Biological Forum
an International Journal 17(7): 168-181(2025)
ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Traditional and Modern Approaches to Sausage Casing: A Review

Ancy Thomas[1] and Blossom K.L.[2]*
[1]Ph.D. Scholar, Department of Fish Processing Technology,
Kerala University of Fisheries and Ocean Studies, Kochi (Kerala), India.
[2]Assistant Professor, Department of Fish Processing Technology,
Kerala University of Fisheries and Ocean Studies, Kochi (Kerala), India.

(Corresponding author: Blossom K.L.)*
(Received: 24 April 2025; Revised: 02 June 2025; Accepted: 28 June 2025; Published online: 17 July 2025)
(Published by Research Trend)

ABSTRACT: Sausage is a commonly consumed culinary product composed of meat and fat with other seasonings to produce a stable mass that is heat treated. Typically, a sausage is formed in a casing traditionally made from intestine. In addition to their containment function, they also protect sausage from moisture loss, microbial contamination, and from the external environment, preserving their quality and safety until they are consumed. Due to technological advancements, alternative artificial casings along with modifications to the edible casing characteristics are being explored in order to overcome the limitations associated with the usage of natural casings. The objective of the current review was to describe the development and processing of natural casings as well as alternative casings, and provide an overall framework for the development of new edible casings by incorporating active ingredients in order to increase consumer acceptability and prolong the shelf life of sausage casings.

Keywords: natural casing, collagen, spent cellulose casing, whey protein, chitosan, nisin.

INTRODUCTION

Sausage is a widely consumed product that consists primarily of meat and fat (solid phase) mixed with other spices and ice (liquid phase) to create a stable mass that will undergo a moderate heat treatment (Mercadante *et al*., 2010). Typically, thin tubular films composed of one or more layers used to protect the meat mixture same time gives a tubular structure to the sausage and casings have an impact on the overall quality characteristics of sausages made with it. It is commonly believed that the Sumerians invented sausages in 4000 BC. The evidence was provided in the world's oldest cookbook (Yale Babylonian collection, New Haven, Connecticut, USA) which resembles the modern sausage as it is encapsulated in goat intestine. Incorporation of natural casings has developed over time and lately includes more than just goat intestines. Casings primarily came from the sub-mucosal layer of small intestine as it is composed of collagen it can provide strength to the casing material. The livestock animals such as goat, cattle and pigs are mainly selected as the source for casings. Layer of the intestine is perfect for retaining and moulding the sausage mixture because it is primarily composed of naturally occurring collagen.

The demand for meat packaging around the world has induced the sausage casing industry to expand into two segments which includes edible casings (natural and collagen) and artificial or inedible (cellulose and plastic). Although natural casings are preferred for making sausages, they are always produced and traded globally (Guan *et al*., 2025). When the demands of the rapidly expanding meat business outstripped the supply of natural casings at the start of the 20th century, lead to the wide utilization of artificial casings. Because artificial casings are uniform in size, shape, and strength, flexible, and hygienic, as well as because microbiological contamination is minimal, low-temperature storage is not required, and product spoilage during storage and transportation is not an issue, they have drawn increasing interest for use in the production of sausages. In general, artificial casings are less elastic, porous, and tension-resistant than natural casings, particularly after heating (Rivas *et al.*, 2018; Djordjevic *et al.*, 2015; Feng *et al.*, 2014).

Moreover, in industrial filling operations, collagen casings operate steadily, but during sausage filling, they are more susceptible to breaking because of several stress exhibited on the casing and incorporation of crosslinkers may increase their strength (Long *et al.*, 2018; Wang *et al*., 2020). However, because of their great durability, inedible casings have also been utilized extensively for packaging meat products. Although cellulose casings are known for their high durability and excellent air permeability, they are vulnerable to fungal contact, which may cause the casings to deteriorate and breakage (Sreenath & Jeffries 2011).

Even though intestinal sausage casings continue to be the most important component in guaranteeing the quality of sausage products due to their unique soft and 'cracking bite' and their demand increased regardless of the quick advancement of artificial casing technology. This is a result of both customer preferences that are mostly based on naturalness of casings and the technological adaptability to combine with other ingredients without compromising on its natural qualities (Feng *et al*., 2014; Chen *et al*., 2020; Onishchenko *et al*., 2021). However, the possibility of contagious animal viruses limits the demand for the natural casings (Dibaba, 2019; Jelsma *et al*., 2021). Hence it is given more emphasis on the antimicrobial property enhancement of natural casing as well as the antioxidant properties, barrier properties and mechanical properties (Bolívar-Monsalve *et al*., 2019; Hamann *et al*., 2022; Simonova *et al*., 2024; Yemenicioğlu, 2024).

Nowadays, a lot of research has been done on the use of bio-based films in the preservation of meat products due to the growing demand for sustainability. Synthetic bio-based materials have low permeability, while natural materials often have significant water solubility (Adzaly *et al*., 2015). Therefore, the necessity to create a strong, highly moisture-permeable, and biodegradable sausage casing is rising. Accordingly, this review aims to assist for the production of improved sausage casings by providing insight into the evolution of various technological breakthroughs in the development of sausage casing.

