MEAT SCIENCE

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Summary

Meat science involves all aspects of the harvesting, processing, packaging, storage and

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consumption of meat and meat products. It involves many disciplines ranging from genetics to materials science, from livestock management to microbiology and biochemistry and begins when a food animal is harvested for meat. The science covers the entire process of the conversion of muscle to meat as well as the factors that contribute to carcass and meat quality and their measurement.

Meat includes game meat, red meat, poultry, seafood and a number of offal foods. This entry refers mainly to red meat which is derived from the skeletal muscles of mammals, in particular the four major livestock species: cattle, pigs, sheep and goats. Poultry or white meat is derived from the skeletal muscles of domesticated birds, in particular chickens, geese, turkeys and ducks. Game meat refers to the flesh of wild mammals and birds as wells as diversified livestock. Offal consists of edible and inedible products other than skeletal muscle and fat harvested from meat animals. These by-products of meat production are ubiquitous and used daily by almost everyone.

Harvesting consists of transportation from the farm of origin to an abattoir, stunning, slaughtering and dressing followed by chilling, processing and packaging of the meat and meat products. Packaging is a rapidly advancing science guided by microbiologists and materials scientists. Packaging must meet a number of sometimes contradictory criteria in particular protection from desiccation and spoilage while maintaining an attractive appearance.The conversion of muscle to meat is a complex biochemical process resulting in a lowering of the pH from about 7.0 to about 5.5 to 6.0. Anything (such as stressing the animal prior to slaughter) that interferes with this process will interfere with carcass and meat quality.

Carcass quality is a combination of the amount and proportions of the three major tissues bone, muscle and fat and their appearance, in particular the color and texture of the muscle and the fat and the amount of marbling (intramuscular fat) in the muscle. Meat quality is the actual taste of the meat and is made up of tenderness, juiciness, flavor and overall appeal; it can be measured by human tasters, by specially designed instruments or by a combination of these two.

Preparation and cooking affects the meat in a number of physical and chemical ways: generally thin slicing and grinding makes tougher meat easier to eat; cooking (heating) makes myofibrillar proteins (the contents of the muscle fibers themselves) tougher and collagen (a connective tissue forming a complex internal architecture that holds the muscle together) more tender (provided there is enough water present to hydrolyze it to gelatin); heating red meat from about 65ºC to 75ºC causes a change in the color of myoglobin from red (rare) through pink (medium) to brown (well-done) and further heating, particularly beyond 100ºC produces a dark brown color and roasted flavor through the Maillard reaction.

1. Introduction

1.1 Definitions

There is no single acceptable definition of “meat” (or by extension meat science). It can be defined very broadly as being synonymous with “food” (“…and to every beast of the

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earth I have given every green herb for meat…" Genesis 1:30), or narrowly as for example "the flesh of mammals". In general meat refers to the flesh of any animal species: red meat from livestock, game meat from wild animals, poultry meat from domesticated birds, fish and seafood from a variety of non-mammalian, non-avian aquatic animals, but it can also include offal meat from edible parts of the animal other than skeletal muscle and fat. Meat science is concerned with understanding all aspects of the production, harvesting, processing, packaging, storage and consumption of meat and meat products.

Although every part of the animal is used for commercial purposes (see Section 1.2), the animal is not all meat. From a meat industry point of view the animal consists of two parts: the carcass and the offal; the carcass in turn consists of meat and trim, the latter being mainly bones and excess fat. The definition of what makes up the carcass is variable, but the definition of offal is always the same: it is everything other than the carcass. In general beef and sheep carcasses do not include the head, feet, tail, skin, blood and internal organs; poultry are similar but include the (de-feathered) skin; while pig carcasses may include everything other than the outer layers of skin, the hair, toenails, blood and internal organs.

Some offal is edible (e.g. liver, tripe, and kidneys), some is inedible (e.g. hides and hooves) and some can be used as pharmaceuticals (e.g. heparin and insulin). All parts of the offal can be sold, and the profitability of the meat packing business has traditionally depended heavily on its ability to market by-products.

1.2. Meat industry by-products

Livestock are often described using such terms as single, dual or triple-purpose meaning that they produce one (e.g. beef from beef cattle), two (e.g. wool and mutton from sheep) or three (e.g. milk, draft power and meat from camels) commercial products; but in truth they are all multi-purpose. The number of by-products harvested from animals in addition to the primary product (meat) is almost limitless, and they are used, generally unknowingly, by almost everyone in all aspects of their daily lives. Meat industry by-products can be divided for convenience into three major groups: edible, inedible and pharmaceutical products. Among the edible by-products are organs such as the heart, liver, kidneys and poultry giblets; as well as natural sausage casings, tripe and the enzyme rennet used in making junket. The list of inedible products is almost endless: traditionally the inedible offal was rendered (ground and heated to remove the fat) and the fat portion used for tallow, candles and soap making while the remainder, a high protein dried meat meal, was used as a protein supplement for animal feed or as a nitrogen fertilizer.

