Utilization of by-products and waste materials from meat and poultry processing industry: A review

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Abstract

Livestock sector plays an important role in Indian economy and it is an important sub-sector of Indian Agriculture. The overall growth rate in livestock sector is steady (4-5%) and has been achieved despite very low investment in this sector. As per the report of Department of Animal Husbandry, Dairying and Fisheries, Government of India, the livestock sector alone contributes nearly 25.6% of value of output at current prices of the total value of output in Agriculture, Fishing & Forestry sector. The overall contribution of Livestock Sector in total GDP is nearly 4.11% at current prices during 2012-13 (MOSPI report, 2014). This contribution would have been much greater had the animal by-products been also efficiently utilized. Efficient utilization of by-products has direct impact on the economy and environmental pollution of the country. Non-utilization or underutilization of by-products not only lead to loss of potential revenues but also increases the cost of disposal and may create major aesthetic and health problems. Besides pollution and hazard aspects, in many cases meat and poultry processing wastes have a potential for recycling raw materials or for conversion into useful products of higher value. Traditions, culture and religion are often important when a meat by- product is utilized for food. By-products such as blood, liver, lung, kidney, brains, spleen and tripe have good nutritive value. Waste products from the poultry processing and egg production industry must be efficiently dealt with as the growth of these industries depends largely on waste management. Available information pertaining to the utilization of by-products and waste materials from meat and poultry industry has been reviewed here.

Keywords: By-products. Meat industry. Poultry. Rendering. Utilization. Bioactive compounds

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Introduction

Growth of human population along with rapid urbanization, industrialization is posing a great challenge for appropriate waste management initiatives. Proper waste utilization helps in augmenting profit to the producer. Technologies are available for waste utilization however some constraints like non availability of raw material in bulk, improper marketing strategies and unawareness etc. are the stumbling blocks in waste management. The utilization and disposal of product specific waste is difficult, due to its inadequate biological stability, potentially pathogenic nature, high water content, potential for rapid auto oxidation and high level of enzyme activity.

The majority of the waste, in the meat industry is produced during slaughtering. Slaughterhouse waste consists of the portion of a slaughtered animal that cannot be sold as meat or used in meat-products, however eating habits of the people in a particular geographical area differentiate between edible and inedible by products. Such waste includes bones, tendons, skin, and contents of the gastro-intestinal tract, blood and internal organs. In the past, by-products were favourite food in Asia, but health concerns have led to an increased focus on non-food uses, such as pet foods, pharmaceuticals, cosmetics and animal feed. Traditional markets for edible meat by-products have gradually been disappearing because of low prices and health concerns. In response to these problems, meat processors have directed their marketing and research efforts towards non-food uses. Average solid waste generation from bovine slaughter house is 275 kg/ton of total live weight killed (TLWK) which is equivalent to 27.5% of the animal weight. In case of goat and sheep slaughter house, average waste generation from slaughtering is 2.3 kg/head equivalent to approximately 4% of animal weight. Slaughterhouse waste material has the potential to partly replace animal feed material. Slaughterhouse wastes can be processed and used as feed supplements for the poultry, fish and pets like dogs and cats. Presently in India, livestock feed production is more of cereal based and less of animal by-product based. This results in livestock, especially poultry, pig and fish competing with humans for grains and cereals which can partly be replaced with recycled / processed slaughterhouse waste. Slaughterhouse waste is first converted into intermediate products like Meat Bone Meal (MBM), Dicalciumphosphate (DCP) & bicalphos (BCP) which are essentially feed supplements. They are then mixed with various crop ingredients to make a complete feed for animals. Meat Bone Meal is a protein and phosphorous supplements for animal feed manufacturers. It is used up to 5% of total feed. DCP and BCP are essentially phosphorous supplements for animal feed manufacturers and are used to the extent of 1% of total feed. Production of MBM in India is around 55200 tones/annum and total estimated demand is 77500 tones/annum. So the gap between production and supply of MBM is around 22300 tones/annum. Similarly the total production of DCP in India is around 27600 tones/annum and total demand is 34800 tones/annum. Therefore the gap between production and demand of DCP is approximately 7200 tones/annum. The vast gap between demand and supply of intermediate products like

MBM, DCP, and BCP etc. is being met by use of substitutes like Soya meal, Meat meal and Fishmeal. There is a vast potential for setting up slaughterhouse waste processing plants for manufacture of MBM/BCP as feed supplement. (http://www.printsasia.in/book/utilisation-of-slaughter-house-waste-material-for-the-preparation-of-animal-feed).

