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SLAUGHTER HOUSE BY-PRODUCT UTILIZATION FOR SUSTAINABLE MEAT INDUSTRY- A REVIEW

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ABSTRACT

Meat sector in India plays an important role in providing livelihood to rural people in the country. Animal slaughtering not only provides meat but also valuable by-products to the mankind. By slaughtering and processing of meat animal, only one third is meat while the rest comprise of by-products and waste, which need to be adequately processed and utilized. Traditional markets for edible meat by-products have gradually been disappearing because of concerns about health and economic returns. In response to these problems, meat processors have directed marketing and research efforts toward inedible applications. Efficient utilization of by-products has direct impact on the economy and environmental pollution of the country, the former being an asset and the latter is a responsibility. The yield of animal by-products ranges between 50-60% of the live weight. According to various statistics 107 million livestock and more than 650 million poultry birds were slaughtered annually in India leading to production of 6.3 million tonnes meat. It leaves huge loads of by-products. The load is further increased by dead and fallen animals. The value of unprocessed by-products from buffalo and sheep in India was reported to be quite high. If these by-products are processed then the returns will be almost equal to the value of the meat derived from an animal. Therefore, the potential and scope of by-product utilization is really great which will result in industrial development, employment generation, environmental management and better returns to the farmers. Non-utilization of animal by-products in a proper way may create major aesthetic and catastrophic health problems. Value addition of animal by-products has two benefits. Firstly, the meat industry gets additional revenue by processing them to industrial, household, and cosmetic products; livestock feed additives; pet foods; pharmaceutical and medical supplies etc that otherwise would have been unrealized. Secondly, the costs of disposing of these secondary items are avoided. Utilization of these byproducts as fertilizer contributes a lot in organic farming and could reduce our dependence on synthetic fertilizers. Animal byproducts and wastes are a good source of renewable energy as well its production is economically feasible.

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INTRODUCTION

*“Only the last cry of animal is wasted”
“All of the pig is used except the sequel and the curl in the tail”*

These old sayings are the hidden market secrets of profitable meat trade. Meat sector in India plays an important role in providing livelihood to rural people, sustaining livestock production and contributes a valuable foreign exchange to the

country. Animal slaughtering not only provides meat but also valuable by-products to the mankind. By slaughtering and processing of meat animal, only one third is meat while the rest comprise of by-products and waste, which need to be adequately processed and utilized. Animal by-product may be defined as every part of a slaughtered animal except dressed carcass (also called as offals or fifth quarter). The quantity of animal by-products available for utilization can be estimated by subtracting the dressing percentage from 100. The economics of the world's meat industry demands that animal by-products be utilized so that the livestock industry can stay economically competitive with vegetable protein sources. Moreover, any industry that turns waste products into valuable products ought to be applauded. Traditional markets for edible meat by-products have gradually been disappearing because

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of concerns about health and economic returns. In response to these problems, meat processors have directed marketing and research efforts toward inedible applications-for example, pet foods, pharmaceuticals, cosmetics, and animal feeds. India is bestowed by nature with a vast livestock resources comprising of 299.9 million total Bovine population (Cattle-190 million, Buffalo-108 million, Mithun- 0.29 million and Yak- 0.07 million), 65.06 million sheep, 135.17 million goats, 10.29 million pigs and 729.2 million poultry (Department of Animal Husbandry, Dairying and Fisheries, 2014). The livestock sector alone contributes nearly 25.6% of value of output at current prices of total value of output in Agriculture, Fishing and Forestry sector. The overall contribution of Livestock Sector in total GDP is nearly 4.11% at current prices during 2012-13. 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, the former being an asset and the latter is a responsibility.

Non-utilization/under utilization of by-products not only leads to loss of potential revenues but also lead to the added and increasing cost of disposal of these products. The general complaint of stinking, foul smell from the slaughter houses emanates mainly from decaying organic by-products like blood, stomach, intestines etc., which are not properly utilized/discharged off. The yield of animal by-products ranges between 50-60% of the live weight. The healthy animals yield less compared to emaciated ones. According to FAO (2008) and GOI (2007) estimates 107 million livestock and more than 650 million poultry birds were slaughtered annually in India leading to production of 6.3 million tonnes meat. It leaves huge loads of by-products. The load is further increased by dead and fallen animals. It accounts for more than 10 million MT of edible and inedible by-products. Though no reliable data is available on the economic losses caused to the nation, yet some estimates put it as Rs 1,000 crore/annum from slaughter houses and Rs 600 crore from dead and fallen animals (Thota, 1999). Moreover, there is a loss of animal proteins, directly for human consumption as well as the proteins containing materials that can be processed and fed back to animals. Today, the cost of animal is higher than selling price of the carcass. Hence the value of by-products must pay the expenses of slaughter and generate profit to the livestock, poultry and aqua feed industries. The animal by-products fetch 10-15% of the value of the live animal in advanced countries and proper utilization contributes significantly to the profitability of meat business as it may meet *all* costs of slaughter house operations or even more thus benefiting the farmers, processor and consumers (Chatli *et al.*, 2005).

