Review Article

Animal Byproducts - Boon to Human Health: A Review

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Abstract

Around 165 million livestock and 2300 million poultry were slaughtered in 2016-17 in India. Besides meat, a large quantity of by-products are produced as a result of slaughtering process. Byproduct includes every part of a slaughtered animal except dressed carcass. The yield of animal by-products ranges between 50-60% of the live weight. 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. Slaughtered animals are the source of general medical and health care products which include antibodies (immunoglobins), beef insulin, bovine collagen, bovine fibrinolysin, bovine super oxide dismutase, bovine thrombin, hyaluronidase, PTH, gelatin pills/capsules, whole serum (vaccine manufacturing) etc. Although the development of synthetic substitutes in the middle of the 20th century decreased the value of many animal byproducts, but their importance in the food industry and the medical/veterinary field are increasing in recent years.

Key words: Antibodies, Byproducts, Health Care, Hormones, Medicines, Nutrients

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Introduction

Valuable byproducts are obtained from slaughtering of meat animals and used for various purposes by mankind. From anti-aging creams to surgical sutures, skin grafting and xenotransplantation to chocolate milkshakes, ice-creams and marshmallows we have used animal products from cattle, sheep and hogs into nearly every corner of our lives. Slaughtering and processing of meat animals can only harvest one third of its weight as meat but the rest comprises of byproducts and waste which ranges from 50-60% of the live weight. BAH & FS, Government of India (2017) estimated that about 165 million livestock and 2300 million poultry birds were slaughtered during 2016-17 in India owing to production of 7.4 million tones of meat. It leaves huge loads of byproducts which were also contributed by dead and fallen animals. It accounts for more than 10 million MT of edible and inedible by-products. The animal by-products are categorized mainly into edible and inedible by-products. On the basis of live weight of animal the by-products account for almost 60%, of which 40% are edible and 20% are inedible (Chatli *et al*., 2005). Another basis for classification of animal by- products is their ultimate use. These include agricultural byproducts (meat meal, bone meal, fertilizer etc.); industrial byproducts (gelatine, glue, casings etc.) and pharmaceutical byproducts (insulin, pepsin, biochemicals, hormones etc.) (Sharma, 2011). The therapeutic value of most meat byproducts are exploited for use in human healthcare.

The art of treating human ailments by using therapeutics derived from animal origin is known as zootherapy (Costa-Neto, 2005). As Marques (1994) states, "all human culture which presents a structured medical system will utilize animals as medicines". By-products obtained from wild and domestic animals (e.g., hooves, hides/skins, bones, feathers, tusks etc.) form important ingredients in the curative, protective and preventive medicine (Adeola, 1992). The World Health Organization (WHO) estimates that as many as 80% of the world's more than six billion people rely primarily on animal and plant-based medicines. Animals have been methodically tested by pharmaceutical companies as sources of drugs for modern medical science (Kunin *et al*., 1996), and the current percentage of animal sources for producing essential medicines is quite significant. Of the 252 essential chemicals that have been selected by the World Health Organization, 8.7% come from animals and of the 150 prescription drugs currently in use in the United States of America, 27 have animal origin (WRI, 2000). Current experiments in xenotransplantation most often use pigs as the donor, and baboons as human models.

Nutritive Value of Edible 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. Various meat by-products have a higher level of moisture than meat. Some examples are blood, skin, lung, kidney, brains, spleen, and tripe. Some organ meat, including liver and kidney, contains a higher level of carbohydrate than other meat materials (Devatkal *et al*., 2004b). Highest fat content and the lowest moisture content of all meat by-products are found in pork tail. The liver, tail, ears and feet of cattle have a protein level which is close to that of lean meat tissue, but a large amount of collagen is found in the ears and feet (Unsal and Aktas, 2003). The amino acid composition of meat by-products is different from that of lean tissue, because of the large amount of connective tissue. As a result, 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 organ meat contains higher amount of vitamins than lean meat tissue. 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, folacin, ascorbic acid and vitamin A. Kidney is also a good

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source of vitamin B-complex. A 100 g serving of liver from pork or beef contributes (450–1,100) % of the RDA of vitamin A, 65% of the RDA of vitamin B6, 3,700% of the RDA of vitamin B12 and 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 livers of beef, lamb and veal. They contribute 90–350% of the RDA of copper (2 mg/day). Livers 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) in meat by-products is found in the thymus and sweetbreads (Devatkal *et al*., 2004). 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).