Current commercial uses of inedible by-products in addition to those already mentioned include ornaments and buttons from horns and hooves; soaps, toothpaste, shaving cream, lotions, lipsticks, deodorants, glues, paints varnishes, polishes, antifreeze, surfactants and even explosives from glycerin; artists brushes from hair and bristles; surgical sutures, violin and racquet strings from intestinal walls; bone china, bone black and hardened steel from bone-ash; rubber and plastic polymerization, fabric softeners, lubricants, plasticizers and bio-diesel, from fat. Even the undigested food from the

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alimentary tract can be composted and sold.

The list of pharmaceuticals collected during harvesting has included progesterone, estrogen, cortisone, ACTH, insulin, thyroxin, heparin, glucagon, thrombin, trypsin, and many others but these days many of these can be synthesized in the laboratory or derived biologically using recombinant DNA technology. For a comprehensive list of meat industry by-products the reader is referred to the World Wide Web and to such publications as "*Encyclopedia of Meat Sciences*" and "*The Meat We Eat*". There is no doubt that humankind continues to have a very close association with a wide variety of animal products on a daily basis.

2. Harvesting

The harvesting process, and the domain of meat science, begins when the animal is judged by its owner or manager to be "finished" i.e. ready to market. The decision on market-readiness is complicated and part of the necessary skill set for a successful farmer. Once the decision is made the animal must be sold either directly to an abattoir or to a meat company who will have it processed in an abattoir. This sale traditionally took place at a public auction, necessitating at least double handling of the animal (from home to the auction and from the auction to the abattoir) as well as the considerable stress to the animal of being in a strange place with strange animals and being handled by strangers during the auction process. This process also exposed the animal to the possibility of bruising, injury and disease. For these and a number of other reasons to do with market efficiency it is now unusual, at least in "western" countries, for animals to go to auction on their way to the abattoir. Instead the animals are sold before they leave home, often with the final price being determined by the ultimate carcass grade or classification (see Section 4.3).

The process of harvesting consists of loading and transportation to the abattoir, unloading and lairage at the abattoir (lairage is the holding period between unloading and slaughter), stunning or knocking (rendering the animal unconscious prior to killing), shackling (attaching the hind leg or legs to chains), hoisting (lifting the animal up by the hind legs while still unconscious), sticking (the process of severing the blood vessels in the neck or thorax), exsanguination or bleeding (which causes death) and finally dressing (separation and removal of the offal from the carcass). Once the carcass is dressed it is weighed, washed and removed to a refrigerated room (drip cooler) to set. Setting is the development of rigor mortis, a process described in detail in Section 3.5.

Once the carcass is fully cooled and stabilized in rigor it can be further processed. The time required for full rigor development depends on the type of carcass, the level of activity or stress prior to slaughter and the temperature to which the carcass is exposed.

In all countries that trade meat on the world market, the entire process, from arrival of live animals at the abattoir to packaged meat leaving the abattoir, is overseen by health and hygiene inspectors. The role of the inspectors is to ensure compliance with regulations covering the health and welfare of the animals prior to slaughter and monitoring all equipment and procedures during processing to ensure the production of healthful meat products. The inspectors' responsibilities include inspecting the

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premises, the equipment and the dressing process to ensure compliance with hygiene standards, and inspection of the live animal and its carcass and offals to identify and isolate any diseased or contaminated carcasses. Inspection will typically include random testing for residues of banned or restricted products (including antibiotics and growth promoters). Inspection of meat and meat products continues through every phase and every change of ownership and premises until the meat is finally sold to a consumer.

2.1. Transportation

Animals are seldom harvested where they live (though small mobile abattoirs are gaining in popularity, particularly for some niche markets) and some may travel great distances to their final destination. Transportation, consisting of loading, traveling and unloading could be a source of great stress to the animal if it were not done properly, and stress can cause a serious loss of meat quality and profitability to the owner (see Section 3.5). It is therefore very clearly in everyone's interest to minimize stress during transportation. In most countries, and certainly those that trade internationally, laws govern all stages of transportation of livestock and poultry, and these laws refer to such things as design, construction and materials for the container, the time that animals can be in transit before being rested and receiving feed and water and the loading conditions such as stocking densities and mixing of different classes and species of animals together in the same container. It is fortunate that the most humane conditions are also the conditions that will cause least economic harm to the animals, however, these conditions may not be compatible with the speediest and cheapest transportation, so sometimes livestock owners and meat processors find themselves at odds with transporters over transportation conditions.