The value of unprocessed by-products from buffalo and sheep in India was reported to be 30% and 35% respectively (Chatterjee *et al.*, 1991) which is quite high. This may be due to the reason that the carcass yields and the edible meat yields from the carcasses are relatively much lower in India where the animals are not raised for meat purpose. If these by-products are processed then the returns will be almost equal to the value of the meat derived from an animal. Therefore, the potential and scope of by-product utilization is really great which will result in industrial development, employment generation, environmental management and better returns to the farmers. The literature indicates that by-products (including organs, fat or lard, skin, feet, abdominal and intestinal contents, bone and blood) of cattle, pigs, and lambs represent 66.0%, 52.0%, and 68.0% of the live weight, respectively. Over 50.0% of animal by-products are not suitable for human or animal consumption due to unusual physical and chemical characteristics (Ockerman and Hansen, 1988). The animal by-products are categorised mainly into edible and inedible by-products. On the basis of live weight of animal the by-products account for almost 60% and out of this 40% are edible and 20% are inedible (Chatli *et al.*, 2005).

A valuable source of potential revenue is lost and the cost of disposal of these products incurred by the meat industry is increased if meat by-products are not efficiently utilized. The USDA Economic Research Service announced that the portion of gross farm economic income from animal by-products is 11.4% for beef and 7.5% for pork. (USDA, 1986). The cost of live animals often exceeds the selling price of their carcasses and the value of the by-products must pay the expense of slaughter and generate the profit for the meat-slaughtering operation. Bengtsson and Holmqvist (1984) have suggested that 7% to 12% of the income from slaughter results from the sale of by-products. However, with efficient utilization, slaughter house by-products can be important and result in profits for meat processors. The modern livestock industry in the past has been an effective utilizer of by-products and it has been stated in the beginning that all of the pig is used except the squeal.

Classification

Animal by-products can be classified as edible and inedible on the basis of whether being used as food or not. Edible by-products are those by-products that can be consumed as a food by human beings generally include liver, kidney, heart, brain, intestine, tongue, spleen etc. They are also called as variety meats. On the other hand, those by-products which cannot be consumed as food by human beings are called Inedible by-products e.g. hides, skins, ear, snout, gallbladder,

Table 1. Value of By-products from buffalo and sheep in India

Species	Live weight (Kg)	Cost of Animal (Rs)	Dressed carcass (Kg)	Cost of carcass (Rs)	Deboned meat (Kg)	Cost of deboned meat (Rs)	Value of hide & skin (Rs)	Value of other by-products (Rs)
Buffalo	300	18,000 at Rs. 60/Kg live weight	150	22,500 at Rs. 150/Kg	105	21,000 at Rs. 200/Kg	400	150
Sheep	20	3,000 at Rs. 150/Kg	9	3,150 at Rs. 350/Kg	6	2700 at Rs. 450/Kg	250	60
Goat	20	3,000 at Rs. 150/Kg	9	3,150 at Rs. 350/Kg	6	3,000 at Rs. 500/Kg	250	60

faetus, hoofs, horns, hair, bristles etc. All parts of dead animal or condemned meat and organs also come in this category. The basic criterion of division between edible and inedible by-products depends upon the purchasing power, custom, tradition, food habits, religious outlook etc. Animal by-products are also divided into principal/primary and secondary by-products (Sharma, 2011). Principal by-products are those by-products which are being directly harvested from the animals e.g. hides and skins, bones, blood, hoofs and horns whereas secondary by-products are those by-products which are derived from principal by-products e.g. bones, a primary by-product may yield secondary by-products like bone meal, fat, gelatin, buttons, cutlery handles etc. Likewise intestines may yield casings, catgut, tennis strips etc. as secondary by-products. Approximate percent yield of by-products from large and small animals is given in Table 2 and 3.

Table 2. Approximate yield of by-product from large animals (Cattle and Buffalo)

(Chatterjee *et al.*, 1991)

S.No	Meat/ By-product	Percent yield
1	Meat (Boneless)	28.57
2	Bone, head, feet	22.85
3	Paunch content and waste	16.00
4	Hide	7.57
5	Blood	3.14
6	Lungs and oesophagous	2.00
7	Liver	1.42
8	Stomach	0.71
9	Heart	0.42
10	Head meat and brain	0.28
11	Tongue	0.28
12	Spleen	0.28
13	Kidneys	0.14
14	Fat	1.71
15	Casings	2.00
16	Other offals (genitalia, udder, tail end etc)	4.00
17	Urine, body fluid, bile, dung	3.50

Table 3. Approximate yield of by-product from Small animals (Sheep and Goat)

(Chatterjee *et al.*, 1991)

S.No	Meat/ By-product	Percent yield
1	Dressed weight	40.00
2	Paunch contents	22.00
3	Skin	9.20
4	Gut and tripe	8.00
5	Head	5.60
6	Blood	3.00
7	Fatty tissue	2.00
8	Lungs and oesophagous	1.00
9	Liver	1.20
10	Hoofs	0.80
11	Heart	0.40
12	Kidney	0.40
13	Spleen	0.20
14	Pancreas	0.16

Another basis for classification of animal by-products is their ultimate use. These include agricultural by-products (meat meal, bone meal, fertilizer etc); industrial by-products (gelatine, glue, casings etc) and pharmaceutical by-products (insulin, pepsin, bio-chemicals, hormones etc) (Sharma, 2011). These animal by-products needs to be utilized properly in order to check the pollution, ensure better returns, supply highly nutritive livestock feed (meat meal, bone meal, carcass

meal etc), establish secondary rural industries, generate employment and to bring crop improvement in the form of manure and fertilizer.