Many organ meats contain more polyunsaturated fatty acids than lean tissue. Brain, chitterlings, heart, kidney, liver and lungs have the lowest level of monounsaturated fatty acids and the highest level of polyunsaturated fatty acids (Liu, 2002). 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. In the past, by products were a favorite food in Asia, but in present situation there is an increased focus on non-food uses, such as pet foods, pharmaceuticals, cosmetics and animal feed (Rivera *et al*., 2000).

By-products in Human Healthcare

Slaughtered animals are the source of general medical and health care products which include antibodies (immunoglobins), beef insulin, bovine collagen (used as injections to fill in scars), bovine fibrinolysin ointment for necrotic tissue, bovine super oxide dismutase cosmetic skin cream to prevent tissue aging), bovine thrombin- clotting agent for blood, culture medium for diagnosis, fetal bovine serum for tissue cultures, hyaluronidase (for efficient drug use), PTH (controls tetany), Pegademase - bovine derivative for patients who are immuno-compromised and helps prevent white blood cells from breaking down, gelatin pills/capsules, whole serum (vaccine manufacturing) etc.

i. 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). 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. Superoxide dismutase (SOD) enzyme can be extracted from cattle and porcine blood for curing osteoarthritis, ischemia and in anti-inflammatory treatment and so forth (Hass *et al*., 1993).

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ii. Arteries

Bovine carotid arteries (DeFalco, 1970) up to 55 cm (21.7 in) in length and 9-11 mm (0.35-0.43 in) in diameter may be treated with an enzyme (to remove parenchymatous immunologically reactive proteins), subsequently tanned (makes collagen stronger and more nonreactive) and then sterilized for later implantation into humans as a femoropopliteal or iliofemoral substitute.

iii. Hide and Skin

a. Gelatin

Gelatin extracted from animal skins and hides can be used for food (Choa *et al*., 2005). Approximately 6.5% of the total production of gelatin is used in the pharmaceutical industry (Hidaka and Liu, 2003). Most of it is used to make the outer covering of capsules. Gelatin can also be used as a binding and compounding agent in the manufacture of medicated tablets and pastilles. 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 (Estaca *et al*., 2009). Such sponges are used in surgery, and also to implant a drug or antibiotic directly into a specific area. 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, photogravure printing etc. (Arvanitoyannis, 2002). A product made from extracted collagen can stimulate blood clotting during surgery.

b. Skin Grafting

Pork skin is similar to human skin, and can be converted into a graft/dressing for burns or skin-ulcers.

iv. Bone

Cartilage

Specifically processed xiphoid or xiphisternal cartilage from the breastbone cartilage of young cattle is used by plastic surgeons to replace facial bone.

Collagen

Unmodified collagen from demineralized bone powder is used for packing holes in gums and bones and is used as standards in diagnostic kits (Slim, 1997).

Gelatin from Bone

Ossein is normally produced from bone for gelatin extraction and gelatin extracted has same use as that extracted from hide and skin.

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Bone Meal

Bone meal is also a nutritional source of calcium (averages 23%) and phosphorus (averages 12%) in the diet. Steamed bone meal has had most of the protein and fat removed and contains approximately 32.5% calcium and 15.1% phosphorus. If ground sufficiently fine, bone can be added to milk to increase the calcium level. Bone meal is also used as a filtering agent in water purification systems.

Bone Marrow

Marrow, marrow extract or red bone marrow, bone powder, and bone ash (approximately 15.3-16.6% phosphorus) products are also available as human and animal dietary supplements. Red bone marrow is used to treat patients who have a low red blood cell count. It can be fed orally and is stable to heat and the action of the digestive juices.

v. Glands and Organs: Medicinal and Pharmaceutical Uses

Animal glands and organs are traditionally used as medicine in many countries, including China, India and Japan.

a. Brain, Nervous System and Spinal Cord

Brains, nervous systems and spinal cords are a source of cholesterol which is the raw material for the synthesis of Vitamin D_3. Cholesterol is also used as an emulsifier in cosmetics (Ejike and Emmanuel, 2009) and anti-aging creams.

b. Trachea

The trachea is used as a source of collagen and GAGs. The trachea also contains a trypsin inhibitor (aprotinin) and is sold as a biochemical reagent and has potential therapeutic value.

c. Lungs

Heparin (mucopolysaccharide), an anticoagulant that prolongs the clotting time of blood, is used to prevent blood clots and can be extracted from the lungs, the liver, or the intestine mucosa (usually pig and beef). It is being used in "minidoses" in the prevention of postsurgical pulmonary emboli by blocking coagulation of blood in the intact blood vessel. Heparin is also used to prevent gangrene in frostbite and as a burn treatment. Lungs also contain aprotinin, a trypsin inhibitor that is used as a biochemical reagent and has potential therapeutic value.