Importance of waste utilization

1. Better returns to the producer
2. Reduce environmental pollution
3. Employment generation
4. Increased soil fertility
5. Conservation of resources
6. Up scaling of national economy

The major technologies for waste utilization include composting, vermicomposting, rendering, effluent treatment, biomethanation, bio remediation, bio energy, land fill, clean development mechanism and animal feed supplements.

By-products in the meat industry and their utilization

It is said that "everything in the slaughterhouse can be utilized except the last cry of animal". The statement is very true but requires careful attention of management. The yield of byproducts from cattle and buffaloes range from 65 – 75% of live weight compared to 50 to 60% of live weight in other animals. Yield of by-products from poultry ranges from 30 to 40% depending on the type of dressing. (Table 1).The value of unprocessed raw byproducts ranges from 10 to 20 % of the total value of the animal while the revenue returns from processed by-products would be equal to the value of meat derived from the animal (Table 2). It is no longer practical to discard by-products and wastes, especially when a significant amount of valuable raw materials have a strong economic potential like the production of new products and functional ingredients with a significant added-value (Toldrá and Reig, 2011). While considering the various options for byproducts utilization, we have to be realistic and be aware that there are several inherent handicaps in the collection and utilization of byproducts from slaughterhouses. It is essential to assess the economic feasibility of establishing by-products based industries, taking into account the availability of raw material, investment required to set up the industry, demand and cost of end product, labour cost and its marketability. Establishing industrial units based on by-products generally requires huge investments. As such, it is essential to evaluate the availability of raw materials and compare the cost involved before jumping into new projects. It may be worth to establish bio-gas plants in small slaughterhouses and plan to utilize blood by drying it under sun light or mix the same with bran, cook it and dry for utilizing it as feed for poultry or pigs. It is desirable to process all by-products into valuable products, for human foods, pet foods, animal feeds, pharmaceuticals, or fertilizer and lately for biodiesel generation (Table 3).

Nutritive value of meat by-products

Edible meat by-products contain many essential nutrients. Some are used as medicines because they contain special nutrients such as amino acids, hormones, minerals, vitamins and fatty acids. Some of the organs like lung, heart, kidney, brains, spleen and tripe have high nutritive value and constitute part of the diet in different countries worldwide (Toldra and Reog 2011). For instance, liver is very rich in vitamins while liver and kidney contain a wide variety of minerals and trace elements. Other products rich in fat tissue like lard or tallow contribute mostly to energy intake. By-products such as ears, feet, lungs, stomach and tripe contain a larger amount of proline, hydroxyproline and glycine, and a lower level of tryptophan and tyrosine. The vitamin content of organ meats is usually higher than that of lean meat issue. Kidney and liver contain the largest amount of riboflavin (1.697– 3.630 mg/100 g), and have 5–10 times more than lean meat. Liver is the best source of niacin, vitamin B12, B6, ascorbic acid and vitamin A. Kidney is also a good source of vitamin B6 and B12. A 100 g serving of liver from pork or beef contributes 100% of the RDA of vitamin A and B12, 65% of the RDA of vitamin B6, 37% of the RDA of ascorbic acid. Lamb kidneys, pork, liver, lungs, and spleen are an excellent source of iron, as well as vitamins. The copper content is highest in the liver of beef, lamb and veal. Liver also contain the highest amount of manganese (0.128–0.344 mg/100 g). However, the highest level of phosphorus (393–558 mg/100 g) and potassium (360–433 mg/100 g) is found in the thymus and pancreas. With the exception of brain, kidney, lungs, spleen and ears, most other by-products contain sodium at or below the levels found in lean tissue. Mechanically deboned meat has the highest calcium content (315–485 mg/100 g).

Conversion of animal blood into commercially useful products

With a ban on collection and utilization of slaughtered animal blood for human use in India, the processing of blood from slaughterhouse is done mainly by dry rendering. Animal blood has a high level of protein and heme iron, and is an important edible by-product Bovine blood consists of 80.9% water, 17.3% protein, 0.23% lipid, 0.07% carbohydrate, and 0.62% minerals (Duarte *et al.* 1999). In Europe, animal blood has long been used to make blood sausages, blood pudding, biscuits and bread. In Asia, it is used in blood curd, blood cake and blood pudding. It is also used for non-food items such as fertilizer, feedstuffs and binders. Blood is used in food as an emulsifier, a stabilizer, a clarifier, a color additive, and as a nutritional component (blood meal). It is used as a protein supplement, a milk substitute, a lysine supplement or a vitamin stabilizer, and is an excellent source of most of the trace minerals. Blood serves several technological functions such as the increase in protein levels, and the enhancement of the water binding and emulsification capacity (Mandal *et al.* 1999). Blood is a significant part of the animal's body mass (2.4–8.0% of the animal's live weight). The average percentage of blood that can be recovered from pigs, cattle and lambs is about 3-5 % of body weight. Plasma is the portion of blood that is of greatest interest, because of its functional properties and lack of color.

