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**SEMINAR PRESENTAION**

**ON THE TOPIC:**

**PROSPECTS AND CHALLENGES OF ANIMAL BY-PRODUCTS PRODUCTION IN FOOD SYSTEM**

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**ABSTRACT**

The consumption of animal by product has continued to witness tremendous growth over the last years. This is due to its potential to combat protein malnutrition and food insecurity in many countries. Shortly after slaughter animal by Product are separated into edible and inedible parts. The edible part accounts for 55%of the production while the remaining part is regarded as inedible by-product. These Inedible By-product (IEBPs) can be reprocessed into sustainable product for agricultural and industrial uses. The efficient utilization of some animal by-products can alleviate the prevailing cost and scarcity of feed materials which have high competition between animals and humans. This will also help in reducing environmental pollution in the society. In this regard, proper utilization of animal by-products can result in cheaper feed production reduction in competition and lower cost of production. Over the years, the utilization of these by-product have been successfully carried out without any adverse effects on the animal. However, there are emerging gaps that need to be further addressed regarding the food security and sustainability of the products. Therefore, the objectives of this review are to highlight the efficiency and effectiveness of using animal by-products as an alternative source of feed ingredient, state the importance of animal by-products in food system and access the constraints associated with their production to boost livestock performance in the industry at large.

**INTRODUCTION**

Animal by-products refers to any part of an animal or product of animal origin that is not intended for human consumption. Some of these by-products are used as ingredients in the production of many other products. When they are used as ingredients for production, they are referred to as animal-derived ingredients (Djagny *et al.,* 2001). These by-products have various uses in the production of animal feed, pet food, fertilizer, and in pharmaceuticals. They can also be used for industrial purposes such as in the production of soap, glue and leather (Echeverry and Sánchez, 2020). Meat and meat products form an important segment of the human diet because they provide essential nutrients which cannot be easily obtained through vegetables and their derived products. They provide a means for reducing malnutrition and increasing household food and food security. The process of converting livestock to meat in abattoirs usually generates a lot of by product which can be further utilized by humans as food or reprocessed as secondary by product for both agricultural and industrial uses. Animal by-products include all parts of a live animal that are not part of the dressed carcass such as liver, heart, rumen content, kidney, blood, fats, spleen and meat trimmings. Over the last 20 years the demand for meat and meat products has increased in many parts of the world (including; Africa, Asia, Europe and United States of America) and this has led to rapid surge in livestock production for sustainable food security. Animal by-products can be grouped into non carcass meat which is also known as the edible by-products (EBPs) and non-meat products that is inedible by-products (IEBPs) (FSIS, 2020). Edible by-products (EBPs) are products that are approved by registered public health inspector and considered safe for human consumption after inspection in the abattoirs. In contrast IEBPs cannot be consumed by humans and are condemned or discarded or reprocessed and used as secondary by-product. Most EBPs especially the liver kidney, tongue and heart have the potential to provide essential nutrients where meat and meat products are limited or insufficient to meet the nutritional requirements of the people. Edible by-products (EBPs) could be employed to reduce the menace of malnutrition and food insecurity. EBPs contain essential nutrients such as vitamins B1, B2, B6 and folic acid, protein, minerals and fat which is comparable to those in muscular tissue. Hence, this work will evaluate the use and challenges posed by-product in different industries.

**OBJECTIVES OF THE SEMINAR**

The objectives of this seminar are to review:

* The efficiency and effectiveness of using animal by-products as alternative source of feed ingredient.
* State the importance of animal by-products in food system.
* Access the constraints associated with their production.

**CLASSIFICATION OF ANIMAL BY-PRODUCTS**

Animal by-products are classified into;

* Edible by-products (EBPs)
* Inedible by-products (IEBPs).