d. Heart

Heart valves from young to market weight pigs are preserved and treated (converted to a "biological plastic") prior to surgical implantation into the human heart in place of a defective valve (often caused by

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rheumatic fever or birth defects). The pig heart valve (xenograft) is often preferred over a mechanical valve, which requires constant infusion of anticoagulant (blood thinning) drugs to prevent the blood from forming clots on the valve (causing sudden malfunction) or free floating thromboemboli (causing stroke or paralysis). If a problem develops with a hog valve, malfunction is usually not fatal because (as with a natural valve) early warning symptoms alert the patient in time for reoperation.

Pericardial tissue (membrane enclosing and attaching the heart in the thoracic cavity) from beef animals is also cleaned, glutaraldehyde-processed, and used to repair or replace the patient's own pericardial tissue after heart surgery. Use of this pericardial patch prevents the adhesion of the patient's myocardium to the sternum following surgery.

e. Glands

The endocrine glands secrete hormones and enzymes that regulate the body's metabolism. These include the liver, pituitary, thyroid, pancreas, stomach, parathyroid, adrenal, corpus luteum, ovary and testes. The glands are collected only from healthy animals.

f. Spleen

The spleen is often collected from beef and pork carcasses for pharmaceutical use. The spleen (largest structure in lymphoid system) extract (splenin fluid) influences capillary permeability, recovery from inflammation (redness and swelling) and blood-clotting time. Spleen extract is also used to treat certain blood and lymph diseases. It is marketed as powder, tablets and capsules.

g. Animal Intestines

The intestines of sheep and calves are used for the manufacture of catgut, to make internal surgical sutures. The lining of the small intestines of pigs and cattle are being processed into casings. It is either preserved in a raw state, or processed into a dry powder for heparin manufacture.

vi. Horns and Hooves

Keratin from horns has been proposed as a hair care unit. Powdered horn and the velvet from deer horns is used as an aphrodisiac supplement in Asia (Slim, 1997).These are also used for manufacturing adhesives, bandage strips, collagen cold cream, cellophane wrap and tape, crochet needles etc.

vii. Animal Fats and Fatty Acids

Used in manufacture of chewing gum, pharmaceuticals, animal foods, biodegradable detergents, biodiesel, cellophane, cement, ceramics, cosmetics, glycerin, glycerol, antifreeze, lubricants, medicines, ointment bases, plasticizers, hair conditioner/shampoo, soaps etc.

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Table1: General Medical and Health Care Products from Animal Glands (Okerman, 2000)