Medicinal and pharmaceutical uses of blood

Blood can be separated into several fractions that have therapeutic properties. Liquid plasma is the largest fraction (63.0%). It consists of albumin (3.5%), globulin and fibrinogen (4.0%). In the laboratory, many blood products are used as a nutrient for tissue culture media, as a necessary ingredient in blood agar, and as peptones for microbial use (Kurbanoglu and Kurbanoglu 2004). Glycerophosphates, albumins, globulins, sphingomyelins, and catalase are also used for biological assay. Many blood components such as fibrinogen, fibrinolysis, serotonin, immunoglobulins and plasminogen are isolated for chemical or medical uses (Young and Lawrie 2007). Purified bovine albumin is used to help replenish blood or fluid loss in animals. It is used in testing for the Rh factor in human beings, and as a stabilizer for vaccines. It is also used in antibiotic sensitivity tests.

Use of blood plasma in food

Blood plasma has an ability to form a gel, because it contains 60.0% albumin (Silva and Silvestre 2003). Plasma is the best water and fat binder of the blood fraction. Plasma gels appear very similar to cooked egg whites. Cooked ham to which were added 1.5 and 3.0% frozen blood plasma, and hot dogs with 2.7% added plasma, were more satisfactory in color than those without it (Autio *et al.* 1985). Blood plasma also has an excellent foaming capacity (Del et al. 2008), and can be used to replace egg whites in the baking industry (Ghost 2001), fractionated plasma proteins like immunoglobulins, fibrinogen and serum albumin, may be added to food and feed ingredients due to their good gelation and emulsification properties (Cofrades *et al.* 2008). Some of the plasma proteins have shown good cross-linking ability of major proteins and protease inhibitory activity or used to enrich in protein products like pasta (Yousif *et al.* 2003). When both thrombin and fibrinogen are mixed and applied to the surfaces of meat pieces, the thrombin enzyme converts soluble fibrinogen into insoluble fibrin polymer giving rise to a half-staggered structure called the protofibril that finally aggregates to form fibers and yielding a three-dimensional network fibrin clot (Mockros *et al.* 1974). The resulting gel network gives meat emulsions with modified physicochemical and textural characteristics, increasing the hardness and springiness.

Utilization of bones and hides into glue and gelatin

Both hides and bones contain large quantities of collagen. Gelatin is one of the most widely used food ingredients. Its applications in food industries are very broad including enhancing the elasticity, consistency and stability of food products. Gelatin is also used as a stabilizer, particularly in dairy products and as a fat substitute that can be used to reduce the energy content of food without negative effects on the taste (Riaz and Chaudry 2004). Besides for the food industry, gelatin is also useful in medicine, pharmaceutical and photographic industries. Gelatin is a valuable protein derived from animal by-products obtained through partial hydrolysis of collagen originated from cartilages, bones, tendons and skins of animals. It is a translucent brittle solid substance, colourless or slightly yellow, nearly tasteless and odourless (Sakr 1997). Gelatin is usually available in granular powder form, although in Europe countries, sheet gelatin is still available (Sakr 1997). Most commercial gelatin is sourced from beef bone, hide, pigskin and, more recently, pig bone. It was reported that 41% of the gelatin produced in the world is sourced from pig skin, 28.5% from bovine hides and 29.5% from bovine bones (Hayatudin 2005). In recent times, the concern and fear of BSE or "mad cow disease" has affected the gelatin market and has shifted the market towards porcine gelatin. Factors such as the outbreak of BSE and increasing demand for non-mammalian gelatin for halal and kosher food markets have revived the interest in gelatin from fish raw materials (Jamilah and Harvinder 2002). Several studies of gelatins from the skin of various fish species have been published (Jamilah and Harvinder, 2002).