**Edible By-Products:** Edible by-products are parts of the animal that are considered and can be consumed by humans (Rosa *et al.,*2002). Common examples of Edible By-products (EBPs)

1. Skin and flesh
2. Animal Brains
3. Heart
4. Kidneys
5. Livers
6. Tongues and chitterlings
7. **Skin and Flesh:** Skin and flesh are important edible animal by-products that have been utilized by humans for various purposes throughout history. In many cultures, these parts of animals have been consumed as food, providing valuable nutrition and flavor (Djagny *et al.,* 2001). Animal skin is often used in traditional dishes across different cuisines. For example, roasted pork crackling is a popular dish made from pig skin, which becomes crispy after cooking. In some countries, such as China and Korea, chicken feet are enjoyed for their gelatinous skin and unique texture. The flesh or meat of animals is widely consumed in countless dishes worldwide. From beef, pork, and poultry to fish and game meats, flesh is the primary component of many traditional and modern recipes. It can be cooked using various methods, including grilling, roasting, boiling, frying, and stewing, to create a wide range of delicious and nutritious dishes (Lonnie *et al.,* 2018). Animal skin contains collagen, the most abundant protein found in mammals. Collagen is composed of amino acids, particularly glycine and proline. Consuming collagen-rich foods, such as animal skin, may contribute to skin health and joint support (Ruxton *et al.,* 2010).
8. **Animal Brains:** Brains as an edible animal by-product have been consumed in various cultures around the world for centuries. Brains are considered a delicacy and are prized for their unique texture and flavor. While not as commonly consumed as other parts of the animal, such as meat or organs, brains offer a distinct culinary experience for adventurous eaters (Bates & Clamp, 2014). The consumption of animal brains dates back to ancient times. Ancient Egyptians, for example, are known to have consumed brain tissue, and it was even mentioned in Egyptian medical texts. Eating brains was also a part of traditional Native American cuisine, where buffalo, cow, or pig brains were considered a valuable food source. In various European cultures, lamb or calf brains have been used in traditional dishes like "brain fritters" or "cervelle de veau" (veal brains) (Bourdain, 2000). They can be sautéed, fried, roasted, grilled, or even used in stews or soups. Different cuisines have unique recipes incorporating brains. Brains are rich in essential nutrients, including vitamins (such as vitamin B12 and B6), minerals (such as iron, zinc, and selenium), proteins, and healthy fats. However, it's important to note that the nutritional composition may vary depending on the animal species and diet (Simoons, 1996). There are a few considerations and potential health concerns associated with consuming brains. One of the primary concerns is the potential risk of transmitting diseases, primarily prion diseases. These diseases, such as Creutzfeldt-Jakob disease in humans, are caused by abnormal proteins that can affect the brain and nervous system. Thus, it is crucial to ensure that the brains are sourced from healthy animals and prepared properly to minimize any potential risk (Bates & Clamp, 2014). It's important to note that the consumption of brains may not be widely practiced or readily available in many places due to cultural, ethical, and legal reasons. Additionally, individuals with specific dietary restrictions, allergies, or health conditions should exercise caution and consult with healthcare professionals before consuming brains or any specific food.
9. **Heart:** Heart as an edible animal by-product has been consumed by various cultures for centuries. Heart meat is highly nutritious and provides various essential nutrients required for the proper functioning of the human body (Sulińska *et al.,* 2020). It is a good source of protein, which helps build and repair tissues, along with several essential vitamins and minerals. Heart meat is known for its high content of iron, zinc, selenium, and B vitamins, including vitamin B12, thiamin, riboflavin, and niacin. Additionally, heart meat contains Coenzyme Q10, a compound that plays a vital role in cellular energy production (NND, 2018). Heart from different animals can be consumed, including beef, pork, lamb, chicken, and even fish. Each type of heart has its own unique flavor profile and texture. Beef and lamb hearts are known for their robust flavor, while pork and chicken hearts tend to be milder. Fish hearts, such as those from tuna or salmon, are relatively small and delicate. Heart meat can be prepared in various ways, depending on cultural and culinary practices. It can be grilled, braised, sautéed, or even used as an ingredient in ground meat. Many cuisines feature heart dishes, such as anticuchos (beef heart kebabs) in Peruvian cuisine, haggis (sheep heart, liver, and lungs) in Scottish cuisine, and "*pâté de cœur"* (heart pâté) in French cuisine (Cherian & Sim, 2011). Consuming heart as an edible by-product is not only a matter of nutrition but also has cultural significance in many societies. In some cultures, it is believed that consuming heart symbolizes strength, courage, and vitality. Heart meat is often associated with special occasions, traditional celebrations, and family gatherings. Its consumption can be rooted in ancient traditions and even religious practices (Sulińska *et al.,* 2020).