Edible, for Human Consumption

The yield of edible by-products from animals varies tremendously depending on species, sex, live weight, fatness and methods of collection. In general, the total by-products range from 10% to 30% of the live weight for beef, pork and lamb and from 5% to 6% of the live weight of chickens (Table 5). The yield of edible by-products including blood and organs in cattle averages 12%, in sheep 14%, and, if pork rinds are also included, 14% for hogs. Biologically, most non-carcass material is edible if the product is cleaned, handled and processed appropriately. In the developing nation meat is maligned with a fact that it is a diet of rich people because of low purchasing power of consumers. Hence, most of the soft tissues are used for edible purposes. This includes all the glandular by-products including liver, heart, brain, lungs, sweet breads (thymus, pancreas), testicles, tongue and gizzard etc. Various by-products such as intestines, skin, stomach, bile which can be used for more valuable processed products such as catguts, collagen sheets, sportguts, leather etc., are being used for edible purposes. Poultry gizzard and pro-ventriculus which account for 3.5- 4.5% of total live weight are also used very commonly for edible purposes generally at very low price. Edibility is determined by customs, religion, consumer acceptance, reputation, availability of the product, economics and hygiene. What is considered edible in one region may be considered inedible in another. The use of blood for edible purposes is forbidden in Islam while it is being used extensively for preparing sausages in many western countries and as a curried fried product in Nepal.

Red viscera, sometimes called 'variety meat' or 'fancy meat', would include the liver, heart, kidney, tongue, neck sweetbread (thymus) and other products frequently used as edible by-products. White offal (intestines and stomach) would also include blood and trimmings. Although animal slaughter has increased over time, the use of edible by-products for human consumption has declined. Many inedible by products are converted into edible by products through technological innovations. Poultry feathers and heads, skin trimmings, fish scales, horns and hooves are converted into protein hydrolysates by acidic/ alkaline /enzymatic hydrolysis. These protein hydrolysates are used as protein fortification agent for concentrated soups and beverages as well as valuable component of solid and liquid seasoning. This can also be used as a diet for the operating patients for better recovery because of high biological value and digestibility. These protein hydrolysates find use in various industries such as textile (for dyeing), paper (for coating), paint (as ingredient), match stick (for shaft), leather industry (as filler syntam), animal/poultry feed, detergents (as foaming and sequestering agent), cosmetics (face creams and lotions), microbiology (media ingredients), pharmaceuticals, tissue culture techniques etc.

Nutritional Values of Edible By-Products

Edible meat by-products contain many essential nutrients. Some edible meat by-products often are used as medical cures

Table 4. Slaughter house by-products and their gainful uses- In general

(Bengtsson and Holmqvist, 1984; Ockerman and Hansen, 2000; Chatli et al., 2005; Jayathilakan et al., 2012).