Uses of gelatin in the food and pharmaceutical industries

Gelatin extracted from animal skins and hides can be used for food. In the United States, Latin America, Europe and some Asian countries, pork skin is immersed, boiled, dried and then fried to make a snack food (pork rinds) and in U.K they are called "pork scratching". Collagen from hides and skins also has a role as an emulsifier in meat products because it can bind large quantities of fat. This makes it a useful additive or filler for meat products. Collagen can also be extracted from cattle hides to make the collagen sausage used in the meat industry. Gelatin is added to a wide range of foods, as well as forming a major ingredient in jellies and aspic (Jamilah and Harvinder 2002). Its main use is the production of jellied desserts, because of its "melt in the mouth" properties, but is also added to a range of meat products, in particular to meat pies. Gelatin is also widely used as a stabilizer for ice cream and other frozen desserts. High-bloom gelatin is added as a protective colloid to ice cream, yoghurt and cream pies. The gelatin is thought to inhibit the formation of ice crystals and the recrystallization of lactose during storage.

Approximately 6.5% of the total production of gelatin is used in the pharmaceutical industry (Hidaka and Liu 2003). Gelatin has been an indispensable excipient in the pharmaceutical industry for many decades. It is popular because of its film forming, its thermo-reversible gelling and its adhesive properties. Pharmaceutical gelatin is mainly used in the preparation of capsules and for vitamin embedding. It is used as an important ingredient in protective ointment, such as zinc gelatin for the treatment of ulcerated varicose veins. Gelatin can be made into a sterile sponge by whipping it into foam, treating it with formaldehyde and drying it. Such sponges are used in surgery, and also to implant a drug or antibiotic directly into a specific area. Because gelatin is a protein, it is used as a plasma expander for blood in cases of very severe shock and injury. Gelatin is an excellent emulsifier and stabilizing agent for many emulsions and foams. It is used in cosmetic products, and in printing for silk screen printing, photograph-printing etc.

Animal bones and their utility products

Bones constitute almost 15 % of the weight of a dressed carcass and the quantity varies with age, breed and state of nutrition. It generally accounts for 20-30 % of live weight in sheep and goat and 12-30 % in cattle and pigs. It contains approximately 50 % water and 15 % marrow (96 % fat). The defatted and dried bones contain organic (Bone collagen- ossein- 33-36 %) and inorganic matter (32.6 % calcium and 15.2 % phosphorus) in the ratio of 1:2 and small quantities of sodium, magnesium, zinc etc. Because of the complex nature of bones different processes have been designed to recover different components like fat, protein and inorganic material. Meat and bone meal and other processed animal proteins were the vector of the bovine spongiform encephalopathy (BSE) epidemic in Western Europe in the 1980-1990s.For that reason, many countries have restricted the feeding of meat and bone meal and some only allow meat and bone meal derived from monogastric animals to be fed to ruminant animals and vice versa. Notably the use of meat and bone meal for livestock feeding was banned in 2002 in the European Union (Regulation (EC) No 1774/2002) (European Community, 2002).It is strongly recommended that potential users check their country's regulations to assess the current status of meat and bone meal regarding its utilization in livestock feeding. In areas where meat and bone meal is authorized for livestock feeding, the use of proper heat treatment is required to control the spread of BSE and other disease agents such as salmonella.

Nutritional attributes of bone derived products

Meat and bone meal is an excellent source of supplemental protein and has a well-balanced amino acid profile. Digestibility of the protein fraction is normally quite high, ranging from 81 to 87% (Kellems *et al.* 1998). It is well suited for use in feeding monogastric and provides not only a well-balanced protein source, but also a highly available source of calcium and phosphorus. Excessive heating during processing will reduce the digestibility of the protein fraction. Limiting amino acids for swine when combined with cereal grains are lysine, methionine and threonine and for poultry it is methionine and cysteine (Kellems *et al.* 1998). Meals that have higher protein content, often contains blood and isoleucine may become the first limiting amino acid. The protein quality is lower than fish meal or soybean meal for applications in feeding swine or poultry when used to supplement protein in cereal based diets. Processing temperature was correlated with lysine availability, as the temperature increased the lysine availability declined (Batterham *et al.* 1986). In addition to the protein (amino acids) meat and bone meal is an excellent source of calcium and phosphorus and some other minerals (K, Mg, Na, etc.). The ash content of the meat and bone meal normally ranges from 28 to 36 %; calcium is 7 to 10 % and phosphorus 4.5 to 6 %. When using meat and bone meal as the primary supplemental protein source the mineral levels may limit its use in some diet formulations. Meat and bone meal like with other animal products is a good source of Vitamin B-12.