Animal gland	Uses
Adrenal gland	Cortisone: for arthritis, skin allergies, anti-inflammatory medicine,
	Epinephrine: aid in raising blood pressure, heart disorders, and allergies
Pineal gland	Melatonin (from bovine, in tablet form) - schizophrenia, mental retardation, anti-jetlag and an anti-seasonal depression treatment.
Pituitary gland	ACTH - arthritis, allergies, rheumatism, skin and eye inflammations, multiple myeloma Prolactin -breast cancer, promotes lactation,
	Vasopressin - diabetes insipidus, blood pressure, "gas shadows" while making abdominal Xrays, controls intestinal and renal functions,
	Oxytocin - assist in childbirth and in obstetrical complications, increasing the release of milk by mammary glands, lowering blood pressure, and as a wound closer (often used by boxers),
	TSH (thyrotropin) - diagnostic tool for the function of the thyroid gland, useful in conjunction with radioactive iodine to locate thyroid cancer,
	Growth hormone (GH) - direct effect on protein, carbohydrate, and lipid metabolism, controls the rate of skeletal and visceral growth.
Thyroid gland	bovine thyroid hormone as thyroid replacementin myxedema and cretinism, thyroid extract –for hypothrodism, Calcitonin (thyrocalcitonin) - lowers calcium and phosphate in blood and to regulate heartbeat, treat Paget's disease(a bone disease)
Parathyroid gland	Parathormone (from beef) – treats human parathyroid deficiency, raises blood calcium, lowers blood phosphorus and increases the amount of calcium and phosphorus excreted in the urine (in powder or tablet form)
Thymus gland	Thymosin - aids in resisting infections, prevention of rickets (powder, tablet, and capsule form)
Liver	Heparin - anti-coagulant, blood thinner prevents gangrene,
	Liver extract - treatment of anemia,
	Intrinsic factor –in pernicious anemia,
	Vitamin B12 -prevention of B-complex deficiencies
Pancreas	Chymotrypsin - contact surgery, Diastase - aid in starch digestion, Glucagon - treat hypoglycemia, insulin - diabetes mellitus, Pancreatin - aid digestion, Trypsin - for burns, wounds, and infection (promotes healing, aids in protein digestion and in cleaning wounds)
Testes	Hyaluronidase - used as a "spreading factor" (increase the rate of absorption, dispersion, distribution and, consequently the effect of other drugs administered with it), Androgens - control male characteristics.
Seminal vesicles	Prostaglandins - induce parturition and to induce abortion (in larger doses), treats gastric ulcers, bronchial asthma, thrombosis, high blood pressure and in synchronization of estrous in animals.
Ovaries	Estrogen and progesterone (from pork) - uterine bleeding, threatened abortion, menopausal syndrome, breast and prostate cancer, oral contraceptive etc. Relaxin (from pregnant sow ovaries) - used during child birth (powder, tablets, and capsules)
Stomach glands	Pepsin(powder, granular, tablet, or glycerol liquid forms) - aid in protein digestion, used in achyliagastrica (failure of stomach to produce acid),bacteriological media, Rennet - aid in milk digestion, cheese making, Intrinsic factor (glycoprotein) -utilization of vitamin B12 (in pernicious anemia), Gastrin – stimulates gastric juices production,
	Secretin–in pancreatic diseases, Cholecystokinin (CCK) – emptying of gallbladder, Enterogastrone (from hog stomach)- mediates secretion and mobility of stomach, stimulates islet of Langerhans, Mucin (from hog)–in peptic and duodenal ulcers, aid food passage through digestive tract (powder or granular form), adjunct to digestive aid products.
Gall bladder	Bile - digestive disorders, constipation, bile tract disorders, fat-digestion disorders, increasing the secretory activity of the liver and manufacture of steroid drugs like cortisone (pain killer, anti-inflammatory in arthritis), Chenodeoxycholic acid (from pig) suppresses synthesis of cholesterol and dissolve gallstones (80% of human gallstones), Gallstones - mystical aphrodisiac value ,used as ornaments

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viii. Glycosaminoglycans (GAGs)

The sources and usage of various GAGs found in animal body are given as follows:

Table 2: Use of glycosaminoglacans from animals (Slim, 1997)

GAG	Sources	Uses
Hyaluronic acid	Skin, Eyes	Moisturizer
Chondroitin sulfate	Trachea	Moisturizer
	Nasal septa	Health food
Dermatan sulfate	Skin Mucosa	Moisturizer
		Antithrombotic
Heparin	Lungs Mucosa	Anticoagulant
		Antithrombotic

Hyaluronic acid can be extracted from the corium of the eyes and is used as a packing material in eye surgery. The more preferred product is extracted from rooster combs. It is also used in cosmetics as a moisturizing agent. GAGs are also sold as health food, cosmetic moisturizer, and to add "feel" to creams. Other reported uses are as stock feed and as a treatment for arthritis. They can be isolated from cartilage and trachea. Heparin is another GAG that is used to prevent blood coagulation. To date, the isolation is still totally from natural sources.

ix. Bioactive Peptides

Meat trimmings, mechanically recovered meat, collagen, blood are rich source of proteins and hence constitute an ideal substrate for proteolysis. These proteins are subject to hydrolysis with specific commercial proteases and are known to have antihypertensive, antimicrobial, anti-obesity, antioxidant activities hence used in various functional/ healthy food preparations (Table 3). In vaccine production and in microbiological culture medium, meat peptone is used as a source of nutrient. Collagen hydrolysate obtained from bovine trachea is used in arthritis (a nutraceutical) and in cosmetics (shampoos and skin creams).

Table 3: Antihypertensive peptides derived from animal by-products

Antihypertensive Peptides				
Source of Protein	**Enzyme**	**Sequence**	**IC_{50} values Activity**	**Reference**
Porcine hemoglobin	pepsin	GFPTTKTYFPF, VVYPWT	4.92 and 6.02 µM No in vivo activity results have been provided	Yu *et al.*, 2006
Bovine gelatin hydrolyzate	thermolysin	Seven di and tripeptides	Intense invitro ACE-I activity and in vivo BP reduction in SHR	Herregods *et al.*, 2011
Bovine achilles tendon collagen	bacterial collagenase	(AKGANGAPGIA GAPGFPGARGPS GPQGPSGPP)	51.10 and 79.85 µM. Retained 80% ACE-I invitro effect after t/t with GIT enzymes	Banerjee and Shanthi, 2012

