dye encapsulated in a solid polymer matrix. Oxygen is quantified by measuring changes in luminescence parameters from the oxygen-sensing element in contact with the gas or liquid sample, using a predetermined calibration. The process is reversible and clean: neither the dye nor oxygen is consumed in the photochemical reactions involved, nor by-products are generated and the whole cycle can be repeated.

Biosensors

Biosensors are compact analytical devices that detect, record and transmit information pertaining to biological reaction. Intelligent packaging systems incorporating biosensors have the potential for extreme specificity and reliability. Market analysis of pathogen detection and safety systems for the food packaging industry suggests that biosensors offer considerable promise for future growth. The majority of available biosensor technology is not yet capable of commercial realization in the food sector.

At present two biosensor systems are commercially available. ToxinGuard® developed by Toxin Alert (Ontario, Canada) is a visual diagnostic system that incorporates antibodies in a polyethylene-based plastic packaging and is capable of detecting *Salmonella* sp., *Campylobacter* sp., *E. coli* 0517 and *Listeria* sp. The Food Sentinel System (SIRA Technologies, California, USA) is a biosensor system capable of continuous detection of contamination through immunological reactions occurring in part of a barcode. The barcode is rendered unreadable by the presence of contaminating bacteria. Such systems give some insight into products likely to become more mainstream in the years to come.

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Outlines of Meat Science & Technology

This book contains 38 chapters on the key aspects of meat science and technology including important areas of poultry and fish products technology in a systematic, clean and concise form. The material has been carefully planned to deal with the subject in the tropical, especially Indian context.

The volume is intended primarily for the students of:

- BVSc and AH
- BSc (Food Science)
- BTech (Food Technology)
- MVSc (Livestock Products Technology)
- MSc (Food Technology)

It will also serve as a useful handbook for meat industry personnel especially:

- Meat Plant Managers and Supervisors
- Meat Processing Technicians

BD Sharma obtained BVSc and AH degree with merit from GB Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India in 1975 and MVSc (Poultry Science) and PhD in Livestock Products Technology discipline from Indian Veterinary Research Institute (IVRI), Izatnagar, Bareilly, Uttar Pradesh in 1977 and 1989, respectively.

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He is the recipient of ICAR—Dr Rajendra Prasad Award (2007–08), IVRI—Best Teacher Award (2004–05), Special Achievement Award by e-PAHEL (2003), Fellow, IAVVR (2003), besides other 32 awards/recognitions including Vice-President, IMSA (2008–2012). He has held the prestigious position as Member, Board of Management, Indian Veterinary Research Institute, Izatnagar (2008–2010).

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