Utilization of edible tallow and lard

Animal fats are an important by-product of the meat packing industry. The major edible animal fats are lard and tallow. Lard is the fat rendered from the clean tissues of healthy pigs. Tallow is hard fat rendered from the fatty tissues of cattle or sheep/goat. Lard and edible tallow are obtained by dry or wet rendering. The quality of the lard or tallow in wet rendering is better than that of products from dry rendering. Low-quality lard, and almost all of the inedible tallow and greases, are produced by dry rendering. Rendered lard can be used as an edible fat without any further processing. However, because of consumer demand, lard and tallow are now often bleached and given a deodorizing treatment before being used in food. Traditionally, tallow and lard were used for deep frying (Weiss 1983). However, this use is declining in the fast-food industry, due to consumer health concerns. An alternative liquid tallow product has been developed for the preparation of French fries and other fast foods, since less fat is absorbed. Tallow and lard are also used for margarine and shortening (Ghotra *et al.* 2002).

Utilization of poultry by-products

The poultry slaughterhouse by-product/ chicken meal is a highly nutritious ingredient which can be an important animal protein source in the diet of swine and chickens. The chicken meal contains 55% proteins, 19% fat, 3% calcium, 0.96% phosphorus. 2.16 % lysine, 0.72 % Methionine, 0.72% cysteine and 3.4 ME Mcal/ kg (Chandrasekaran 2013). The availability is limited as most of the slaughter is done locally in a traditional manner where these are entirely wasted. The increasing awareness on hygiene the consumers are showing interest in buying processed chicken which indicates that in future the chicken meal can form a part of the poultry and swine diet reducing the burden on the conventional feed ingredients as the composition is better than or equal to good quality conventional protein supplements like fish meal or soybean meal. Dry rendering of dead layer birds was studied (Kulkarni and Sivakumar 2011) and utilization of spent hen by dry rendering and its utilization in pet food was attempted by Karthik *et al. 2010* ; Rajendrakumar *et al.* 2011).

Hatchery by-product meal:

The hatchery by-product meal is a promising feed ingredient as all the hatching is done in organized sector it can be either sterilized and dried and included in the diet of chicken or swine or can be cooked and fed as wet mash to swine if swine farms are located near the hatcheries. The nutrient composition of hatchery by product meal includes 27% proteins, 3.1% crude fiber, 10.6 % fat, 20.6% NFE, 21.6 % calcium, 0.65% phosphorus. 1.11 % lysine, 0.51 % Methionine, 0.30% cysteine and 2.89 ME Mcal/ kg (Chandrasekaran 2013).

Utilization of animal fat and rendered oil as biofuel

There is also a growing demand for animal fats and greases as a renewable energy source. Their use for energy is two-fold. First, they can be used directly in industrial burners. As energy prices rise, there is more direct burning occurring, especially within renderers' own plants. Second, the growing biodiesel industry will also demand more. Currently, in the United States, most of the biodiesel facilities utilize soybean oil, and in the EU, they use canola oil. However, there are a growing number of plants that can use multiple sources of feedstock, and some that utilize animal fats and greases alone. Since this industry is at the beginning of major expansion, it is hard to predict the ultimate impact. However, the expansion will result in increased demand for animal fats and greases. Rendered products are the solution to two major problems being faced today and in the foreseeable future are the growing cost of energy and the growing cost of fish meal**.** Biodiesel fuel acquired from the oils and fats of meat and fish is a substitute for, or an additive to diesel fuel derived from petroleum. There is an extensive literature on biogas production from cattle manure, piggery waste waters and by- products of aquaculture (Arvanitoyannis and Kassaveti 2008). As per EIA 22M Survey feedstock utilized for biodiesel production 2014 was soybean oil 52 %, canola oil 11% distillers corn oil 10% animal fats 10% recycled oils 14% other 3% .Yield and quality characteristics of rendered chicken oil for biodiesel production was evaluated by Abraham et al 2014. In this study dead layer birds were subjected to dry rendering and rendered oil was converted to biodiesel. The cost of one liter of biodiesel produced from rendered chicken oil was Rs. 36.68 and the cost of one liter of biodiesel produced by solvent extraction method after dry batch rendering was Rs. 22/L, since it took 16 dead birds of average 1.25 kg to produce one liter biodiesel and it took only 6 birds of the same body weight to produce one liter biodiesel by solvent extraction.