Natural sausage casings. The submucosa, which is primarily the intestinal collagen layer, forms the natural casings. Both the inner mucosal lining and the fat are eliminated. Since small intestine is naturally composed of collagen, they share many qualities when compared with other forms of collagen, most notably the special quality of changeable permeability (Ockerman, 1996). Drying and smoking processes harden and reduce the permeability of natural casings. Relative humidity (RH), cooking, and smoking must all be carefully regulated because heat and moisture tend to weaken and increase the porosity of casings (Rust & Knipe 2014).

One benefit of using animal casings is that they provide the impression of being used from ancient years to maintain good quality characteristics for sausages. Their physical and chemical characteristics make them highly suitable as containers as well as to provide the appropriate shape to the sausage products. Even though it can be act as a packaging material the greatest advantage it holds is that it does not require peeling before consumption. As it possesses high qualities and being natural origin and the limited availability, makes it as the costliest kind of casing (Wu *et al*., 2014).

The characteristic qualities of natural casing may depend on species, age, food pattern, raising conditions and the part of gastrointestinal tract utilized for casing manufacturing. It also depends on the processing and handling and storage conditions. Some of the following parameters has to be considered while assessing the quality of casings.

Length: Depending on the nation where the casing was gathered, the quantity of pieces per bundle frequently changes. The desired length is also influenced by the nation in which the product will be used. Sheep and hog casings are typically 91.4m (299.8ft), beef rounds are packed in 18m (54ft) bundles (Wu *et al*., 2014).

Diameter: The diameter of the casing depends upon by its intended use country and the contents it will contain. However, in order to provide sufficient machinability, modern sausage production equipment demands that the diameter be uniform. Sheep casing with a diameter of 20–24 mm (0.78–0.95 inches) is most in demand. The larger sheep casings can occasionally be replaced with small-diameter hog casings. Over 35mm (1.38 inches) hog casings are in the highest demand. Typically, beef rounds measure 33 mm (3.09 inches) (Wu *et al*., 2014).

Strength: Casings must be able to sustain the pressures placed on them during the filling, stuffing, processing, cooking and subsequent storage conditions. Intestinal submucosa possesses the necessary strength to accomplish all such processing and storage conditions a casing may undergo (Wu *et al*., 2014).

Cleanliness: Casings should be sound and free of pinholes, as well as free of off odours, blood stains, fat particles, parasites, nodules, and ulcers which can in turn affect the storage stability of casings and overall acceptability and shelf life of the sausages made there by Wu *et al*. (2014).

Curing: Casings are rarely dried; they are typically cleaned and then salted as some of the countries prefer salted products. Fresh, high-quality salts with tiny particle sizes should be used for the curing process as it should not cause damage to casing. The casings might be occasionally frozen also as per the requirements (Wu *et al*., 2014).

Type of natural casings. Since ancient times, natural sausage casings have been used to give different kinds of sausages their natural flavour and texture. Natural casings can be divided into three categories: hog, sheep, and beef. All three are made from the intestines of the appropriate animal (Ockerman, 1996; Wu *et al*., 2014; Knipe, 2024). Table 1 indicates the different kinds of natural casings.

Hog casings. For traditional sausages, hog casings are the most prevalent option because of their superior "snap" and adaptability. These casings are manufactured from pig intestines, can be used for a variety of sausages, including bratwursts, smoked polish sausages, and kielbasa. They typically hold sausages that range in diameter between 1.5 and 2.5 inches (Knipe, 2024).

Sheep casings. In spite of their small diameter and soft texture, natural casings which are manufactured from the sheep small intestine are ideal for thin, delicate sausages. These casings are often used for sausages, including frankfurters and breakfast sausages. In addition to their gastronomic advantages, sheep casings are valued for their ease of handling when producing sausage (Knipe, 2024).

Beef casings. Beef casings were derived from the portion of large intestine. These natural casings are the most resilient and are commonly utilized for huge, hearty sausages such as cotto salami, mortadella, liverwurst, and salami. Because of their hardness and thickness, beef casings are especially well-suited for fermented and long-aged sausages that need an extensive amount of moisture and protection as they cure (Wu *et al*., 2014).

Table 1: Classification of Natural Casings.

Natural casing	Location	Appearance
BEEF		
Round	Small intestine	Easy to handle, Reduced damage, Ring like.
Middles	Large intestine	High-priced, Evenness
Bladder	Urinary bladder	Oval shape
HOG		
Round	Small intestine	Edible
Bung	Cecum	Sewed
Middles	Large intestine	Curly appearance
SHEEP		
Round	Small intestine	Tender

Source: Ockerman (1996). Meat Chemistry. Columbus, OH: The Ohio State University.

Processing of natural casing from the animal intestine. In order to prevent bacterial spoiling, which happens very fast, it is advised to remove fat and mesentery. The intestine should be processed for sausage casing production as soon as it can be after slaughter, preferably while the tissue is still warm to maintain the quality of the casing. The subsequent step involves "sliming," which involves using specialized instruments to gently scrape or remove the exterior fat and inner mucosa layers from the intestines. This process exposes the submucosa layer. Submucosal layer that remains after processing is composed of connective tissue, which is edible, strong and elastic.