<i>By-product</i>	<i>% of live weight</i>	<i>Raw by-products</i>	<i>Processed By-products</i>	<i>Uses</i>
Blood	7	Edible raw blood	Plasma and Red blood corpuscles	Adhesives for sausages, pharmaceutical products, blood sausages or pudding
		Inedible raw blood	Blood meal, poultry feed, blood albumen	Additives for livestock feed, leather finishing agent, plywood adhesive, fertilizer, mordant
Bones	20-30	Raw bone classified as edible	Edible fat pieces	Shortening, bone gelatine, bone meal, livestock and poultry feed
		Raw bone classified as inedible	Inedible fat pieces	Lubricant gelatine: photographic, pharmaceutical, printing.
Hide	6-8	Hides	Preserved hide, hair and wool	Tallow: soap, cosmetics, food, bone ash, ceramics. Glue: adhesive, abrasive.
		Hide and Pelt	Trimmings for inedible rendering	Leather products, falls, upholstery
		Pig skin	Edible	Fertilizers and textiles.
		Pig skin	Tanned skin	Collagen: cosmetics, face creams, shampoo, detergents
Intestines	2		Sausage casings Intestines	Used in various comminuted meat product up to 7-10%. Leather products
				Sausage skins, edible
				Surgical sutures, sports guts, musical strings, prosthetic materials, collagen sheets, burn dressing, dialyzing membrane, animal feed, heparin, protein meal
Horns & hoofs	0.6	Cattle feet	Neats foot oil	Fine lubricant
		Horns & hoofs	Gelatine extracted protein	Gelled food products, foaming in fire extinguishers, felt, upholstery, brushes
		Toe nails	Meal	Mixed with livestock feed or fertilizers
Hair, bristles & wool	-	Hair		Pelting, fabrics and pillow,
		Bristles		Brushes
		Wool		Yarn, blankets, carpet, lanolin, fertilizer
Stomach	2	-	Pharmaceuticals	Rennin, dairy industry
Lungs	1.2	-	Edible products	Direct consumption, variety meat, sausage ingredient
Brain	0.18	-	Pharmaceuticals	Cholesterol, sphingomyelins
Bile/gall stone	0.06	-	Pharmaceuticals	Bile paste in detergents, cholic acid, deoxy cholic acid, chenodeoxycholic acid used in pharmaceuticals
Pancreas	0.7	-	Pharmaceuticals	Trypsin, bate, insulin pharmaceuticals
Liver	1.2	-	Edible	Direct consumption, variety meat, sausage ingredient
Fat	Varying with individual & Species	Edible raw fat	Edible fat oleostearin cracklings	Fatty acids, frying purpose, margarine, j shortening, candy chewing gum, pet foods or meat meal
		Inedible raw & mixed condemned materials	Inedible fat, meat and bone meal	Lubricants, soaps, candles, glycerin additives for livestock and poultry feed
		Inedible raw fat	Inedible (rendered) fat	Lubricants, soap, candles, glycerin, additive for livestock and poultry feed
Glands	Varying with individual & Species	Liver	Liver extract	
		Lungs	Heparin, peptone	
		Pituitary gland	Anterior (GH, LH, FSH, prolactin) and postpituitary lobe hormone (oxytocin, vasopressin)	
		Thyroid gland	Thyroxine	
		Parathyroid	Parathormone	
		Pancreas	trypsin, insulin, pancreatin, glucagon	
		Adrenal	Adrenaline	
		Suprarenal gland	Cortex (cortisone) and medullary hormones (adrenaline and noradrenaline).	
		Testes	sex hormones, hyaluronic acid	
		Thymus	histone, Deoxyribonucleic acid	
		Vitreous humour	hyaluronic acid	

because they contain special nutrients such as amino acids, hormones, minerals, vitamins, or fatty acids. Except for blood, many meat co-products have higher levels of moisture than meat. Examples would be lung, kidney, brain, spleen, and tripe. Some organ meats such as liver and kidney contain a higher level of carbohydrates than other meat material; pork

tail has the highest fat and the lowest moisture level of all the meat by-products. Liver, beef tail, ears, and feet have the closest protein level when compared with lean meat tissue but a large amount of collagen is found in the ears and feet (Vaughn et al., 1979; 1981). The lowest protein level of by-products is found in the brain, in chitterlings, and in the fatty tissue.

Table 5. Edible By-product yield from various species(Gerrard and Mallion, 1977; Ockerman, 1996; Ockerman and Hansen, 1988, 2000 and Romans *et al.*, 1985)

By-product	Percentage of live weight			
	Cattle	Pig	Lamb	Poultry (1.4–2.3 kg)
Blood	2.4–6	2–6	4–9	
Dried blood	0.7			
Brain	0.08–0.12	0.08–0.1	0.26	0.2–0.3
Breast fat	0.07			
Cheeks	0.03–0.32			
Chitlings (in Europe chitterlings)	0.06			
Cracklings	3.0	2.2		
Ears	0.02			
Edible kill fat (edible fat removed on the slaughter floor)	1–7	1.3–3.5	12	
Feet	1.9–2.1	1.5–2.2	2.0	
Gizzard				1.9–2.3
Gullet	0.03	0.1		
Hanging tender	0.19			
Head		5.2	6.7	
Head and cheek meat	0.32–0.4	0.54–0.6		
Head trimmings	0.03			
Heart	0.3–0.5	0.15–0.35	0.3–1.1	0.3–0.8
Intestines		1.8	3.3	
Jowl		2.7		
Kidney	0.07–0.24	0.2–0.4	0.3–0.6	
Large blood vessels	0.07			
Lips	0.1–0.24			
Liver	1.0–4.5	1.1–2.4	0.9–2.2	1.6–2.3
Lungs	0.4–0.8	0.4–0.85	0.7–2.2	0.7
Omasum	0.38			
Abomasum (maw)	0.48			
Pancreas	0.06	0.1	0.2	
Pizzle (penis of male animal)	0.18			
Rendered edible fat	2–11	12–16	9	
Rennet	0.23			
Skirt	0.15–0.3	0.4–0.5	0.5	
Spinal cord	0.3			
Spleen	0.1–0.27	0.1–0.16	0.1–0.4	0.15
Stick trimmings	0.48	0.21		
Tail	0.1–0.25	0.1		
Tongue	0.25–0.5	0.3–0.4		
Tripe (stomach)	0.75	0.6–0.7	2.9–4.6	
Weasand (muscle tissue of the oesophagus)	0.04–0.09	0.05		