10. **Kidney:** The kidney produce urine by removing toxic waste products and excess water from the body. Kidney is an edible animal by-product that is frequently consumed in various culinary traditions. It is highly valued for its unique flavor, tender texture, and nutritional benefits. In this response, we will discuss the consumption of kidneys from different animal sources, their culinary uses, nutritional composition, and potential health considerations (Skelly *et al.,* 2006). Kidneys can be obtained from various animals, including beef, pork, lamb, veal, and poultry. Each type of kidney possesses distinct characteristics in terms of size, flavor, and texture. Beef and lamb kidneys, for example, are known for their rich and strong flavor, while pork kidneys have a milder taste. Poultry kidneys, such as chicken or duck, are smaller in size and have a more delicate flavor (Skelly *et al.,* 2006). Kidneys are used in a variety of traditional dishes across different cultures. They are commonly utilized in stews, pies, sautés, and even grilled preparations. Kidney dishes are particularly popular in British and French cuisines. Steak and kidney pie, for instance, is a classic British dish that combines diced beef or lamb kidneys with steak, onions, and gravy, all encased in a pastry crust. In France, dishes like *"Rognons de Veau*" (veal kidneys) and "*Ris de Veau*" (veal sweetbreads) showcase the versatility and culinary elegance of kidneys (Porter & Kaplan, 2012). Kidneys are nutrient-dense organs that offer several essential nutrients. They are an excellent source of high-quality protein, essential amino acids, vitamins, and minerals. Kidneys are particularly rich in vitamin B12, which is crucial for the formation of red blood cells and the proper functioning of the nervous system. They also contain significant amounts of vitamin A, vitamin D, iron, zinc, and selenium. However, it is important to note that the nutritional composition may vary slightly depending on the animal source (Porter & Kaplan, 2012). While kidneys can be a nutritious addition to a balanced diet, there are a few health considerations to keep in mind. Kidneys are high in cholesterol, so individuals with high cholesterol levels or specific dietary restrictions may need to consume them in moderation. Moreover, kidneys are a source of purines, which can be problematic for individuals with certain kidney conditions or a predisposition to gout (USDA, 2019).
11. **Livers**: Livers are highly valued and widely consumed edible animal by-products. They are nutrient-dense organs that provide various health benefits and are used in numerous culinary traditions around the world (The Guardian, 2014; Rousselot-Pailley *et al.,* 2021). Livers are considered one of the most nutrient-rich organs, packed with essential vitamins, minerals, and proteins. They are particularly abundant in vitamins A, D, E, and K, as well as B vitamins, including folate, riboflavin, and vitamin B12. Livers are also excellent sources of minerals such as iron, zinc, selenium, and copper. Additionally, they provide a significant amount of high-quality proteins and essential amino acids (OSU, 2017). Livers from various animals are consumed worldwide. Some of the most commonly used livers come from animals such as: Beef Liver which are respected for its bold flavor and tenderness, beef liver is widely enjoyed in dishes like liver and onions, pâtés, and liverwurst (The Spruce Eats, 2021; Choi & Stamenkovic, 2019). Chicken livers have a milder taste compared to beef liver and can be found in dishes like chicken liver pâté, stir-fries, and traditional Jewish dishes like chopped liver. Pork liver is often used in dishes like liver sausage, liver dumplings, and certain Chinese cuisine recipes. Lamb liver has a distinctive flavor and is utilized in dishes like lamb liver curry, sautéed liver, and various Middle Eastern recipes (OSU, 2017). Livers are highly versatile and feature prominently in traditional cuisines throughout the world. They can be cooked in numerous ways, including sautéing, frying, grilling, and baking (The Spruce Eats, 2021).
12. **Tongues and chitterlings:** Tongue and chitterlings are both considered edible animal by-products that are derived from livestock, particularly pigs. These parts have been consumed as food in various cultures around the world for centuries (FSIS, 2020). Tongue, often sourced from cows, pigs, or lambs, is highly regarded in many culinary traditions. It is known for its tender and flavorful meat. The preparation of tongue involves removing the outer layer of skin and cooking it through simmering, boiling, or braising (Gaviglio, 2016). The tongue is a rich source of protein, providing essential amino acids required for various bodily functions. It also contains significant amounts of vitamins and minerals including vitamin B12, iron, zinc, and selenium (FamilySearch, 2019). Chitterlings, commonly referred to as chitlins, are the small intestines of pigs. They have been consumed as a traditional delicacy, particularly in Southern US cuisine and in some European countries. Chitterlings are typically cleaned thoroughly to remove any impurities, and then boiled or stewed until tender. Due to their strong flavor and aroma, chitterlings are often seasoned with herbs, spices, and onions to enhance their taste. They can be served alongside other sole food dishes or used as an ingredient in stews, soups, and casseroles (Gaviglio, 2016). Chitterlings are a good source of protein and contain certain vitamins and minerals, including iron and vitamin B12. However, they are also high in cholesterol and fat, so they should be consumed in moderation as part of a balanced diet (USDA, 2019).