The portion of small-intestine of the pig, sheep and goat are frequently employed for developing small breakfast sausage casing. This type of casing is considered edible and is usually consumed along with sausages because it is composed of submucosal layer of intestine. While processing the small intestines of horses and bovine, the muscular layer typically stays in place, unlike in sheep and pigs. This type of casing usually comprises of both layers since the large intestine's muscle and submucosa layers are closely linked. Because they are tough and challenging to chew, these casings are not eaten even though they are considered edible. This impacts the mechanical resistance and permeability of the casing. Different components of gastrointestinal system that can serve as natural casings are handled differently and have thicker, stronger walls. As a result, they are regarded as inedible and must be peeled off from the final product before consumption. Processing of the digestive tracts was followed by measurement, washing using salt solution drying the casing, dry salting, and storage of the natural casing (Heinz & Hautzinger 2007). After the sliming process, the casings are separated according to size and quality. The diameter of hog and sheep casings varies from 30 mm to around 44 mm and 16 mm to 28 mm, respectively. The sausage casings are usually graded after sorting to produce consistent product combinations. Fig. 1 shows the procedures for processing natural casings from the animal intestine. The casings are processed further, such as by salting, curing, or smoking, before being used to make sausages. In order to preserve them and extend their shelf life, it is soaked in salt solution. A combination of salt and other preservatives can be used for curing, and smoking gives the casings a unique flavour and aroma (Koolmees *et al*., 2004).

Typically, natural casings are sold as salted and dried. It is necessary to rinse the salt with cold water before stuffing. Following that, the dry-salted casings must soak in water for a few hours (in warm water for three to five hours or in cold water for overnight). In addition to removing any leftover salt, immersion in water improves the elastic properties of the sausage casings.

Natural casings can also be stored in saturated saline solution. After soaking for a few minutes to an hour and thoroughly washing, these casings are ready for use. Natural casings need to be kept in a refrigerator if they are kept this manner (Bradley, 2002). Sausage casing has a dual purpose, starting during the stuffing process and continuing at the place of serving for the customer. Sausage casing has a direct and indirect impact on the structural, and organoleptic changes that occur in the sausages during production process of sausages. Selecting the right casing is a crucial step in producing sausages with predetermined qualities (Djordjevic *et al*., 2015).

Separate intestine of the slaughtered animal

↓

Running of the separated intestine (remove the mesentery fat from the intestine)

↓

Stripping of the animal intestine (remove the intestinal contents inside the intestine)

↓

Washing of the stripped intestine in cold water (10ºC)

↓

Mechanical stripping or hand stripping to remove the remaining intestinal contents

↓

Scrapping of the intestinal layer to remove fat.

↓

Mechanical slimming for removal of tissue layers (in revolving drums with hot water (46ºC) or hand slimming of the intestine.

↓

Stripping or hand removal of appropriate tissue layers.

↓

Soak over-night in chilled condition with 15–20% saturated salt solution.

↓

Grading of the casing as per size, quality and the species.

↓

Curing of sausage casing for 1 week with salt.

↓

Remove excess free salt

↓

Packing and storage (once adding 40% fine salt)

↓

Flushing of the sausage casing prior to use.

Source: Ockerman (1996). Meat Chemistry. Columbus, OH: The Ohio State University.

Fig. 1. Process flow chart of sausage casings developed from animal intestine.

Natural sausage casing from pig intestine. It is possible to transform the pig's stomach, small intestine, bungs, large intestines or other intestinal segments into sausage casings. The small intestines are the most significant among them. The process employed is similar to the production of sheep casings. The epithelium layer, the muscle layers, the serosa, and typically the basement membrane and muscularis mucosae are removed when small runners are pushed successively between rollers; this leaves just the collagen-rich submucosa. Pig intestinal submucosa layer is less brittle and has a network of collagen and elastic fibres than beef casing, that possesses both the muscularis and mucosa layers. Slime can be collected during processing of casings and used by the pharmaceutical sector to develop anticoagulants. Small-diameter, "A" quality casings are used to make emulsion-type sausages. The "B" quality casings should be strong and have other physical attributes, even though they might contain a few tiny holes. They are utilized mainly for freshly made pig sausages (Heinz & Hautzinger 2007; Savic, 2012; Suurs & Barbut 2020).

Handling and storage of natural casings. When you receive or buy natural sausage casings, verify their freshness to maintain the quality of sausage produced. Fresh quality casings will be transparent, firm, and have a faintly salty odour. Sliminess or an unpleasant, decaying smell are signs indicates that the casings were deteriorated. In order to preserve the integrity of the natural sausage casing, handlers should be more conscious of the potential for cross-contamination during the manufacturing process. As a result, employees should maintain personal hygiene and maintain the processing area clean. Before preparing the sausages, natural casings should rinse in chill water to eliminate excess salt and contaminants adhered to the surface. After rinsing in chill water soak the casing for 15 to 30 minutes in hot water (40°C) to regain the elasticity. Prefer to store the natural sausage casings always in cool, temperature-controlled environment (5°C to 10°C). Most households, storing them in the refrigerator is the most convenient. Casings can last up to a year if stored properly; however, a temperature increase of 10°C to 20°C may bring down the shelf life to six months. Rather than storing them in a closed container keep them immersed in the initial salt solution. The salt solution preserves the natural casings pliable and moist by preventing them from drying out and breaking (Wu *et al*., 2014; Meatmagnate.com, 2025).

Quality characteristics of casings. Mechanical strength, gas and water permeability, adhesion, elasticity, chemical inertness, fat impermeability, homogeneity in diameter, resilience to temperature changes etc. are examples of fundamental casing properties.