USDA (1983, 1986) states that mechanically deboned beef and pork are required to contain at least 14% protein and a maximum of 30% fat. The amino acid composition of meat by-products is different from that of lean tissue due to the high amounts of connective tissue; this results in a larger amount of proline, hydroxyproline, and glycine and a lower level of tryptophan and tyrosine for by-products such as ears, feet, lungs, stomach, and tripe (Rice, 1971). The vitamin content of organ meats is usually greater than that of lean meat tissue. Kidney and liver contain the highest amounts of riboflavin (1.697 to 3.630 mg/100g) and have 5 to 10 times more than lean meat. Liver is the best source of niacin, vitamin B₁₂, B₆, folacin, ascorbic acid and vitamin A. Kidney also is a good source of vitamin B₆, B₁₂, and folacin. In addition to supplying vitamins, lamb kidney, pork liver, lungs, and spleen are often act an excellent source of iron. The copper content is the greatest in the livers of beef, lamb, and veal. Livers also contain the highest amount of manganese (0.128 to 0.344 mg/100 g). Among the raw material, mechanically deboned meat has the highest calcium content (315 to 485 mg/100 g). Many organ meats contain more polyunsaturated fatty acid

than does lean tissue. Brain, chitterling, heart, kidney, liver, and lung have the lowest level for monounsaturated fatty acids and the highest amount of polyunsaturated fatty acid. In addition to higher levels of cholesterol (260 to 410 mg/100 g), which are three to five times higher than those of lean meat, large quantities of phospholipid also are found in these meat organs. Brain is the highest in cholesterol (1352 to 2195 mg/100 g) and also has the highest amount of phospholipid when compared with other meat by-products (Weihsrauch and Son, 1983). A high cholesterol content in many organ meat and the possible accumulation of pesticides, residues of drugs, and toxic heavy metal contribute to the recommendation for limited consumption.

Casings and Others

Various parts of the digestive and excretory tracts like oesophagus, large and small intestines, caecum, rectum and bladders are processed into natural casings that serve as containers or packaging materials for comminuted meat products like sausages, salami etc. India, being a country with

Table 6. The Potential Uses and Preparation of Sheep and Goat Edible by-products

(Ockerman and Hansen, 2000; Chatli *et al.*, 2005)

Kind	Storage and preparation	Methods of usage
Liver	Frozen, fresh, or refrigerate Whole, sliced, or grind	Braised, broiled, fry, loaf, patty, and sausage
Kidney	Fresh or refrigerate Whole or sliced	Broiled, cooked in liquid, braised, fried, stew, and soup
Heart	Frozen, fresh, or refrigerate Whole or sliced	Braised, cooked in liquid, roasted, stuff, luncheon meat, patty, loaf, and sausage ingredient
Brains	Frozen, fresh, or refrigerate Whole	Broiled, braised and cooked in liquid, poach, and fried
Tongue	Fresh or refrigerate	Boiled, stew, jelly, grilled, and cooked in liquid
Stomach	Fresh or refrigerate	Honeycomb tripe and container for haggis
Sweetbread	Frozen, fresh, or refrigerate Whole	Fry, broiled, braised, poach with sauce, cream and cooked in liquid
Spleen	Frozen, fresh, or refrigerate	Pie, melt, blood sausage ingredient, and variety meat
Intestine (small and large)	Fresh or refrigerate Remove manure, soaking, washing, and salting before use	Sausage casing
Cheek and head trimmings	Frozen, fresh, or refrigerate	Cooked sausage, stew, and soup
Testicles	Frozen, fresh, or refrigerate	Fried
Lungs	Fresh or refrigerate	Haggis, pet food
Feet	Frozen, fresh, or refrigerate	Jelly
Fat	Frozen, fresh, or refrigerate	Shortening, drippings, sweets, oleomargarine, and chewing gum
Blood	Frozen or refrigerate	Black pudding, sausage, blood and barley loaf
Bone	Frozen, fresh, or refrigerate	Gelatin, soup, jelly, and mechanically deboned tissue

numerous states and vast area, has resources for production of animal casings of high quality with excellent calibration and shining colour. This makes India one of the major exporter of animal casing in the world. The country has exported 352.21 MT of Casing products to world for the worth of Rs. 28.45 crores during the year 2013-14 (APEDA, 2014). The major export destinations during the period 2013-14 are Albania, Spain, South Africa, Romania, Japan, USA European union and Lebanon. The other products from intestines include cat gut or surgical sutures, music strings and tennis racket strings.

Inedible By-Products

Inedible meat by-products have a prehistoric significance that was established before the advent of the meat industry. As animal protein (meat) was acquired primarily by hunting, and individual animals were 'cleaned' for food purposes, the inedible portions were left for nature's disposal or used for clothing, components for housing, fuel and other life-support functions that complemented the use of the animal as a basic component of nutrition. The major inedible by-products include wool, hair, fiber, skin, bones, horns, bristles, hooves, manure, litter, fish scales, hatchery by-products, snout, teeth, trimmings etc. Moreover, the animals which die due to its natural death or at the slaughter house prior to slaughter and animals unfit for human consumption until and unless the disposal of these through other means is warranted, the same can be processed economically. All these can be processed into different value added products (Table 4).

