GENERAL NUTRITIVE COMPOSITIONAL CONSTITUENTS OF MEAT AND RECENT TRENDS AND TECHNIQUES ADOPTED FOR MEAT PROCESSING SYSTEMS: A REVIEW

Sabahu Noor[1], Nair Shruti Radhakrishnan[2] and Khalid Hussain[3]

Division of Livestock Products Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu, India

[1]MVSc Scholar, Division of Livestock Products Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu, India

[2]MVSc Scholar, Division of Livestock Products Technology, College of Veterinary Science & A.H. Navsari Agricultural University, Navsari, Gujarat, India

[3]Doctor, KAAHC, Riyadh, Ministry of Agriculture, Kingdom of Saudi Arabia

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ABSTRACT

Meat is the most valuable livestock product and for many people serves as their first-choice source of animal protein. Meat is either consumed as a component of kitchen-style food preparations or as processed meat products. Processed meat products, although in some regions still in their infancy, are globally gaining ground in popularity and consumption volume. Meat processing has always been part of FAO's livestock programmes, not only because of the possibility of fabricating nutrient-rich products for human food, but also owing to the fact that meat processing can be a tool for fully utilizing edible carcass parts and for supplying shelf-stable meat products to areas where no cold chain exists. Changing consumer demands and increasing global competition are causing the meat product manufacturing sector to embrace new processing technologies and new ingredient systems, which is remarkable if one considers the historically traditional and long term approach to product and process development in the meat industry. Meat has long been known for its nutritive composition which could explain why it is being consumed by many people worldwide. The protein profile of meat consists of amino acids that have been described as excellent due to the presence of all essential ones required by the body. This review explained the general nutritive compositional constituents of meat and recent trends and techniques adopted for meat processing systems.

Keywords: Meat, Meat constituents, Nutritive composition, protein profile, Meat processing

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INTRODUCTION

Meat is defined is as 'the flesh of animals used as food, now chiefly butcher's meat, excluding fish and poultry'. Since the predominant portion of the edible flesh of animal carcasses consists of muscular tissue, meat can be conveniently regarded as the *post mortem* aspect of muscles. The principal attributes of eating quality in meat, for which consumers value the commodity, viz. colour, texture (including tenderness and juiciness) and flavour, thus depend upon the structure and chemistry of muscle. Meat is widely consumed a source of protein; it is either eaten cooked or processed into other forms to avoid associated spoilage (Olaoye et al., 2010). The most abundant chemical in meat is water followed by protein then fat. Carbohydrates, minerals and vitamins occur on much smaller amounts but nevertheless are very important metabolically and nutritionally. In addition to protein and fat, meat is a significant source of several other nutrients. These include the minerals iron and zinc, and most of the B—vitamin complex (B1, B2, niacin, B6 and B12). Meat is defined as 'the edible part of the skeletal muscle of an animal that was healthy at the time of slaughter (CFDAR, 1990). Meat is a nutritious, protein-rich food which is highly perishable and has a short shelf-life unless preservation methods are used. Shelf life and maintenance of the meat quality are influenced by a number of interrelated factors including holding temperature, which can result in detrimental changes in the quality attributes of meat (Olaoye and Onilude, 2010).

Meat has long been known for its nutritive composition which could explain why it is being consumed by many people worldwide. The protein profile of meat consists of amino acids that have been described as excellent due to the presence of all essential ones required by the body. It has also been proved that protein and vitamins (especially A and B12) in meat could not be substituted for by plant sources, further justifying the nutritive importance of the former. Various biochemical changes and microorganisms are associated with meat, during the process of slaughter, processing and preservation. Changing consumer demands and increasing global competition are causing the meat product manufacturing sector to embrace new processing technologies and new ingredient systems, which is remarkable if one considers the historically traditional and long term approach to product and process development in the meat industry. This is likely because the long standing positive consumer perception that meat and meat products are very good sources of minerals, vitamins, and contain complete proteins (i.e. proteins that in contrast to many plant-based proteins contain all nine of the essential amino acids) is gradually giving way to a more negative view (Verbeke et al., 2010). This review explained the general nutritive compositional constituents of meat and recent trends and techniques adopted for meat processing systems.