However, mechanical strength of casing and permeability of the casing material to gases and water are the most crucial casing properties that influence not only the sausage's final weight and shape but also its integrity of the structure, which is necessary to maintain during entire processing stages of sausage production to maintain the final quality of the product (Savic, 2012). The degree of interaction that occurs between the sausage meat mix and the processing and storage environment determines the degree of casing permeability, which serves as a barrier between sausages and the external environment to maintain the quality characteristics of the final product. Additionally, the intended processing methods that result in the development of specific structural, compositional, and sensory features typical for the product have an impact on casing permeability. Water activity (Aw), pH, cleavage of fresh sausages, hydrolysis of fat, water loss, oxidation of fat, and sensory parameters are influenced by the degree of casing permeability to light, gas, and water vapour transmission. Dimensions, shape, volumetric variations, texture, and final product look are affected by the mechanical characteristics of the casing, including its tensile strength, elasticity, temperature conditions and transparency (Savic, 2012).

Fermented Natural Sausage Casings. Both natural and artificial casings can be used for making fermented sausages, but they need to be hard, elastic, and retractable (after the stuffing contracts during drying), as well as permeable to gases, water vapour, and smoke. Adherence to stuffing is crucial for casings used to produce fermented sausages, both throughout the stuffing and following drying process at which stuffing volume decreases (Heinz & Hautzinger 2007).

Natural casings are elastic, firmly adhere to the sausage stuffing, are permeable to gases, water vapour and smoke, are strong enough to withstand pressure and can be clipped or bound at the end of the sausage. Due to the irregular casing diameter, this form of casing is usually employed in the processing of conventional fermented sausages (Sremska sausage, Slavonskikulen, Banijska sausages, etc. (Djordjevic *et al*., 2015). Serio *et al*. (2020) observed that the quality of fermented sausages was significantly impacted by the type of casing used, which may have an impact on the biogenic amine formation and production of certain volatile flavour compounds by altering proteolysis during the ripening process.

Advantages of Natural Sausage Casings. Natural sausage casings are among the top choices for sausage manufacturers. The superior taste, softness, and texture of natural casings are well known. The use of natural casings to enhance the sausage's taste is among its most evident advantages. The casings allow the flavours of smoke to penetrate through and infuse the meat, giving it a greater, more intense flavour during the processing of smoke cured sausage manufacturing. This is especially important for traditional sausage recipes. where a suitable flavour profile depends on the casing's flavour which is essential for achieving the overall organoleptic qualities. Another important factor to take into account when choosing casings for making sausages is texture. As the natural sausage casings are with high collagen content it offers a special blend of pliability, thinness, and softness that synthetic casings are unable to replicate.

Natural casings provide a smooth surface and a constant, tightly fit around the sausage meat because of the collagen that helps them expand when filled. This creates the ideal "snap" as the sausage is chewed, resulting in a satisfying and authentic chewing sensation. Natural sausage casings are not only aesthetically appealing, but they also provide a superior taste and texture. An appealing display is produced by simply gathering and twisting the sausage casings, which come in various sizes, to create sausages in various shapes and styles. Furthermore, the appealing golden-brown colour of sausages made with natural casings enhances both its visual appeal and appetite-stimulating characteristics (Ockerman, 1996; Rust & Knipe 2014; Wu *et al*., 2014; Meatmagnate.com, 2025).

Limitations of Natural Casing. Even though the natural casings are considered to be one of the most preferred casings for the sausage manufacturing, as are developed from animal intestines they may differ in thickness and width, which makes it challenging to get an identical appearance among sausages. The variation in casing thickness and width could contribute to the cooking process, causing the sausages to be overcooked or undercooked, which could affect their quality. Natural casings may be more challenging to deal with throughout the sausage production process. To prevent tearing or spoiling, they need to be handled and stored with careful handling. Natural casing preparation can be time-consuming and labour-intensive, particularly for sausage producers with little expertise or resources. Finally, natural casings may affect persons who have dietary restrictions. For instance, people who eat halal or kosher food could insist on sausages made with natural casings from animals that have been killed and prepared in conformity with their specifications. Furthermore, some consumers may be hesitant to consume animal byproducts and instead prefer synthetic casings because of ethical or dietary concerns. Additionally, of the above considerations the price of natural casing also limits the adoption of natural casing by sausage producers (Ockerman, 1996; Wu *et al*., 2014; Knipe, 2024; Meatmagnate.com, 2025).

Artificial Casings. Synthetic sausage casings are man-made replacements to natural casings derived from animal intestines. These casings, developed to meet the growing demand for sausages and salami, are available in a variety of materials and have several advantages over the natural ones. There are several synthetic varieties available, including plastic, cellulose, and collagen. Due to market demand in the early 20th century, these are relatively recent entrants to the artificial field. In the past, only natural casings, mostly made of pork were used to package sausages. Nowadays, products are flavoured and protected by casings in addition to being contained and shaped. A comparison of artificial and natural casings is given in Table 2.

Customers have a constant need to preserve traditional quality characteristics of sausages. It is far simpler for manufacturing companies to employ artificial casings rather than natural ones, particularly in large production facilities. Although preparation is typically quick and easy, artificial casings have an extended shelf-life and don't need to be stored at low temperatures. They also allow for the maintenance of production standardization (the width and shape of the sausages). Because the product is tougher and cleaner, there are fewer tearing losses than with natural casings. The company appears to be choosing to incorporate artificial casings rather than natural ones due to the rising cost of natural casings (Zając *et al*., 2021). Sausage casings are classified into different categories based on origin is given in Table 3.