**INEDIBLE BY-PRODUCTS:** Inedible by-products are parts of the animals that are not intended for human consumption (Irshad *et al.,* 2015). Common examples of Inedible By-products (IEBPs) includes:

1. Bones
2. Horns and hooves
3. Wool or fur
4. Teeth
5. Manure
6. Trimmings
7. Rumen contents and glands
8. **Bones**: Bones are an inedible animal by-product that serve various purposes in different industries. They are composed primarily of the mineral calcium phosphate, which provides strength and rigidity to the skeletal structure of animals. While bones are not typically consumed as food by humans, they have a multitude of valuable uses in several fields, including medicine, agriculture, and manufacturing (Gokhale *et al.,* 2013). One of the most significant applications of bones is in the field of medicine. Due to their structural strength and ability to withstand compression, bones are used extensively in orthopedic surgeries for bone grafting, joint replacements, and dental procedures. Bone grafts, which involve using bone tissue to promote healing or to replace damaged or missing bone, are common in reconstructive surgeries and in the treatment of fractures. Additionally, bones are utilized in the production of medical implants, such as screws, plates, and rods, to provide support and stability during the healing process. In agriculture, bones have several uses as well (Gokhale *et al.,* 2013). They are ground into bone meal, a high-calcium fertilizer that helps replenish nutrients in soils. Bone meal can promote healthy plant growth and development due to its calcium content. It is particularly beneficial for crops that require calcium, such as tomatoes and potatoes. Apart from fertilizer, bones are also processed into gelatin, which is used in animal feed as a source of protein and in certain supplements for livestock (Gokhale *et al.,* 2013). In conclusion, while bones are not consumed as a food product, they play a vital role in various industries. They are used in medicine for procedures like bone grafts and implants, in agriculture as a source of calcium for soil fertilization, and in manufacturing as a component in gelatin and collagen-based products. The utilization of bones as an inedible animal by-product demonstrates the significance of sustainable utilization and resourcefulness across different sectors.
9. **Horns and Hooves:** Horns and hooves are considered inedible animal by-products that have various uses in different industries. They are sourced from different animals, primarily cattle, buffalo, and goats, and serve diverse purposes ranging from industrial applications to traditional practices (Klemm & Lesemann, 2004). Horns and hooves are composed mainly of keratin, a tough and fibrous protein found in the outer layers of animal skin, hair, and nails. They have distinct characteristics that make them suitable for various applications. Horns are hollow, bony structures that protrude from the skull of certain animals, such as cattle, buffalo, and antelope. They are comprised of an inner core called the medulla, surrounded by a layer of living tissue known as the corium, and topped with a hard, keratinized outer layer called the sheath. On the other hand, hooves are hard coverings that protect the ends of the feet of animals, like horses, cattle, and goats. Hooves are composed of keratinized epidermal tissues, and they provide support and protection during locomotion (Klemm & Lesemann, 2004). Horns and hooves are used extensively in various industrial sectors. They are commonly employed in the manufacturing of buttons, combs, hair accessories, decorative items, and handicrafts. The natural variation in color and textures of horns and hooves makes them ideal for creating visually appealing products (Fagbenro & Akinwekomi, 2013). Horns and hooves can also be processed into a nutrient-rich organic fertilizer known as horn meal or hoof meal. These by-products are rich in nitrogen, phosphorus, and other minerals, making them valuable additions to soil amendments for promoting plant growth and soil health (Gokhale *et al.,* 2013). Extracts derived from horns and hooves are used in the pharmaceutical and nutraceutical industries. They are incorporated into supplements, capsules, and ointments due to their potential benefits for hair, skin, and nail health (Gokhale *et al.,* 2013).