General nutritive compositional constituents of meat

Meat is defined as 'the edible part of the skeletal muscle of an animal that was healthy at the time of slaughter (CFDAR, 1990). Meat is frequently associated with a negative health image due to its "high" fat content and in the case of red meat is seen as a cancer-promoting food. Therefore a low meat intake, especially red meat is recommended to avoid the risk of cancer, obesity and metabolic syndrome (Biesalski, 2005). Chemically meat is composed of four major components including water, protein, lipid, carbohydrate and many other minor components such as vitamins, enzymes, pigments and flavour compounds (Lamber et al., 1991). The relative proportions of all these constituents give meat its particular structure, texture, flavour, colour and nutritive value. However, because of its unique biological and chemical nature, meat undergoes progressive deterioration from the time of slaughter until consumption (Lamber et al., 1991). Broadly, the composition of meat, after rigor mortis but before post-mortem degradative changes, can be approximated to 75% water, 19% protein, 3.5% soluble, non-protein, substances and 2.5% fat. Proteins are the major component of the dry matter of lean meat (Briggs & Schweigert, 1990). Nine of the amino acids present in proteins are essential (or semi-essential) because the human body cannot synthesize them from other compounds, and therefore must taken them up from food. Therefore, the requirement for dietary protein consists of two components; (a) a requirement for the nutritionally essential amino acids, and (b) the need to meet the requirement for non-specific nitrogen in order to supply the nitrogen necessary for synthesis of the nutritionally not essential amino acids and other physiologically important nitrogen containing compounds (nucleic acids, creatine, porphyrins) (Pellett and Young, 1990). The proteins in muscle can be broadly divided into those which are soluble in water or dilute salt solutions (the sarcoplasmic proteins), those which are soluble in concentrated salt solutions (the myofibrillar proteins) and those which are insoluble in the latter, at least at low temperature - the proteins of connective tissue and other formed structures (Lawrie and Ledward, 2006). The sarcoplasmic proteins are a mixture of several hundred molecular species. Several of the sarcoplasmic proteins are enzymes of the glycolytic pathway and may be present in more than one form (isozymes). Proteins of beef consist of essential amino acids such as leucine, isoleucine, lysine, methionine, cystine, phenylalanine, threonine, tryptophan, valine, arginine and histidine; of these the last two are considered essential for infants. Amino acids are important for maintenance and repair of body tissues in human (Lawrie and Ledward, 2006).

Fat is the richest dietary source of energy and supplies essential nutrients such as essential fatty acids as well as precursors of compounds that regulate a number of physiological functions (e.g. prostaglandins) and helps to absorb fat-soluble vitamins (A, D, E and K). Further fat has a decisive relevance as the most compact energy store of the body, as fixation as well as a protection of the organs and as source of fatty acids which again act as structural element of cell membranes. Fat also provides palatability and flavor to food. In the right proportions it is therefore an essential component of any balanced diet, and hence the degree of fat reduction must not only take into account sensory or technological factors but it must also be such as to avoid loss of nutritional benefits (Colmenero, 2000). Adipose tissue contains little moisture; therefore, the fatter the animal, the lower the total water content of its carcass or cuts. Beef muscle from mature and relatively fat animals may contain as little as 45 percent moisture, while veal muscle from very youthful and relatively lean animals may contain as much as 72 percent moisture. Texture, color and flavor of muscle are affected by the amount of water in muscle tissue (Lawrie and Ledward, 2006). In addition to protein and fat, meat is a significant source of several other nutrients. These include the minerals iron and zinc, and most of the B—vitamin complex (B1, B2, niacin, B6 and B12). The importance of meat as an essential source of some micronutrients is due to the fact that it is either their only source, or they have a higher bioavailability. Vitamins A and B12 occur exclusively in meat and can hardly be compensated for by plant-derived provitamins (Biesalski, 2005). Vitamins are a complex group of organic compounds that are generally present in small quantities in foodstuffs. Vitamins are important as cofactors in enzymatic processes and also possess hormonal activity. Traditionally, vitamins have been classified on the basis of their solubility in either lipid or aqueous solvents, and they are therefore broadly divided into fatand water-soluble vitamin categories (McDowell, 2000; Cheeke, 2005). Fat-soluble vitamins tend to be mainly stored in the liver and adipose tissues of animals, in association with stored fat, and they are not readily excreted. Water-soluble vitamins, on the other hand, tend to be stored to a far lesser extent in the body. The vitamins contained in animal and human diets are predominantly derived from either plant or microbial synthesis. Animal cells maintain the ability for de novo synthesis of some vitamins, such as vitamin D and, depending on the species involved, niacin and ascorbate, as well as the ability to convert precursors (provitamins) to their active form. Additionally, commensal microorganisms in both the ruminant and non-ruminant digestive tract can serve as source of vitamins, such as vitamin K and the water-soluble B-complex vitamins (Sahlin & House, 2006). Meat has long been recognized as a good source of B vitamins for human nutrition.