Collagen casings are one of the most often used synthetic casings. These casings, made from the collagen found in animal hide and bones, are distinguished by their consistent size, strength, and ease of manufacturing. They are preferred for their steady performance. Cellulose casings are another popular form of synthetic casing. These casings, made from the cellulose found in plant cell walls, are tough and long-lasting, making them ideal for high-speed production. Often used for skinless sausages such as hot dogs, cellulose casings are removed after cooking, resulting in a smooth and tender product. The third alternative is fibrous casings, which are made of paper pulp and coated with viscose layer. Fibrous casings, which are highly resistant to breaking and hold their shape well, are commonly used for dry or semi-dry sausages and other cured meats. These casings are not edible and must be peeled before consumption (Zając *et al*., 2021).

Finally, plastic casings are produced from a variety of synthetic materials, including polyamide and polyvinyl chloride. These casings have outstanding barrier qualities, making them suited for a variety of applications, including cooked, smoked, and dried items. They are also used to package other food products, which require airtight packaging conditions (Ockerman, 1996).

Table 2: Comparison of different type of casing.

	Natural casing	**Collagen casing**	**Cellulose casing**
Cost of production	Expensive	Reasonably priced	Low-cost
Temperature of storage	Low temperature	Low temperature	Ambient temperature
Tenderness	Tender	Tougher	Skinned
Breakage on processing	Breakage	Reduced damage	Highest resilience
Soaking & flushing	Before use	Not required	Occasional soaking
Smoke penetration	High penetration	Low penetration	Negligible
Machinability	Poor	Low	High
Printability	Unprintable	Poor	Best

Source: Ockerman (1996). Meat Chemistry. Columbus, OH: The Ohio State University.

History of Artificial Casings. In the early days of sausage manufacture, natural casings were primarily produced from the submucosa layer of animal intestines, made up of naturally occurring collagen. In the 1960s, synthetic polymer casings or plastic casings were introduced, beginning with the production of polyvinylidene chloride (PVDC) casings. This development was a historical moment in sausage manufacturing since it provided a cost-effective alternative to natural casings with more consistent size and shape. In the 1970s and 1980s, the manufacture of synthetic casings advanced further with the introduction of monolayer nylon casings, which provided greater mechanical strength and flexibility than previous PVDC casing types (Ockerman, 1996; Wu *et al*., 2014; Knipe, 2024; Meatmagnate.com, 2025).

Table 3: Classification of casings according to origin.

Source	Type of casing	References
Animal origin	Non-edible collagen casings, Edible collagen casings	(Ockerman, 1996; Knipe, 2024; Koolmees *et al*., 2004; Wang *et al*., 2020; Zając *et al*., 2021; Yan *et al*., 2022)
Plant origin (synthesized)	Cellulose casings Fibrous cellulose casings	(Ockerman, 1996; Sanders *et al*., 2000)
Synthetic	PVDC casings Polyester casings Polyamide (nylon) casings Multilayer casings (nylon + polyolefin + other polymers)	(Ockerman, 1996; Rust & Knipe 2014; Wu *et al*., 2014; Knipe, 2024)
Modified casings	Whey protein casings, chitosan casings, nisin impregnated collagen casing	(Batpho *et al*., 2017; Simelane & Ustunol 2005; Mubururu *et al*., 2014; Adzaly *et al*., 2016)

Collagen Casings. Collagen, a gelatinous material present in all mammals' connective tissue, bones, and cartilage, is used to make this type of casing. Collagen is extracted from the animals and reconstructed to sausage casing (Hood, 1987). Compared to the natural casings, regenerated collagen casings have various kinds of benefits, such as greater consistency in width and thickness, strength, and versatility under different manufacturing circumstances. Additionally, they exhibit higher consistency in net product weight and cleaner, more hygienic circumstances when compared to natural casings (Kutas, 1987). The small casings are commonly utilized for fresh pork sausage and are edible. Aldehydes are applied to large collagen casings in order to cross-link and strengthen the collagen. This kind of casing must be pulled off prior to consumption (Ockerman, 1996). The consistency of the produced collagen casing makes it easier to pack consistently, which increases portion control. Moreover, regenerated casings can be kept for longer than natural casings and soaking before stuffing is not required (Savic, 2012). Animal skin is typically used to extract collagen casing, which is then treated through a number of stages include acid swelling, neutralization, plasticization, and hot air drying. From the extraction of the raw materials to the recombination of the films, all these processes affect the structure and arrangement of collagen. Modifications to the fibre microstructure, as a result of casing production processes of the collagen casing may further enhance the qualities of the film (Liu *et al*., 2023). The mechanical characteristics of the casing are enhanced by the employment of cross-linking agents. To reinforce the material, linkages can be formed using glutaraldehyde, 1-ethyl-3-(3-dimethyl aminopropyl) carbodiimide, acylazide, diimidoesters-dimethyl suberimidate, and 3,30-dithiobispropionimidate or procyanidin (Charulatha & Rajaram 2023; Angele *et al*., 2004).

Development of collagen casing. The middle corium layer of cattle hides, which is produced by mechanically removing the flesh and epidermal layers, is where the collagen is found. After pretreatment, the collagen-rich corium layer is referred to as the "limed collagen split." The procedure creates a pure, food-grade collagen material by thoroughly washing, decalcifying, and buffering the limed collagen split. This is further reduced to a fibrous slurry in order to produce a homogenous collagen gel and combined with vegetable cellulose fibre and food-grade acid. The final product's strength and stability are greatly enhanced by the crisscross structure created by the arrangement of the collagen fibres (Wu *et al*., 2014).