2.2. Stunning, Slaughter and Dressing

In most countries and for most species of animals there are strict rules, usually enshrined in law, to ensure the humane slaughter of animals. Typically the animal must be stunned by some acceptable method prior to slaughter to render it unconscious before being bled and it must bleed to death before regaining consciousness. There are some exceptions to this, including an exemption in many countries for religious reasons. For example Jewish and Islamic religious slaughter practices (Kosher and Halal respectively) do not normally allow stunning prior to killing the animal (there are some exceptions for Halal slaughter) and although most countries allow this exemption from stunning on religious grounds there is increasing pressure from humane organizations to ban it and require that all meat animals be stunned prior to slaughter.

There are a number of acceptable ways to stun meat animals including:

- a captive–bolt pistol that drives a small piston-like bolt into the animal's brain and then returns back into the gun (cattle and sheep);
- a percussion stunner that delivers a forceful blow to the skull without penetrating it (adult cattle and other large animals);
- an electric stunner that passes a high voltage either across the brain or between the

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head and the back of the animal (pigs, sheep and poultry);
- carbon dioxide gas in a pit (pigs).

In most of these cases the animal is stunned (rendered unconscious) but not killed; death comes as a result of exsanguination following the severing of the large blood vessels, this is known in the industry as “sticking”. Head to back electrical stunning, however, stops the heart and therefore both stuns and kills the animal. The animal is suspended by the hind legs during and after sticking while the blood drains out. It was assumed in the past that having the heart still pumping during bleeding (i.e. the animal alive but stunned) would allow a more complete draining of the blood. Recent research suggests that this is not so and that stopping the heart (as in head to back electrical stunning of pigs) does not compromise bleed-out.

Once the animal has bled out it is “dressed” meaning all of the offal (see Section 1.1) is separated from the carcass and the carcass is then weighed, washed and moved to a cooling area. In most countries the whole process is subject to inspection to ensure both hygiene and humane treatment of the animals. The inspection includes edible offal.

2.3 Packaging, Processing and Storage

Packaging of meat and meat products serves a number of purposes, some of which are antagonistic. Its primary purpose is to protect the product from contamination, deterioration and evaporative losses, particularly during transportation and storage, but at retail the packaging also needs to display the product safely and attractively while conveying labeling information (some of which is required by law) product promotion and consumer education. The retail packaging must also be rugged enough to withstand repeated handling by browsing customers.

It is unlikely that any single packaging material would have all the qualities necessary to meet all of these objectives. For example permeability of the package to oxygen allows the growth of a number of spoilage and pathogenic organisms, and allows oxidative rancidity of the fat, yet it also causes red meat to bloom to an attractive cherry-red color (see Section 3.4). Unfortunately, continued exposure to oxygen through such a film will cause the attractive red colored oxymyoglobin to be oxidized to the less attractive brown colored metmyoglobin, causing customer resistance.

Moisture permeability of the packaging film is another case in point: loss in moisture represents a loss in weight and therefore value, but free water retained in the package and unable to pass through the over-wrap will appear in the package as unsightly “purge”, a red colored liquid that consumers typically assume to be blood. Often the only way to solve these antagonistic requirements is to repackage the meat at different stages in its progress from packing plant to retail meat counter.

Like human consumers, a number of microorganisms find meat to be an excellent nutrient. In general bacteria, molds and yeasts can grow on meat and have the capacity to cause spoilage in a number of ways and in some cases can be pathogenic (disease causing). Three factors can have a major influence on the rate of growth of these

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organisms: moisture, temperature and pH. While yeasts and molds can generally tolerate drier and more acidic conditions than most bacteria, they rarely cause spoilage in meat. Bacteria on the other hand are a serious concern. Bacteria not only cause meat spoilage (objectionable appearance and smells) they can also be pathogenic. In general the bacteria that cause spoilage are aerobic, meaning that they require oxygen to grow, but some are facultative anaerobes meaning that even though they grow best in aerobic conditions they can grow, though at a reduced rate, under anaerobic conditions. Some bacteria are true anaerobes meaning that they grow best in the absence of oxygen; these bacteria generally metabolize carbohydrates rather than proteins in the meat and the end product of their metabolism is lactic acid. This is beneficial because lactic acid itself is neither harmful nor distasteful to the consumer and it will lower the pH of the meat, inhibiting the growth of other spoilage organisms.