Meat is a very good source of various micronutrients: low-fat pork contains 1.8 mg iron, 2.6 mg zinc; and pigs' liver contains 360 mg magnesium, 20 mg iron and 60 μg selenium per 100 g. A daily intake of 100 g of meat and liver can supply up to 50% of the recommended daily allowance for iron, zinc, selenium, vitamins B1, B2, B6, B12 and 100% of vitamin A (Biesalski and Nohr, 2009).Vitamin A, one of the micronutrients in meat, is essential for the growth and development of various cells and tissues. Its active form, retinoic acid (RA), controls the regular differentiation as a ligand for retinoic acid receptors and is involved in the integration of cell formation, i.e. the formation of gap junctions (Kurokawa et al., 1994). People dieting to lose weight could obviously be at risk of micronutrient deficiencies (Biesalski and Nohr, 2009). However, the levels of iron, magnesium, zinc, fat-soluble vitamins and essential fatty acids should be controlled during the diet. A meta-analysis has shown that protein-rich diets that were low in carbohydrates but with a moderate-to high fat content resulted in a better weight loss than diets low in protein and fat, but high in carbohydrates. In pregnant women, risk of deficiency of vitamin D, folic acid, zinc and iron is due to enhanced demands, especially when meat is avoided in the diet (Saletti *et al*., 2000). Meat is not only an important source of available iron, but also of zinc. It is well known that absorption of dietary zinc from animal protein based meals is higher compared to wholegrain cereal based meals (King and Turnland, 1989). The main reason is, as described for iron, the absence of zinc absorption inhibiting factors like phytate and fibers. Iron has a higher bioavailability from meat than from plants (heme iron), as has folic acid which is nearly 10-fold more, especially from liver or eggs, compared to vegetables (Biesalski, 2005). In addition, it has been shown that meat protein enhances zinc absorption from phytate containing meals due to its affinity for zinc compared to phytate (Kirchgessner, Paulicks & Roth, 1990). The trace element selenium (Se) is a crucial nutrient for human health. It is a component of a number of important selenoproteins including enzymes required for such functions as antioxidative defense, reduction of inflammation, thyroid hormone production, DNA synthesis, fertility and reproduction (Raymann, 2000). It can also be converted in the body to Se metabolites that are thought to reduce the blood supply to tumors and kill cancer cells (Combs & Lü, 2001).

Recent trends and techniques adopted for meat processing systems

Meat is one of the most valuable and demanding food products. Worldwide meat consumption is growing and the variety of products available as convenience foods is on the increase. Meat processing in the East European countries, Asia and South America continues on an upward path. These are all factors that contribute to the need for efficient, fully optimised meat processing. The continuously growing focus on automation along the entire meat processing chain is closely linked to the growing use of information technology. Hygiene and traceability are of crucial importance, requiring full monitoring of all processes along with the continuous documentation of origin and production data, in the interests of consumer protection. Fully automated, continuous production processes with material deliveries by meat suppliers just in times can now be found in the meat manufacturing sector. In modern meat processing, most of the processing steps can be mechanized. In fact, modern meat processing would not be possible without the utilization of specialized equipment. Such equipment is available for small-scale, medium-sized or large-scale operations. The major items of meat processing equipment needed to fabricate the most commonly known meat products are listed and briefly described hereunder.

Meat grinder

A meat grinder is a machine used to force meat or meat trimmings by means of a feeding worm (auger) under pressure through a horizontally mounted cylinder (barrel). At the end of the barrel there is a cutting system consisting of star-shaped knives rotating with the feeding worm and stationary perforated discs (grinding plates). The perforations of the grinding plates normally range from 1 to 13mm. The meat is compressed by the rotating feeding auger, pushed through the cutting system and extrudes through the holes in the grinding plates after being cut by the revolving star knives. Simple equipment has only one star knife and grinder plate, but normally a series of plates and rotary knives is used. The degree of mincing is determined by the size of the holes in the last grinding plate. If frozen meat and meat rich in connective tissue is to be minced to small particles, it should be minced first through a coarse disc followed by a second operation to the desired size. Two different types of cutting systems are available, the "Enterprise System" and the "Unger System". In combination with specialized separator blades, hazardous parts such as bones, gristle, sinews and other solid particles can be removed from the meat product (Fischer, 1988a, b). However, while the operating principle may be simple, there are a significant amount of variations with respect to available knife perforated plate combinations. Pump grinders can increasingly produce finer meat batters. Pump grinders can also handle addition of water instead of ice making operating temperatures above 0°C feasible. This noticeably reduces required cutting forces as materials are viscous rather than a solid. Pump grinder may reduce or eliminate issues such as microbial spoilage and oxidative based on the fact that the raw material is relatively mildly treated and air pockets in the meat batter are reduced by the applied vacuum (Honikel, 2004). Theoretically, pump grinders should therefore able to one day completely replace bowl choppers in the production of fine disperse batter. To date, pump grinders are mostly used for the continuous manufacturing of raw fermented sausages although development of fine dispersing systems is underway (Buchele, 2009).