The "dry and wet" processes are the names given to the two manufacturing techniques that are employed. The wet method extrudes using a gel or low solid content, While the dry method has a high solid content. On hides, the hair is removed from the follicle by washing, de-fleshing, and treating them with a weak acid or alkali. A machine then separates collagenous corium layer and leather layer or the grain from the hide. Following that, the corium layer is neutralized, cleaned, and coarsely ground. It next goes through an ultrafine, high-speed chopper to produce a shammy.

After acidifying the shammy, which contains 5% collagen (low solids), it absorbs water, and the pasty gel is filtered, homogenized, and extruded. To align the collagen fibres and fibrils, the extruder passes through an annular die. After being neutralized and cleaned with water, the extruded tube is chemically treated to increase its pliability (glycerin) and strength (sugar). Following a drying process at a specific humidity and temperature conditions. In order to fit most stuffing horns, the casings have been cut and shirred. The casings are then put into boxes wherein moisture content has been measured. After maintaining a moisture content of 13–18%, the boxes are sealed. The collagen casings can be retained for a long time as long as the storage conditions are favourable. Apart from large diameter casings, which can be soaked in water between 80 and 90ºF before to use, the casings are ready to use as soon as they have been taken from the package. The ideal cooking temperature for the sausages in these casings is between 40 and 45 percent relative humidity. Cooking it below this relative humidity could result into splitting of casing, and it will hydrolyze and spill the emulsion if it is cooked above (Ockerman, 1996).

He *et al*. (2011) examined the use of procyanidin, a naturally occurring plant polyphenol, to modify collagen in acidic environments. Fruits and vegetables contain procyanidin, a type of condensed plant polyphenol. Procyanidin and other natural plant polyphenols have long been used for curing the collagen in animal hides in acidic environments, giving the resulting leather greater stability against heat and putrefaction. In this study, a procyanidin solution of 0.1–0.4 mg/ml was added to aqueous collagen solution of 5 mg/ml to create collagen sausage casing. The solution was cast onto a 15 cm diameter polytetrafluoroethylene (PTFE) plate for producing the collagen/procyanidin films, which had a thickness of around 0.03 mm. The plates were then allowed to dry for approximately a week at ambient temperature. The findings revealed that the primary mechanism by which procyanidin stabilizes collagen is the hydrogen bond interaction. Less procyanidin is needed to increase the hydrophobicity of the collagen/procyanidin films when compared to pure collagen. The procyanidin treatment causes collagen microfibrils to aggregate rather than breaking down collagen's triple helix structure. However, the film water vapour permeability is inversely proportional to the procyanidin content because procyanidin and collagen cross-link to generate a denser network structure. It was discovered that the water vapour permeability of the collagen procyanidin film decreased when procyanidin levels increase. Additionally, the procyanidin-modified collagen shows enhanced heat stability. Thus, the study opened up possibilities for enhancing the casing properties with procyanidin modified collagen films.

Harper *et al.* (2012) investigated variations in strength between five distinct sausage casings. The manufacturer labelled them as a "tender breakfast" casing (MC1), a "breakfast sausage" casing (MC2), a "European wiener" casing (MC3), and a general casing for "processed sausage" (MC4). A 23 mm diameter natural sheep (SH) casing was also assessed in order to compare these commercially available manufactured collagen casings. The burst and puncture tests indicated the force the casings could tolerate during stuffing, While, shear tests evaluated the amount of force and effort required to "bite" into sausages that were packaged in specific casings. The impact of the casings' structure on their mechanical properties was measured using light microscopy images. The results showed that there were notable differences in flexibility as well as strength for sausages in five different casings. For each of the five types of casings, it took more to shear raw sausages than it needed to shear cooked sausages. Regardless of the style of casing, shearing uncooked sausages width wise required greater force than shearing them lengthwise. The cooked sausage products did not exhibit this phenomenon to the same degree. The "processed sausage" casing most closely resembled the natural sheep casing's light transmission. Therefore, the study's outcomes imply that synthetic collagen casings with mechanical qualities equivalent to those of a natural sheep casing are commercially available in the market.

Wang *et al.* (2020) examined how eight distinct oils affected the characteristics of collagen sausage casing films both before and after the casing aged. Triglycerides with short, medium, and long chains (SCT, MCT, and LCT), vegetable oils such as corn oil (CO) and soybean oil (SBO), and food-grade white oil (based on the increased molecular weight and viscosity) were used as lubricants to treat the collagen casings and enhance their qualities. Oiling and ageing films led to significant decreases in water absorption and shrinkage when compared to aged films without oiling. Furthermore, the aged and oiled films possessed lower water wettability and average friction coefficients. It was found that 0.25 mL/m was the ideal oil concentration for coating collagen casing films. There was a negative correlation between viscosity and the oil contact angles on the films. Poor spreading on collagen casing films was indicated by the SCT sample's highest contact angles. Long-chain triglycerides (LCT) and soybean oil (SBO) distributed the best when applied to collagen casing films. The films coated with soybean oil (SBO) showed the highest longitudinal tensile strength (TS) and Young's modulus (YM) values after ageing, increasing by 38% in TS and 26% in YM.