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		PAGNPGADGQP GAKGANGAP		
Porcine liver		2 hydrolysates	0.18 and 0.31 mg/ ml. Dose- 1 g/rat In vivo BP	Inoue *et al.*, 2013
Bovine skin gelatin	Serial digestion (alcalse, Pronase E, collagenase)	Gly-Pro-Leu Gly-Pro-Val	2.55µM 4.67µM	Byun and Kim (2001)
Chicken leg collagen	Aspergillus derived protease	Gly-ala-Hyp-Gly-Leu-Hyp- Gly-Pro	29µM Decrease BP in SHR, Stimulation of NO synthesis Invivo activity in humans (5.2g/ day) 11.8 & 4.1 mmHg	Saiga *et al.*,2008; Shimzu *et al.*, 2010
Chicken Bone	Pepsin	Tyr-Tyr-Arg-Ala	33.9µM	Nakade *et al.*, 2008
Porcine skin gelatin	Protease	Gly-phe-Hyp-Gly-Pro	91µM, decrease in B.P. in SHR	Ichimura *et al.*, 2009
Antioxidant Peptides				
Source	**Enzyme**	**Sequence**	**Function**	**Reference**
Bovine skin Gelatin	Pronase E	Gly-pro-hyp-gly-pro-hyp-pro-hyp-gly	Inhibits lipid peroxidation, increase cell viability exposed to organic hydroperoxide	Kim *et al.*, 2001
Porcine hemoglobin	alcalase followed by flavorenzyme	-	exerted good antioxidant activities	Chang *et al.*, 2007
Water buffalo horn	Different proteases	QYDQGV, YEDCTDCGN, AADNANELFPP	protect rat cerebral cells against H_2O_2- induced injury, reduce the DPPH radical	Liu *et al.*, 2010
Porcine liver & Bovine liver	Thermolysin	under 3 and 10 kDa Contained His-pro-met-phe	Invitro antioxidant acticitiy	Bernardini *et al.*, 2012
Antimicrobial Peptides				
Source	**Enzyme**	**Sequence**	**Organism inhibited**	**Reference**
Bovine Haemoglobin	Pepsin	VTLASHLPSDFT PAVHASLDKFL ANVSTVL (107-136) fragment of α chain	*M. luteus* A270, *Listeria innocua*, *Enterococcus faecalis*, *Bacillus cereus*, *Staph saprophyticus*, *Staph. simulans*	Daoud *et al.*, 2005
Bovine hemoglobin	Pepsin	α107-141, α107-133, α137-141 and β126-145	*Micrococcus luteus* A270, *L. innocua*, *E. coli* and *Salmonella enteritidis.*	Nedjar-Arroume *et al.*, 2006
Bovine hemoglobin	Pepsin	24 peptide chain from α-chain 6 from the β-chain	cell population of all the tested bacteria species decreased by at least 97% after a 24-h incubation with any of the peptides at their IC_{50}	Nedjar-Arroume *et al.*, 2008
Bovine α-hemoglobin		VNFKLLSHSLLV TLASHL Mol wt- 1992 Da	*E. coli, Staph aureus,* and *C.albicans*	Hu *et al.*, 2011

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x. Wool

Wool grease contains 15% cholesterol. The oil glands of sheep are the source of lanolin. Some ophthalmic drugs contain lanolin as an ingredient. It is used as a carrier in certain drugs that are injected to body. Lanolin is also is found in eye drops because it has antibacterial properties and can protect against dry eyes.

Conclusion

By-products from the meat industry are rich sources of many fine chemical and biochemical extracts needed in the pharmaceutical, food and cosmetic industries. Some of the classes of material which can be extracted from meat industry by-products and are having therapeutic value for human healthcare are - steroids, polysaccharides, proteins, thymus extracts, hormones etc. Meat producers have, for a long time, efficiently used meat by-products in processing into either edible or inedible products. Today, with increasing concerns about health and environmental protection, many new techniques, operating procedures, and research have been developed to permit more efficient processing and utilization of these by-products. Contributions and efforts are also necessary for the meat industries to change in an innovative manner and to widen the opportunities to utilize meat by-products. Furthermore, although the development of synthetic substitutes in the middle of the 20th century decreased the value of many animal byproducts, but their importance in the pet food industry and the medical/veterinary field are contributing to an increase in byproduct values in recent years. 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 byproducts.

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Conflict of Interest

There is no conflict of interest to disclose.

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