Utilization of Hides and Skins

Animal hides and skins have been utilized for shelter, clothing and weapons and as food containers by humans since prehistoric times. The hides and skins contain a very notable portion, 7 and 11 percent (e.g., cattle: 5.1%-8.5%, average: 7.0%; sheep: 11.0%-11.7%; swine: 3.0%-8.0%) of the live weight of large and small animals respectively (Jayathilakan *et al.*, 2012) and generally are one of the most valuable animal by-products. Examples of finished product from cattle hide, hog skin, and sheep pelts are the following: cattle cured and tanned hides-shoes, bags, belting, rawhide, athletic equipment; cattle corium layer-picking bands, textile shuttle holders and passers, reformed sausage casing, and cosmetic products; calf skin-lightweight leather, gloves, drum heads, and fabric trimmings; pig skin- sausage, edible gelatin, glue, gloves, belts, shoes; sheep slats (skin after wool or fleece is removed)-shoes and slippers, hat sweat bands, fancy shoes, gloves, sporting goods, diplomas; sheep pelts (wool or fleece left on)-heavy coat material, moutons, and shearlings. India is the world's largest producer and exporter of hides/skins and their products. It is estimated that India has 10-12% share in the world's leather market. In India alone, 23.2 million cattle hides, 20.3 million buffalo hides, 90.6 million goat skins and 37.3 million sheep skins are produced as primary/principal by-product worth Rs 30,220 crore out of which Rs 20,000 crore come through exports (FAO, 2014). But unfortunately, in developing countries, they are not exploited up to their full potential as often they are thought of as intrinsically unclean

and finally end up being discarded or wasted because of ignorance and misinformation (Leach and Wilson, 2009). These hides can be sold as such after semi processing. The value of these raw hides and skin accounts 10-15% of the total realization from slaughtered animals. However, the value addition of these raw hides and skin in to processed leather enhances their value by 5-6 times (Naidu, 2003). The leather produced from hides and skin is used at industrial level for production of foot wares, garments and assorted leather goods such as wallets, passport cases, key chains, hand bags and brief cases etc and contributes immensely to the Indian economy through way of exports (ranks 8th in the world) (Anon, 2008), besides improving the livelihood security of the people right from producers to the processors. The Indian leather industry meets 10% of global finished leather requirement. India exports 65%, 12%, 11% and 12% finished leather to the Europe, North America, Hongkong and China; and rest of world respectively (Anon, 2008). For value addition of the by-product into a high quality value added product, the quality of raw material is of utmost importance which can be maintained during pre-slaughter, slaughter and post slaughter stages.

Utilization of Bone

Eleven percent of pork carcasses, 15% of beef carcasses, and 16% of lamb carcasses or around 20-25% of the live weights of animals is composed of bone, and these values would be higher if adhering meat is included. In addition to the attached lean, the amount of marrow in a bone can also contribute to the yield of mechanically deboned products (Ledward *et al.*, 1983). The marrow can average 4.0% to 6.0% of the carcass weight. For centuries bones have been used to make soup and gelatin. In recent years the meat industry have attempted to get more meat from bone and new separation techniques have been utilized for this purpose. The mechanical deboning or separation technique produces tissue that at times has been called mechanically separated beef, pork, or lamb, mechanically deboned beef, pork, or lamb, and mechanically removed meat. Mechanically deboned or separated meat is now approved for use in meat products (mixed or used alone) in many countries.

Approximately 5.0 lakh tonnes of bones are available in the country but only 50% are collected and used. Bones are the raw materials for tallow, crushed bones sinews, ossein, dicalcium phosphate, bone meal, bone clear, glue and gelatine. Bone Morphogenic Protein (BMP) is extracted from bones which have no antigenic sensitivity so it is used in human facial, dental and aesthetic surgeries. It fastens the recovery process even 20-30 times. Bone cartilage is used to replace facial bones in surgery. Slaughter house bones are also used to extract soup stock, buttons, handles and in sugar refinery, water purification systems, steel hardening etc. Collagen, glue and gelatine are extracted from cartilaginous substances including hides, bones, horn pith etc. Collagen forms 30% of the body's organic matter or 60% of body's proteins. Collagen sheet is used for healing of bums and lprosy wounds. Glue and gelatine are water soluble, hydrophilic colloidal proteins (albuminoids) produced by controlled hydrolysis of collagen. Glue is a crude form of gelatine. Gelatine can be used in pharmaceutical capsules, tablet binder, plasma extender in

blood transfusion, edible gel in soft chocolate and other frozen desserts or glue used as adhesive in plywood and other industries. Medicinal uses also include application of gelatine in digestive problems, ulcers, muscular disorders and to encourage nail growth.