An investigation comparing the characterization of edible collagen sausage casings with the natural ovine casing was carried out by Zając *et al*. (2021). The study was performed using natural ovine casing with three distinct collagen casings: A: made without a cross-linking agent and intended for fresh sausages; B: made with 0.15% glyoxal (w/w) of the amount of collagen mass and suitable for scalded sausages; and C: made with 0.20% glyoxal (w/w) of the amount of collagen mass and suitable for dry sausages. As per the study's findings, the three commercially available collagen sausage casings and natural ovine casings differ significantly. Every artificial casing was weaker and less elastic than the natural one, which could lead to handling issues when making sausages. The shear force value was the only indicator of the variations between sausages made with the tested casings, and it was lowest for sausage in casing A. Casing A exhibited a lower shrinking temperature, higher wet elongation at break values, a* and b* colour characteristics, and higher swelling capacity and water solubility. The remaining characteristics were similar to those of other collagen casings. In comparison to the collagen casings, the ovine casing was redder, less yellow, and contained more water; it also exhibited higher swelling, solubility, and water vapour permeability.

A study conducted by Yan *et al.* (2022) examined how the quality attributes of fermented sausage were affected by collagen casings (CC) and natural casings (pig casings, PC). The Study findings indicated that collagen casings improved the fermented sausage's textural qualities, lowered its pH, and decreased the amount of biogenic amines it contained. Collagen casing has no significant impact for the development of volatile flavour compounds or microbiological growth. The fermentation process enables lactic acid bacteria to produce acid, which lowers the pH of fermented sausage. At every step following fermentation, the CC groups pH value was lower than the PC groups. Furthermore, it was noticed that fermented sausage manufactured using collagen casings had lower colour values than sausage prepared with pig casings. Collagen casings are made of extracted collagen and other materials as compared with natural casings results in reduced transparency, greater thickness, decreased flexibility, lower air permeability, and a reduced capacity to bind with oxygen.

Cellulose casings. Produced cellulose casing is often used for high volume products like salami, bologna, and sausages of the frankfurter varieties. These strong casings are suitable for use on highly automated machinery. Portion control is simple due to their consistency and controllable degree of stretching. Cellulose casings must be peeled off before ingestion since they are indigestible. An automated high-speed peeler at the plant removes the casing from tiny diameter items, such as hot dogs. The customer typically peels off the casing of higher diameter items, such as salami. To increase adherence to the product, a protein coating is applied to some cellulose-type casings. Non-fibrous, fibrous, and plastic-coated cellulose casings are the three categories of cellulose casings. Hot dogs, skinless wieners and smoked sausages are mostly produced using non-fibrous cellulose casings with small diameter which are made to provide the highest degree of homogeneity in diameter. In order to create fibrous casings, it is reinforced with regenerated cellulose fibres which is composed of a cellulose xanthate derivative. Fibrous casings come in three main varieties: easy peel, standard and moisture-proof (PVDC coated). Easy peel and PVDC coated fibre casings are used for cooked cold cut sausages and other large diameter products (Harper, 2013; Barbut, 2015).

Development of Cellulose casing. Cellulose sausage casings are developed by using inters which are mechanically cleaned, cooked in diluted alkali to eliminate soluble components from the linters and then washed to eliminate salt. The fibres swell once caustic soda is mixed with 98% pure alpha-cellulose [from wood pulp or cotton linters]. After squeezing the fibres and removing any extra caustic, the sheets are shred into small particles called alkali cellulose crumbs which is white in colour. The crumb is then mixed with carbon disulphide in the rotating drum results in a yellow-orange product (cellulose xanthate) is subsequently homogenized in high-speed blenders and vacuum-stored to maturation. After passing through several filters, the solution is extruded into a casing and placed in an acid bath for coagulation. The casing is rinsed and purified after extruding the gelatin-like cellulose film (80% moisture content) and separated into a cylindrical shape. After washing, the inflated casing is dried to remove 90% of the water. The casing is then coiled onto wheels for ageing. The casing is unwound and mounted on a shirring machine soon after ageing. To fit over a filling horn, the machine compresses and pleats the casing into straight strands (Ockerman, 1996).

Cellulose casings have higher productivity and are less expensive than collagen casings. Cellulose is a moisture-sensitive membrane that allows water-soluble materials like smoke to flow to the sausage's surface. Small diameter cellulose casings are typically used to make smoked and cooked products, which are then removed before marketing it. Fibrous cellulose casings are smoke-permeable, easy to remove after cooking and cooling and with extended shelf life. Cellulose casings must be removed prior to consumption. The main disadvantage of using cellulose casings is spent casing.

Excellent size uniformity, printability, clipping, string-tying, cutting, and shirring potential, permeability to moisture and smoke, strength and mechanical resistance and non-refrigerated storage, high durability are some of the advantages attributed to fibrous casings (Wu *et al*., 2014).

Henderson and Dietrich (1926) conducted a study to find the need for the cellulose casing. A suitable synthetic casing has not developed till now which could satisfactorily replace animal intestines, despite the fact that, even with the greatest care, food handlers of natural casings were unable to produce a truly clean or uniformly calibrated natural sausage casing, because of small holes, long lengths of intestines, deterioration or other defects pave a way to look forward for an alternate casing. However, an acceptable casing has been developed as a result of the work carried out by the Erwin O. Freund Industrial Fellowships. Study conducted with several materials includes gelatin, casein polymers, carbohydrates (e.g. agar, algin), cellulose and starches followed by thorough analysis of these compounds, a specific cellulose type was selected for the development of casing. The high-quality variety of purified cotton linters were found to be the most appropriate material for the casing preparation.