The availability of wet biomass as waste from industrial processes and the need to meet the environmental standards stand for the main stimuli towards investigating all options in order to dispose this waste. The thermal recycling of residues as secondary fuel is of increasing interest for power plant operators (Arvanitoyannis and Ladas 2008). Studies documented the usage of poultry litter as an alternative for natural fuel source generation. It is noteworthy that poultry litter with water contents less than 9% can burn without extra fuel. Therefore these samples were suitable for being used as fuel for generation of electrical power. Physicochemical treatment of meat industry waste- water is used to increase the organic matter removal efficiency, and it generates great amounts of sludge. Treatment using commercial ferric sulfate as coagulant for this specific wastewater gave high organic matter removals, decreasing considerably the amount of waste material to be treated in biological systems, and also allowing the retention of 0.83–0.87 kg of biomass fuel for each m^3 of treated (De Sena *et al.* 2008). Due to sanitary, environmental problems and operational costs related to the discharge, land disposal and re-use of wastes, the utilization of this Biofuel (dried sludge) for steam generation has shown to be a viable alternative. This type of fuel has a high heating value, and it is a renewable energy source. The combustion test with a Biofuel to sawdust ratio of 4:1 met the technical requirements for the characterization of this promising fuel; nevertheless, operating conditions must be well designed to achieve NO_2 and SO_2 emissions below local and/or international limits.

Antihypertensive peptides from meat/meat by-products

Arihara *et al.* (2006) identified two ACE inhibitory pentapeptides from the thermolysin digestion of porcine myosin. These were named myopentapeptides A and B and their sequences determined. The amino acid sequence of myopentapeptide A was found to be MNPPK, which corresponded to positions 79–83 on the myosin heavy chain, while myopentapeptide B, with the amino acid sequence ITTNP, corresponded to positions 306–310 on the myosin heavy chain. The antihypertensive activities of myopentapeptide A and myopentapeptide B were investigated in SHR, in addition to other thermolysin hydrolysates of porcine skeletal muscle proteins. Administration of myopentapeptide A and myopentapeptide B at a concentration of 1 mg per kilogram of animal weight resulted in a maximum decrease in SBP of 23.4 ± 3.0 mmHg and 21.0 ± 3.1 mmHg after 6 h, respectively. At 24 h, the SBP of both test groups was still significantly lower than that of the control group, indicating that both myopentapeptide A and myopentapeptide B are potent antihypertensive peptides *in vivo*. Another ACE inhibitory octapeptide VKKVLGNP was discovered corresponding to positions. Another ACE inhibitory octapeptide VKKVLGNP was discovered corresponding to positions 47–54 on the myosin light chain. This peptide was generated following the digestion of crude myosin light chain with pepsin. The IC value of this peptide was calculated to be 28.5 µFollowing the administration of this purified peptide to SHR at a concentration of 10 mg per kilogram of animal weight, the SBP decreased up to 3 h post-administration with SBP returning to the pre administration value after 9 h. It was therefore postulated that the peptide VKKVLGNP was an effective hypotensor *in* Porcine skeletal muscle also was found to be a source of antihypertensive peptides when crude myosin B was hydrolyzed with pepsin. Indeed, within this hydrolysate a novel peptide M6 was identified with the amino acid sequence KRVITY. This peptide corresponded to positions 191–196 on the myosin heavy chain. The SBP of SHR was immediately reduced following oral administration of M6 peptide with a maximum decrease of 23 mmHg after 6 h, with the SBP of test animals returning to the control after 9 h. This reduction in SBP of SHR would indicate that the M6 peptide is a potent hypotensor *in vivo*. Furthermore, the M6 peptide retained its ACE inhibitory activity after heating the myosin B to 98 °C for 10 min prior to hydrolysis by pepsin. Retention of ACE inhibitory activity after such thermal treatment clearly indicates that bioactivity is retained even after the cooking process.

Antihypertensive peptides from collagen

Structural constituent of connective tissue. All collagens contain repetition of the proline rich tripeptide Gly-X-Y; that forms the trimeric collagen triple helices. Recently, it was reported that ACE inhibitory peptides were purified from the hydrolysate of bovine skin gelatin. Five proteases were employed, Alcalase, a chymotrypsin, Neutrase, Pronase E, and trypsin. In a comprehensive research work carried out at Irish Food Research Centre, it was conclusively demonstrated that liver, lung, heart and other low value meat cuts can be effectively used for isolation of active compounds through different isolation methods. Following hydrolysis (thermolysin) and ultrafiltration (10-kDa and 3-kDa molecular weight cut off) of bovine liver sarcoplasmic proteins, filtrates and RP-HPLC fractions were assessed for antioxidant activity. The peptide contents of each fraction were characterized using electrospray quadruple time-of-flight (ESIQ-TOF) mass spectrometry with the resultant spectrum analyzed using the software Programmes Protein Lynx Global Server 2.4and Turbo SEQUEST. Similarities between the amino acid composition of characterized peptides and previously reported antioxidant peptides were found demonstrating that liver can be utilized as raw material for the generation of bioactive peptides. Similarly, bovine lung tissue was hydrolyzed (thermolysin for 8 hours at 37 °C) and filtrated (10-kDa, 3kDa).Resultant filtrates were tested for antioxidant, antihypertensive and antithrombotic activities. Both filtrates showed antioxidant activity while the 10kDa filtrate displayed ACE-I inhibitory activity. No PAF-AH inhibitory activity was detected. Peptides isolated from the filtrates were identified using electrospray quadruple time of-flight (ESIQ-TOF) mass spectrometry. Homologies between the sequences of three identified peptides and previously reported ACE-I inhibitory peptides were observed.