Bowl cutter/chopper

The bowl cutter is the commonly used meat chopping equipment designed to produce small or very small ("finely comminuted") lean meat and fat particles. Bowl cutters consist of a horizontally revolving bowl and a set of curved knives rotating vertically on a horizontal axle at high speeds of up to 5,000 rpm. Many types and sizes exist with bowl volumes ranging from 10 to 2000 litres. The most useful size for small- to medium-size processing is 20 to 60 litres. In bigger models bowl and knife speed can be regulated by changing gears. Bowl cutters are equipped with a strong cover. This lid protects against accidents and its design plays a crucial role in the efficiency of the chopping process by routing the mixture flow. Number, shape, arrangement, and speed of knives are the main factors determining the performance of the cutter. Bowl cutters should be equipped with a thermometer displaying the temperature of the meat mixture in the bowl during chopping.

Meat Slicers

In many supermarkets, the amount of sliced and packaged convenience meat products in the refrigerated section increases while demand for over-the counter meat products decreases. Consumers prefer the longer shelf life of meat products that is achieved when products are sliced under hygienic conditions followed by vacuum or modified atmosphere packaging (Fankhanel, 2008). Continuous slicer lines are increasingly installed by meat product manufacturers (Holac, 2009). Slicers represent the last in the line of meat production processing steps and are often used in combination with portioning units and/or stacking/shingling devices (Rust, 2004). Today, software is available that allows meat manufacturers to custom design decorative patterns and combine single, shingles and stacks. This is important since the display of sliced products has become a key selling point (Heinrich, 2008).

Filling machine

These machines are used for filling all types of meat batter in containers such as casings, glass jars, cans etc. The most common type of filling machine in small and medium size operations is the piston type. A piston is moved inside a cylinder forcing the meat material through the filling nozzle (funnel, stuffing horn) into the containers. Piston stuffers are either attached to the filling table or designed as floor models. In small-scale operations manual stuffers are usually sufficient, sometimes even simple hand-held funnels are used to push meat mixes into casings. Modern filling machines for larger operations are designed as continuous vacuum stuffers. During the filling process a substantial part of the enclosed air is removed from the product, which helps to improve colour and texture of the finished products. These models are usually equipped with a portioning and twisting devise and have a casing grip devise attached for filling of "shirred" (folded) uncut collagen and plastic casings. This type of continuous filling equipment is relatively expensive and are thus not used in small- to medium-size operations.

Clipping machines

Clipping machines place small aluminium sealing clips on the sausage ends and replace the manual tying of sausages. They can be used for artificial or natural casings. Clipping machines can also be connected to filling machines. Such machines work with so called casing brakes, which are devices for slow release of the shirred casings from the filling horns ensuring tight filling. Then the filled casing segments are clipped in portions. So called double clipping machines place two clips next to each other, which ensures that the individual sausage portions remain clipped on both ends and easy separation of the sausage portions is possible. When using shirred casings, the time consuming loading of pre-cut casings is no longer necessary. Wastage of casings can be reduced to a minimum by tight filling and leaving only as much casing for the sausage end as needed for the placing of the clips. Clipping machines are mainly used in larger operations and in most cases operated by compressed air. For medium-scale operations manually operated hand clippers are available

Meat Homogenizers

From the standpoint of traditional processing of emulsion-type sausages of the frankfurter type, bowl choppers are the preferred production equipment. However, as production quantities grow due to consolidation of meat product manufacturers, bowl choppers had to be further and further increased in size. Today, bowl choppers with volumes of 1200 L are available for industrial production of fine sausages (Seydelmann, 2002, 2009). Thus, bowl choppers are beginning to be replaced by continuously working fine homogenizers that have design principles similar to those of colloid mills and high shear dispersers used in the broader food industry to manufacture products such as for example mayonnaise. In these systems, residence times are short and dead volumes , that is volumes where no processing occurs, are low (Inotec, 2009).

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