Pharmaceutical By-products

Natural products including the animal by-products provide many chemical and biochemical extracts needed in the pharmaceutical, food and cosmetic industries. There are large number of glands (pituitary gland, intestinal mucus, adrenals, liver, lungs, thymus etc) present in an animal involved in the syntheses and secretion of enzymes, hormones, pigments and vitamins. These are involved in the metabolic process in living cell and hence their availability in their natural form is very useful in pharmaceutical industries. The glands/tissues of a slaughtered animal obtained as a by-products are a source of substances of pharmaceutical importance. The glands/tissues are collected only from healthy animals and locating the glands requires experience because some of the glands are often small and are often encased in other tissue. Different animals have different glands that are important, and their function is dependent on the species, sex, and age of the animals. The best method of preserving most glands and stopping autolysis and bacterial growth is by quick freezing. Before freezing, the glands must be cleaned and trimmed from surrounding fat and connective tissue. They are then put on waxed paper and kept at -18°C or less. When the glands arrive at the pharmaceutical plant, they are again inspected, then chopped and mixed with different solutions for extraction or placed in a vacuum drier for the drying process. If the dried gland contains too much fat, solutions such as gasoline, light petroleum, ethylene dichloride, benzene, and acetone are used to remove the fat. After drying and defatting, the glands or extracts are milled to a powder form and dispensed as capsules, tablets, or injections or utilized as a dilute liquid. They are tested for safety and potency prior to sale.

By-Products as Livestock Feed

Animal by-products including condemned parts or even whole carcasses can be utilized as a feeding supplement for the livestock including poultry and pet animals. These by-products are rich source of nutrients including vitamins and minerals. The advantages of value addition of by-products as livestock feed include better animal health, good returns, employment generation which in turn improves the livelihood security. These primary by-products can be processed into a value added products viz; meat meal, bone meal, carcass meal etc for supplemented feeding. Meat meal is the major secondary by-products of the slaughtering industry and is an important components of stock feeds for pigs and poultry. It can be prepared from the carcass trimmings, condemned carcasses, condemned livers, inedible offal, and also from the rendering of dead animals. It is used as a supplement for feeding of livestock as it is a good source of high quality proteins (well-balanced amino acid profile), energy, vitamin B and minerals. Addition of about 10% meat meal helps to satisfy the animal requirement for essential amino acids like lysine, methionine, theronine and tryptophan. Besides that meat meal also acts as a good source for vitamin B,

particularly thiamine. Meat meals can be included in the diets for pigs and poultry of all ages. Bone meal, another important secondary by-product is a mixture of crushed and coarsely ground bones (less than 2 mm size) used as a supplement in livestock feeds (Sharma, 2003). The composition of bone meal depend upon the type of bones used for its preparation, weather green or desert ones. Quality of bone meal is determined by the presence of phosphorous and calcium that should be ideally present in the ratio of 1:2. The average composition of bone meal is calcium (30.5%), phosphorous (15.5%), protein (7.0%) and fat (1.0%) (Sharma, 2003).

By-Products as Fertilizer

With the development of animal by-product industry, rendering has grown to include all the processes leading to the conversion of slaughter house offal into stock feeds (meat meal, bone meal, carcass meal etc), fertilizers and fats. The factor which decides whether the finished product obtained after rendering shall be used for stock feed or fertilizer is the nature of raw material. Clean and fresh material is used to make good stock feed while material which is contaminated and decomposed is suitable for fertilizer preparation. Animal by-products can be used as a valuable resource as agricultural fertilizer and soil conditioner. Their application can improve the soil health in a variety of ways by improving its structure and biology. Soil health is improved either directly through addition of carbon and nutrients that feed the micro organisms or indirectly through improved plant growth, which in turn leads to the addition of organic matter. They improve the soil structure by decreasing bulk density, increasing permeability, increasing cation exchange capacity and increasing aggregate stability. These changes in the soil structure leads to higher infiltration and moisture retention, better nutrition retention and better plant growth. The disadvantage associated with the application is that soil structure may get damaged during application by compaction and other contaminants like salts and metals may be added. However, these risks can be minimized by good management practices.

By-Products as Energy Source

Animal residues and slaughter houses wastes viz; dung, droppings, urine, ruminal contents, blood, meat and fat trimmings etc can be utilized to alleviate the pollution problems besides providing light and heating energy source to farm, abattoir etc. Fuel from animal waste is a renewable energy. The source of this energy is plentiful and constant. The waste product is utilized effectively and contributes to the continuous generation of an efficient energy source. The animal wastes constitutes a good substrates for biogas production with methane potential of $619 \text{ dm}^3\text{kg}^{-1}$ from mixed animal wastes, which is much higher than simple manure ($20\text{--}30 \text{ dm}^3\text{kg}^{-1}$) (Hejnefelt and Angelidaki, 2009). Power plants have been designed to produce biogas (60% methane, 30% carbon dioxide and traces of hydrogen, carbon monoxide etc) by digestion of animal waste (Sharma, 2003). Biogas is produced from animal wastes due to their anaerobic fermentation. It involves the collection of animal waste and by-products, storage in airtight tanks called digesters where anaerobic digestion occurs. The resulting gas is then compressed in tanks and distributed to consumption. The fuel

is then burnt for steam production so it can force turbines to turn and create electricity. It can also be used to cooking, heating, lighting and even power car engines. It has been reported that it is economically feasible for the larger dairies to utilize the by-products from livestock to produce biogas which can be used to generate electricity for their different uses (Anon, 1997).