10. **Wool or fur:** Wool and fur are both widely known as animal by-products that have been used for various purposes throughout human history. While they share similarities in terms of their origin and utilization, there are also some distinct differences between the two. Wool is derived from the fleece or hair of certain animals, most commonly sheep. It is a natural fiber with a unique structure that sets it apart from synthetic materials. Wool fibers have a crimped and scaly structure, which allows them to interlock and create insulation properties. This natural insulation makes wool suitable for a wide range of applications in clothing, textiles, and various other industries (Simpson and Crawshaw, 2020). Fur is obtained from the pelts of animals, including but not limited to minks, foxes, rabbits, and chinchillas. It has been used for centuries for its warmth, luxury, and aesthetic appeal. Fur consists of a dense layer of soft, fine hairs that help animals regulate their body temperature in cold environments. These hairs possess distinct qualities depending on the animal species (IFF, 2019). Wool is widely used in the production of clothing items such as sweaters, jackets, suits, and socks. Its insulating properties enable it to keep the wearer warm even in damp conditions. The versatility of wool extends to the production of various textiles, including blankets, carpets, upholstery, and drapery. Its durability and stain-resistant qualities make it popular in these applications (IFF, 2019; Simpson and Crawshaw, 2020).
11. **Teeth:** Teeth are highly relevant in the context of animal by-products as they are one of the most common remnants found after an animal's death. However, teeth themselves are considered inedible as a whole due to their hardness and mineralized structure (Hillson, 2005). Teeth are complex structures composed mainly of mineralized tissues, primarily calcium phosphate in the form of hydroxyapatite crystals. The structure of teeth includes several layers, including the enamel, dentin, cementum, and pulp. Enamel covers the outer layer of the tooth, while dentin makes up most of the tooth's bulk. Cementum forms the outer layer of the tooth's root, and the pulp contains connective tissues and blood vessels (Sasaki & Nishikawa, 2019). Teeth serve various functions depending on the animal species but are primarily used for biting, tearing, chewing, and grinding food. Different animals possess teeth adapted to their specific dietary needs. For instance, carnivores typically have sharp and pointed teeth for tearing flesh, while herbivores have flatter teeth for grinding plant matter (Hillson, 2005). While teeth play a crucial role in an animal's physiology, they are generally considered inedible due to their hardness, mineralized structure, and lack of nutritional value. The high mineral content of teeth makes them resistant to degradation and challenging to digest (Newland, 2021). Additionally, the abrasive nature of teeth can pose a risk to the digestive systems of animals if ingested (Sasaki & Nishikawa, 2019). Although not directly edible, teeth have found various uses as by-products. Historically, teeth have been used for ornamental purposes across cultures, often incorporated into jewelry, adornments, tools, and artwork. In some cultures, teeth have cultural and symbolic value, such as the extraction and preservation of human baby teeth or the use of animal teeth in traditional rituals. Teeth have also been utilized in scientific research, particularly in fields like anthropology, paleontology, and forensic science. The study of teeth can provide valuable information about an animal's diet, evolutionary history, and environmental adaptations (Lucas & Luke, 2004).
12. **Manure:** Manure or animal droppings refer to the solid excrement produced by various animals, including livestock, poultry, and other domesticated animals. It is considered an invaluable by-product of animal farming and plays a crucial role in agriculture and soil fertility. While manure is not meant for direct consumption by humans, it serves as a vital organic fertilizer and soil amendment, enhancing crop growth and improving soil health (Kelleher & Leahy, 2017). Manure has been used in agriculture for centuries due to its various benefits. It enriches the soil with essential nutrients, improves soil structure, enhances water-holding capacity, and promotes soil microbial activity. The organic matter in manure helps to increase soil carbon content, reduce erosion, and contribute to long-term sustainable farming practices. Furthermore, manure can be utilized as a renewable energy source through anaerobic digestion, producing biogas and reducing greenhouse gas emissions (Gregorich, 2005). The composition of manure varies depending on the animal species, diet, age, and health. Generally, manure consists of organic matter, nutrients, moisture, microbes, and other substances. The major components of manure include nitrogen (N), phosphorus (P), potassium (K), carbon (C), and micronutrients, along with different levels of organic contaminants, such as antibiotics and heavy metals, which may require proper management and treatment (Mikkelsen, 2003). Manure from animals like cattle, swine, sheep, and goats has its own nutrient composition and characteristics. Incorporating manure as a fertilizer can be economically beneficial for farmers, particularly for small-scale and organic farming systems (Kelleher & Leahy, 2017).
13. **Trimmings:** Trimming refers to the process of removing excess or unwanted parts from an animal's body during butchery or meat processing. These trimmings are considered inedible because they are not commonly consumed as standalone food products (Food Navigator (2019). According to NRA (2020), some common types of trimmings include:

* **Fat Trimmings:** These are the fatty tissues that are trimmed off during meat processing. They are often used to make lard, tallow, or other rendered fats for various industrial applications such as soap, candles, or biodiesel production.
* **Skin Trimmings:** Animal skins are often removed during butchery for meat production or during the leather-making process. These trimmings can be further processed to produce leather goods, such as shoes, bags, or upholstery.
* **Bone Trimmings:** Bones are commonly left over after meat processing. They can be used to produce bone meal, which is used as a fertilizer or animal feed supplement. Bones can also be processed for gelatin production, which has various culinary and industrial applications.

Despite being inedible, animal trimmings play a crucial role in various industries due to their valuable uses. Animal trimmings can vary depending on the type of animal being processed.

1. **Rumen Contents:** Rumen contents refer to the partially digested and fermented food material present in the rumen, which is the first chamber of the stomach in ruminant animals. Ruminants like cows, goats, and sheep have a unique digestive system that allows them to efficiently utilize plant material by fermentation in their rumen. Although rumen contents are not fit for human consumption, they can serve as a valuable source of nutrients and have various uses as an inedible animal by-product (McGavin & Zachary, 2016). Rumen contents are a complex mixture of feed particles, liquids, microorganisms, and fermentation end-products (Russell & Rychlik, 2001). The composition can vary depending on the animal's diet and stage of digestion. Rumen contents can be utilized as a component in animal feed formulations; fertilizers, biogas production, composting and research (Mwenya *et al.,* 2011; Dey & Singh, 2015). It's important to note that the utilization of rumen contents should be carried out following appropriate regulations and guidelines to ensure safety, efficient nutrient utilization, and compliance with local regulations.