Bioactive peptides from blood

An emerging new area, focused on obtaining bioactive peptides from blood fractions, has been developing intensively over the past decade. Major peptides from blood sources have angiotensin I-converting (ACE)-inhibitory activity, antioxidant activity, antimicrobial properties, mineral-binding ability, and opioid activity. These will be described in detail in the following sections (Li *et al.* 2004).

Angiotensin I-converting enzyme inhibitory peptides

Angiotensin I-converting enzyme (ACE) is a dipeptidyl carboxypeptidase that converts an inactive form of the decapeptide, angiotensin I, to a potent vasoconstrictor, octapeptide angiotensin II (Li *et al.* 2004). ACE also inactivates bradykinin, which has a depressor or vasodilatation (widening of blood vessels) action. Through these actions, ACE elevates blood pressure. Furthermore, the activities reported for natural peptides with ACE-inhibitory activity usually have other bioactivities (multifunctional properties) and are easily absorbed (Korhonen and Pihlanto 2003). Although the activities of bioactive peptides in the sequences of the parent proteins are latent, they can be released by proteolytic enzymes. In this aspect, meat (and also blood) proteins have possible bioactivities beyond a nutritional source of amino acids alone (Arihara and Ohata 2006). Proteolytic enzymes hydrolyze the peptide linkage between amino acids of proteins, yielding a mixture of peptides of different molecular size and free amino acids. As the ability of peptidases to hydrolyze proteins is highly variable, the selection of suitable enzymes for production of hydrolysates having defined physicochemical and nutritional characteristics is essential

(Clemente 2000). Researchers have used a number of proteases to hydrolyze animal blood in the initial stages of attempting to obtain peptides with ACE-inhibitory activity. Alcalase (EC 3.4.21.62), Neutrase, pepsin (EC 3.4.23.1), papain (EC 3.4.22.2), trypsin (EC 3.4.21.4) and Flavourzyme have been utilized to determine which enzyme is best able to generate crude hydrolysates with the highest ACE inhibitory activities

Conjugated linoleic acid from ruminant meat and fat

In 1979, Pariza, *et al.* reported the occurrence of antimutagenic substances in pan-fried hamburger, which subsequently were found to inhibit the initiation of mouse epidermal tumors (Pariza and Hargraves, 1985). The fatty acid responsible for this effect was identified as conjugated linoleic acid (CLA). Conjugated Linoleic Acid (CLA) is a naturally occurring free fatty acid found mainly in meat and dairy products. Conjugated linoleic acid (CLA) refers to a mixture of positional and geometric isomers of linoleic acid (c9, c12-C18:2, LA) with a conjugated double bond. Scientific research suggests that CLA helps to build muscle and reduce body fat, and possesses potential anticarcinogenic, anticholestrolemic and immune-modulatory health benefits. Researchers have reported that ruminant's fat and meat are the best natural source of CLA. However, there are no technologies for large scale extraction and separation of CLA from meat by-product stream. Ruminant meat by-products are rich sources of conjugated linoleic acid (CLA), a healthy fat that has shown potential to fight obesity, cancer, and diabetes. In recent years, much attention has been paid to the tertiary functions of foods. Tertiary functions are the roles of food components in preventing diseases by modulating physiological systems. Examples of such functions of foods are anticarcinogenicity, antimutagenicity, antioxidative activity and antiaging activity. Meats have great potential for delivering important nutrients such as fatty acids, minerals, antioxidants and bioactive peptides etc., into the diet. This new approach to improving health status is especially interesting for the meat industry. Conjugated linoleic acids (CLA) represent a heterogeneous group of positional and geometric isomers of linoleic acid, which are predominantly found in milk, milk products, meat and meat products of ruminants (Steinhart et al., 2003; Benjamin et al., 20051). CLA are getting momentum in alleviating major killer diseases such as cancer, atherosclerosis, and diabetes in humans. Over the years, the biological significance of conjugated fatty acids has been demonstrated. Many studies demonstrated the action of CLA as anti-carcinogenic, anti-diabetic and immune-modulator (Eicker *et al.* 2007). Compound. Although there is no agreement regarding its function on fat metabolism, some authors revealed that its consumption also decreases the fat deposition.