Immediately after dressing, most of the bacteria found on the surface of the carcass will be aerobic (oxygen requiring) mesophils (preferring warm temperatures) originating from the animal's skin and gut. As the carcass cools, the population of microbes will change to cold tolerant types (psychrotrophs and psychrophiles) since the lower temperatures will favor their multiplication and growth. Many of the aerobic spoilage organisms are cold tolerant and can continue to grow, though slowly, at quite low temperatures (less that 5ºC).

There are a number of packaging methods that can be used to maintain the quality and integrity of meat after harvest as follows:

2.3.1. Vacuum Packaging

Packaging meat in the absence of oxygen will limit, though not necessarily prevent the growth of most spoilage and pathogenic (aerobic) organisms, and encourage the growth of anaerobic (lactic acid producing) organisms. After rigor mortis is complete and the carcass has been chilled to a few degrees above freezing (meat freezes at about -1.5ºC), most livestock and poultry carcasses are cut into parts (primals and sub-primals cuts), and either frozen or vacuum packed in low OTM (oxygen transmission rate), low WVTR (water-vapor transmission rate) barrier film, sprayed with hot water to shrink the film, then heat sealed and placed in cardboard boxes for transportation across the country or around the world. Care must be taken to ensure that the plastic film is not punctured during packaging or handling particularly with bone-in cuts. To protect the film against sharp edges any exposed bone in a bone-in cut is covered with a protective material. Provided the initial microbial load is low, the plastic bags are not penetrated and the temperature is maintained close to freezing, the shelf life of these fresh meat products can easily be in excess of 70 days and sometimes more than six months.

Because the barrier film creates an anaerobic (oxygen free) atmosphere inside the package, vacuum packed fresh meat will exhibit a dull color and a sour or "dairy" odor when the package is first opened. Although sophisticated consumers would recognize that both of these traits are harmless and temporary, most consumers would find them objectionable. The sour smells are from the action of anaerobic, lactic acid producing bacteria, which are not pathogenic and metabolize carbohydrates rather than proteins in the meat. Protein metabolism typically leads to the extremely unpleasant nitrogen based

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"putrid" smells of rotting and decomposition, while metabolism of carbohydrates, which contain no nitrogen, leads instead to the sour, dairy smells of organic acids. These acids lower the pH of the meat, further protecting it from microbial spoilage. Once the package is opened and exposed to air the sour smell will quickly disappear and in the case of beef and lamb, the dull purplish-red colored deoxymyoglobin will bloom to the more familiar bright cherry-red oxymyoglobin (see Section 3.4).

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Biographical Sketch

Emeritus Professor Mick Price was born on a farm in Herefordshire, UK during World War II. He completed High School in Hereford and went on to read agriculture at what was then the University College of Rhodesia in Salisbury (now Harare, Zimbabwe) graduating with a BSc (Agriculture) in 1967. This was followed by an M.Rur.Sc. (1971) and PhD (1976) in animal science at the University of New England (UNE) in Armidale, NSW, Australia.

Following High School in England he worked on the family farm until leaving for Rhodesia in 1964. He worked for the Rhodesian Department of Research and Specialist Services as a research assistant 1965-66 helping to develop a new beef carcass grading system. In Australia he worked as a Teaching Fellow at UNE 1969-74 and then moved to Canada to take up an NRC Post Doctoral Fellowship at the University of Alberta in Edmonton. In 1976 he was appointed an Assistant Professor in Animal Science at the University of Alberta and later served as Associate Dean of Agriculture (1983-87) and Chair of Animal Science (1987-95). He retired in 2004 and is now the CEO of a small agricultural consulting company in Edmonton, Alberta. His areas of research concentrated mainly on sustainable methods of increasing efficiency and decreasing costs of production in meat production systems. He has published over 120 scientific papers in peer-reviewed journals and text books, and over 130 extension articles in trade and industry magazines. He is immediate past Editor of the Canadian Journal of Animal Science, and a member of the Industry Advisory Board of the IFASA (Institute for Food and Agricultural Sciences, Alberta) Value Added Meat Program.

Prof. Price is a member of many scientific and professional organizations including the Agricultural Institute of Canada, the Alberta Institute of Agrologists, the Canadian and British Societies of Animal Science, the Canadian Meat Science Association and the Society for Teaching and Learning in Higher Education.

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