**ROLES OF ANIMAL BY-PRODUCTS**

* **Nutrients source:** Animal by-products refer to the parts of an animal that are not intended for human consumption and are derived from the processing of animals for meat, milk, and other products (DiLorenzo *et al.,* 2008). These by-products can include organs, blood, bones, fat, feathers, and other animal tissues. While some consider them as waste, they can actually serve as valuable nutrient sources for both humans, animals and plants. Animal by-products contain a variety of essential nutrients such as proteins, amino acids, vitamins, minerals, and fats (Liaquat *et al.,* 2019). These nutrients are crucial for supporting growth, development, and overall health. Utilizing animal by-products as nutrient sources can contribute to sustainable food production and reduce waste in the animal industry. Properly managed composting of rumen contents can result in the production of nutrient-rich compost, which can be used as a soil amendment, improving soil structure, fertility, and microbial activity (Dey & Singh, 2015). The high nutrient content, including proteins and VFAs, makes it a valuable feed ingredient for non-ruminant animals like poultry and swine. However, the use of rumen contents in animal feed may be subject to regulations and restrictions in different countries. Rumen contents, rich in plant nutrients and microorganisms, can be used as an organic fertilizer. It provides a source of organic matter, nitrogen, phosphorus, and potassium, promoting soil health, microbial activity, and crop growth ((Dey & Singh, 2015).
* **Waste reduction:** Animal by-products are often discussed in waste management and sustainability conversations as they have the potential to be utilized as valuable resources rather than being treated as waste. Animal by-products refer to any part of an animal that is not intended for human consumption, including bones, blood, feathers, organs, and fat. These by-products can be derived from animals used for food production, slaughterhouses, and other animal-related industries (Viera-González *et al.,* 2018) One significant way to reduce waste through animal by-products is by adopting a circular economy approach. In a circular economy, by-products are considered as valuable materials that can be repurposed or recycled, thus minimizing waste generation. Animal by-products can be utilized in various sectors, including agriculture, energy production, manufacturing, and healthcare (Leghari *et al.,* 2016). Moreover, animal by-products can also serve as a valuable source of renewable energy. Technologies like anaerobic digestion and biomass conversion can convert organic waste, including animal by-products, into biogas and biofuels. Biogas can be used for heating, electricity generation, or even as a vehicle fuel. This process not only helps in waste reduction but also reduces greenhouse gas emissions by capturing methane, a potent greenhouse gas, that would otherwise be released into the atmosphere (Leins *et al.,* 2018).
* **Value-added products:** Animal by-products play a significant role as value-added products in various industries. These by-products are derived from animals used for food production, such as meat, poultry, and fish. Instead of being discarded as waste, they are utilized to create valuable products, minimizing waste and maximizing the value obtained from each animal (Simek, 2016). Animal hides and skins are processed to produce leather and fur products. Leather is widely used in the fashion industry for manufacturing shoes, handbags, belts, and apparel. Fur obtained from animals like mink, fox, or chinchilla is used in the production of luxurious coats, hats, and accessories (Olechnowicz, 2019). Gelatin is derived from the connective tissue, hides, and bones of animals. It is commonly used in the food industry for making desserts, candies, marshmallows, and some dairy products. Gelatin also finds applications in pharmaceuticals (capsule shells) and photography (photographic paper and film). Most animal products are used in the pharmaceuticals and agro-processing industries to improve their products (Simek, 2016).
* **Economic benefits:** Animal by-products play a significant role in generating economic benefits across various industries. These by-products are derived from the processing and slaughtering of animals for human consumption, and their utilization extends beyond food production (Badii, 2014). They are integral to several sectors, including agriculture, pharmaceuticals, cosmetics, and energy production. This comprehensive utilization serves to minimize waste, maximize resource efficiency, and enhance overall economic sustainability. Overall, the utilization of animal by-products across different sectors enhances resource efficiency, reduces waste, and contributes to economic growth. It is crucial to maintain appropriate regulatory frameworks and sustainable practices to ensure that these benefits align with environmental and ethical considerations (Silva, 2019).
* **Food safety:** Animal by-products play a significant role in ensuring food safety, particularly in the context of processing and production. These by-products, which include various tissues, organs, and other parts derived from slaughtered animals, have diverse applications in the food industry (USFDA, 2021). While some animal by-products are utilized for human consumption, others are primarily used in animal feed production, pet food manufacturing, or the creation of other useful products. The proper management and utilization of animal by-products contribute to both food safety and waste reduction. Certain animal by-products, like bones, cartilage, and connective tissues, are commonly used in the preparation of stocks, broths, and sauces. These by-products add richness, depth of flavor, and desirable textures to culinary preparations, enhancing the overall taste experience of various dishes. Certain animal by-products, like bones, cartilage, and connective tissues, are commonly used in the preparation of stocks, broths, and sauces. These by-products add richness, depth of flavor, and desirable textures to culinary preparations, enhancing the overall taste experience of various dishes (Echeverry and Sánchez, 2020).

**ULTILIZATION OF ANIMAL BY-PRODUCTS IN FOOD SYSTEM**

* **Animal feed:** Animal by-products are essential in the production of animal feed. By-products like bone meal, blood meal, and fish meal are rich in nutrients such as proteins, minerals, and vitamins, making them valuable components of animal diets. These by-products provide a cost-effective and sustainable source of feed ingredients, reducing the dependence on expensive synthetic alternatives. Their use in animal farming helps in improving animal health, growth rates, and overall productivity, thereby contributing to the profitability of livestock producers (Gaviglio, 2016).
* **Food ingredients:** Animal by-products, such as meat, poultry, and fish, are valuable sources of essential nutrients like proteins, vitamins, and minerals. These by-products are commonly incorporated into processed foods, providing consumers with an array of essential nutrients important for a healthy diet. Certain animal by-products, like bones, cartilage, and connective tissues, are commonly used in the preparation of stocks, broths, and sauces. These by-products add richness, depth of flavor, and desirable textures to culinary preparations, enhancing the overall taste experience of various dishes. Gelatin, a food ingredient derived from animal by-products such as bones, skin, and connective tissues, has numerous applications in the food industry. It is commonly used as a gelling agent, stabilizer, and thickener in various food products such as desserts, confectionery, yogurts, and some meat products (Klemm & Lesemann, 2004)
* **Fertilizer**: Animal by-products, such as manure and slurry, are widely used as organic fertilizers. They are nutrient-rich and enhance soil fertility by replenishing organic matter and essential nutrients. The use of animal-based fertilizers reduces the need for synthetic fertilizers, which can be costly and have negative environmental impacts. By recycling animal by-products into fertilizers, agricultural systems can improve soil health, increase crop yields, and mitigate soil erosion, thereby positively impacting the economy (Mikkelsen, 2003).
* **Biogas:** Animal by-products can also be utilized in the generation of bioenergy. Biomass derived from animal residues, including fats, oils, and other organic materials, can be processed into biogas through anaerobic digestion. Biogas is a renewable energy source that can be used for electricity generation, heat production, and even as a vehicle fuel. The conversion of animal by-products into biogas contributes to the development of sustainable energy systems and reduces reliance on fossil fuels, thereby driving economic growth (Olechnowicz, 2019).
* **Pharmaceuticals**: Animal by-products are valuable sources of various pharmaceutical and medicinal compounds. For example, certain animal organs, tissues, and glands can be used for manufacturing therapeutic products, such as insulin, vaccines, and antivenoms. Collagen, derived from animal skins and bones, is widely used in wound healing and tissue engineering applications. The pharmaceutical industry relies on animal by-products for the development of drugs and treatments, thus contributing to economic advancement (Silva, 2019).