Meat from ruminants has higher levels of CLA than meat from non-ruminants. The highest CLA concentrations were found in lamb (4.3–19.0 mg/g lipid) and with slightly lower concentrations in beef (1.2–10.0 mg/g lipid). Some data on CLA in meat of animals less common in human diets like meat from elk (1.3–2.1 mg CLA per gram fatty acid methyl ester (FAME)), bison (2.9–4.8 mg/g FAME), water buffalo (1.83 mg/g fatty acids), and zebu-type cattle (1.47 mg/g fatty acids) are also available (de Mendoza *et al.* 2005; Rule et *al.* 2002). However, no investigation was carried out on natural CLA in meat and meat by-products in India. Hence, NRC-Meat, Hyderabad has undertaken a research project to fill this research gap and provide the valuable scientific data and information on CLA and its commercial applications.

In conclusion, effective utilization of meat industry by-products is essential to meet the growing demands for animal proteins globally. Further utilization of meat industry wastes for animal feeds would augment the supply of low cost feeds to poultry and aquaculture industries. Pet food industry will also benefit immensely by adopting latest technologies for conversion of meat by-products into pet food. Extraction of high value by products like bio peptides and other bio chemicals offers great scope in human nutrition other related areas like health foods and food supplements.

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Table 1: Yield of carcass and byproducts (%) as percentage of live weight in meat animals

Meat animal	Blood	Head	Forefeet	Skin	Stomach	Intestine	Heart	Liver	Lungs	Kidney	H. Feet	Fat	Trimming	Carcass
Cattle	12.88	13.22	4.68	22.84	30.34	15.41	1.22	2.73	3.27	0.82	4.72	2.77	99.46	45.37
Buffalo	6.20	5.14	1.89	9.63	15.41	5.76	0.42	1.02	0.95	0.28	1.75	1.91	1.70	47.92
Pig	3.51	7.03	2.38	-	4.62	7.43	3.40			0.35	2.35	-	0.47	66.36
Sheep	4.20	6.84	1.83	10.66	14.40	7.63	3.78				1.61	1.66	1.47	45.98
Goat	4.28	6.93	1.83	9.35	14.86	7.68	3.93				1.46	1.75	1.07	46.86
Chicken	2.65	2.78	4.65 (shank)	13.79 (feathers)	2.79 (gizzard)	5.84	0.68	2.55	-	-	-	1.79	2.22	60.31

Ref: NRC-Meat project report on "Study on Statewide yield of meat and byproducts of cattle, buffalo, sheep, goat, pig and poultry" Submitted to Central Statistical OfficeMinistry of Statistic and Programme implementation. New Delhi

Table 2. Approximate estimated value (Rs.) of carcass and saleable byproducts in meat animals

Species	Live animal	Head	Fore & Hind feet	Skin	Stomach	Heart	Liver	Kidney	Fat	Bones	Boneless meat	Total value
Cattle	16279	200	125	1000	150	60	130	40	221	158	15349	17432
Buffalo	19478	150	150	1000	125	47	127	37	558	198	18365	20757
Pig	6168	75	75	-	75	240		23	147	6168		6803
Sheep	3441	150	-	125	125	240			96	3226		4102
Goat	3317	100	75	100	75	228			54	3209		3742
Chicken			-	-	3.28 (gizzard)	0.92	3.53	-	-	147.18-		154.91
	143.91	-										

Ref: NRC-Meat project report on "Study on Statewide yield of meat and byproducts of cattle, buffalo, sheep, goat, pig and poultry" Submitted to Central Statistical OfficeMinistry of Statistic and Programme implementation. New Delhi.

Table 3: List of importing markets for a product exported by India

Importers Sources: ITC calculations based on UN COMTRADE statistics	**Exported value in 2009** Unit : US Dollar thousand	**Exported value in 2010**	**Exported value in 2011**	**Exported value in 2012**	**Exported value in 2013**
05 Products of animal origin,	52,166	73,008	193,559	126,960	136,116
0510 Bile and other animal glands for pharmaceutical preparation	788	1,330	1,947	2,934	4,070
World 0502 Bristles, hair & waste of pigs, hogs etc	82	55	522	395	431
World 0504 Guts, bladders and stomachs of animals other than fish	5,920	7,666	5,684	3,672	5,074
World 0505 Feathers for stuffing and & down	25	14	57	96	151
World 0506 Bones & horn-cores de-gelatinized	19,372	18,360	25,888	28,213	35,639