Constraints in Slaughter House Waste Utilization

Indian meat industry has inherent handicaps which hamper the proper utilization of the animal by-products. At present we do not have major industries based on by-products processing. The major constraints are:

Lack of modern abattoir: Generally in local or panchayat slaughter houses, on an average less than 5 large animals or 15 sheep or goat are slaughtered per day. The clandestine slaughter at various meat shops or family functions is also very common. The quantum of by-products from such small slaughter houses will be small and collection of by-products is difficult. However, the total volume of all these small slaughter houses will be huge but because of lack of facilities it is not collected. It is not economically feasible to have rendering plants or by-products utilization plant, attached to such individual small slaughter houses.

Lack of collection and transportation systems: The system and facilities (carriage vans) for the collection as well as transportation of animal by-products and fallen animals from small slaughter houses to the processing plants is lacking.

Preference to hot meat: Indians like to purchase hot meat. The sight of poultry birds being slaughtered on the roadside meat shops before the eyes of the customers is very common. The heaps of poultry feathers or other poultry by-products on the side of these shops create an obnoxious scene and environment pollution.

Collection of bones: In general, the Deboning is not done in the slaughter houses. It is being done either at home or restaurants. So it becomes very difficult to collect the bones for further processing.

Unorganized meat industry: Indian meat industry is regulated by unscrupulous uneducated meat traders. They do not know the benefits of processing of animal by-products both in turn of economics as well as pollution and health hazards.

Dead and fallen Animals/Birds: It is estimated that around 36 million dead and fallen animals are available in the country every year. Not more than 30% of these being utilized for by-product processing or properly disposed off. It is a major source for spread of diseases.

Lack of processing facilities: There are hardly 183 organised carcass utilization plants (CUPs) in such a vast country processing not even 1% of the raw materials available. The rendering units are attached to upcoming modern abattoirs only.

Lack of human resource: There is also dearth of technically trained and scientific personnel in this area. The Veterinary

Education Institutes/Universities or Veterinary Colleges in State Agricultural Universities lack the programme, facilities as well as the curriculum to train the personnel in by-product processing.

Lack of Research and Development: There is lack of linkages between laboratory and industry. Even the modern abattoirs and big houses in meat industry do not have proper R&D Section. There is an urgent need for engineering R&D in the development of low inventory, low priced equipments/rendering units for animal by-product processing.

Diseases: The problems such as Salmonellosis or recent problems of Bovine Spongiform Encephalopathy (BSE) in Europe especially Great Britain are being linked with feeding of meat meal or meat-cum-bone meal, severely disrupted the market of animal by-products.

Synthetic substitutes: Many synthetic substitutes have come to the market affecting the marketing of inedible by-products. Cellulose, plastic and reconstituted collagens have replaced many of the natural casings which are used for sausages. Vegetable fats have replaced many inedible fats for industrial uses. Inedible fats used in soap industry have been replaced; synthetic insulin produced from animal pancreas is being replaced by biotechnology.

Agitation by ethical groups: Some social ethical groups are agitating to discourage the use of animal by-product for processing into different valuable products. This is also a big hindrance for the development of animal by-product industry.

Identification of markets: There is an urgent need to identify markets (domestic as well as international) for both raw and processed animal by-products.

Conclusion

The utilization of animal by-products are often ignored, however, these items contribute a significant value to the livestock and meat industries. Non-utilization of animal by-products in a proper way may create major aesthetic and catastrophic health problems. Value addition of animal by-products has two benefits. Firstly, the meat industry gets additional revenue by processing them to industrial, household, and cosmetic products; livestock feed additives; pet foods; pharmaceutical and medical supplies etc that otherwise would have been unrealized. Secondly, the costs of disposing of these secondary items are avoided. Value addition can also sometimes acts as a cushion to cover losses suffered in the trade. Furthermore, although the development of synthetic substitutes in the middle of the 20th century decreased the value of many animal by-products, but their importance in the pet food industry and the medical/veterinary field are contributing to an increase in by-product values in recent years. Utilization of these by-products as fertilizer contributes a lot in organic farming and could reduce our dependence on synthetic fertilizers. Animal by-products and wastes are a good source of renewable energy as well its production is economically feasible. The utilization needs become significantly stronger due to competition. This is important because increasing profit and decreasing the cost is

required in the future for the meat industry to remain viable. These contributions and efforts are also necessary for the meat industries to change in an innovative manner and to widen the opportunities to utilize by-products. However, the saying "the packer uses everything but the squeal" has always existed in the meat industry and will continue to influence the utilization of meat by-products.

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