**PROBLEM AND CHALLENGES OF ANIMAL BY-PRODUCTS IN FOOD SYSTEM**

* **Food safety concerns and Contamination risks:** One of the primary challenges is ensuring the safety of animal by-products used in the food system. These by-products may carry pathogens, contaminants, or residues of veterinary drugs that can pose health risks to consumers if not properly handled or processed. Ensuring rigorous inspection, testing, and quality control measures are in place is essential to mitigate these risks (Gornall, 2008). Animal by-products can act as a potential source of zoonotic diseases, which are infectious diseases that can be transmitted between animals and humans. Improper handling, storage, or processing of these by-products can increase the risk of zoonotic disease transmission. Proper biosecurity measures, hygiene practices, and adequate processing techniques are crucial to minimize this risk (Grace *et al.,* 2012).
* **Environmental concerns:** The production and processing of animal by-products can have significant environmental impacts. The disposal of by-product waste can lead to soil and water pollution if not managed properly. Additionally, the production of animal-based ingredients contributes to greenhouse gas emissions and unsustainable resource usage, further exacerbating environmental challenges (Food and Agriculture Organization, 2013).
* **Regulatory challenges:** The utilization of animal by-products can also pose threats to animal health and contribute to the spread of diseases within animal populations. The improper management, disposal, or recycling of by-products can result in the transmission of infectious agents or toxins back to animals. Hence, regulatory frameworks are formulated to ensure that by-products are appropriately sourced, processed, and utilized to prevent disease outbreaks and ensure animal welfare. The USDA regulates the use of animal by-products in the United States through agencies such as the Food Safety and Inspection Service (FSIS) and the Animal and Plant Health Inspection Service (APHIS). Various guidelines and regulations are in place to address issues related to food safety, animal health, and environmental impact resulting from animal by-product utilization (USFDA, 2021).
* **Consumer perception**: Consumer perception of animal by-products in the food system can pose significant challenges for the industry. Animal by-products are derived from the processing of animals for meat or other purposes, and can include parts such as bones, organs, blood, and fat. These by-products are often used in various food products, including processed meats, soups, and pet food, among others. One of the main challenges associated with consumer perception of animal by-products is the negative stigma attached to them. Some consumers may associate animal by-products with unpalatability, unhealthiness, or even unethical practices. This perception can result in a reluctance to consume or purchase products that contain these ingredients (Food and Agriculture Organization, 2013).
* **Ethical concerns**: Animal by-products are often derived from slaughtered animals or result from the processes of meat production. Ethical concerns about animal welfare arise regarding the treatment and slaughter of animals solely for the utilization of their by-products. Advocates argue for more sustainable and ethical alternatives to minimize animal exploitation in the food system (Rothgerber, 2015). The use of animal by-products can also pose challenges in culturally and religiously diverse societies. Some religious or cultural groups may have restrictions on the consumption or use of specific animal-derived ingredients, making it difficult to incorporate these by-products into certain food products, resulting in limited options or controversies within those communities (Carrington, 2016).

**CONCLUSION**

Animal by-products in the food system can pose several challenges and problems. These challenges include waste management, environmental impacts, sustainability concerns, potential health risks, and ethical considerations. However, innovative solutions are being developed to address these issues and ensure the responsible utilization of animal by-products in terms of waste management, biogas production, value-addition, utilization in agro-processing, cosmetics and food industry

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