The viscose process was the most effective way to fabricate cellulose into tubular form. They invented machinery to produce thin-walled, seamless cellulose tubes suited for sausage casings.

Pearson *et al.* (1996) also documented the fabrication of cellulose casings made from cotton bags, processed cotton linters, and wood pulp. Fresh pig sausage, smoked sausage and some specialist foods like Taylor rolls have a limited but well-defined market for cotton bags made from different diameters of cotton thread.

He also stated that decreased cotton production and the usage of more cost-effective materials, such as wood pulp, have grown common over the years. According to him, the advantages of these sausage casing tubes include homogeneity, strength, cleanliness, and convenient handling. They can be coloured or printed to give visually appealing look.

Irklei (1990) investigated concerns linked with the production of cellulose casings and discussed improvements and alterations in present technological operations of cellulose casings with an emphasis on to eco-friendly technology. According to his findings the basic challenge is to produce high-quality spinning solutions while minimizing the use of sodium hydroxide and carbon disulphide, which are both hazardous. Efforts to minimize carbon disulphide consumption are crucial for the viability of the viscose process of manufacturing cellulose casings. The study also reported that, urea added during xanthation produces high-quality cellulose xanthates with reduced consumption of carbon disulphide.

The author also mentioned certain process improvements to improve quality characteristics. To increase the adhesion of coating formulations and cellulose films, their surfaces are treated using adhesives, such as melamine-formaldehyde (MF) resin.

Along with improving adhesive strength, the coated films' heat seal strength increases, paving the way for high-speed processing. Furthermore, lacquers based on nitrocellulose, vinyl chloride copolymers (VCVD-40), or polyvinyl chloride are applied to the indicated material to decrease the vapour permeability of films and casings, stabilize their shape and dimensions under a range of temperature and humidity conditions, and enable heat sealing on high-speed automated packaging machines.

As an anti-listeria barrier for frankfurters, a study was conducted to investigate the bio preservation effect of nisin coating on cellulose casing. Frankfurters were produced with and without 1.4% potassium lactate and 0.1% sodium diacetate, then filled and processed in cellulose sausage casings coated with nisin and cellulose casing without nisin coating. For both casing 100 pounds of frankfurters were made and in cellulose casings coated with nisin (NaCl, yeast extract, and 2.5% nisin) at a concentration of 50,000 IU of nisin per square inch of surface area is applied as a coating to the cellulose casing. The results showed that after 90 days of storage, *L. monocytogenes* levels reduced by 1.15 log CFU in packages containing frankfurters made with sodium diacetate and potassium lactate which is filled and processed with nisin-coated cellulose casings (Luchansky & Call 2004).

Spent cellulose casings (SC) are a byproduct of the frankfurter/sausage processing industries. Landfills and land application are the two conventional disposal methods, nowadays they are getting more costly or becoming expensive or impractical. Utilizing the spent cellulose casing as animal feed would be a suitable way to dispose it without altering the environment. In light of the mentioned situation, Sanders *et al*. (2000) conducted an experiment to determine the digestibility of spent casings using four different cellulase enzymes. One of which was ruminal bacterial cellulase, as well as three different commercial cellulase sources. Ruminal bacteria's cellulases were unable to hydrolyze SC much, with both untreated and treated SC degrading by less than 10%. The cellulase C2 (commercial cellulase-fungal origin in solid form) clearly was capable of degrading SC and degradation rates increased with increasing enzyme concentration and incubation time. C4 cellulase (commercial -liquid form) efficiently converted cellulosic substrates into glucose (95% by 6 h and 98% by 12 h). Particle size and SC pigmentation had minimal effect on degradation, although C3 cellulase (commercial-liquid form) activity peaked at pH 4.0 and 56±60ºC. Therefore, it came to light that the spent cellulose casings might be utilized as an alternative source of animal feed; however, a bioprocessing method is needed to increase the glucose content. As a result, this method would remove expenses and the liabilities associated with the disposal while reinvesting the resources into the food producing systems.

A comparable approach to the problem mentioned above was also developed by Sreenath & Koegel (2008). This study describes the use of cellulolytic fungi, lactobacillus, and yeasts to bio convert spent cellulose casings (SCC) into lactic acid, enzymes and ethanol. Trichoderma reesei RUT C-30 was grown on solid substrates (SSC) and blends, yielding a maximum of 152 filter paper cellulase (FPase) activity and roughly 100 carboxymethylcellulase activity (CMCase)/g dry weight substrate. When the SSC was directly combined with 10% fresh SCC, it generated an enzyme-rich casing with 50 FPase. Lactobacillus plantarum sp. 14431 produced over 70g/l of lactic acid, and Kluveromyces marxianus IMB-3 produced 30g/l of ethanol under both saccharification and fermentation conditions (SSF). Apart from generating co-products and value-added items, this process of bioconversion could potentially reduce disposal expenses for sausage manufacturers (compared to traditional landfills).

Gabiatti *et al*. (2020) conducted an investigation to incorporate the components extracted from the spent casings into the beef emulsion modelling systems. The aim of this study was to ascertain whether the RSC component could entirely or partially substitute the binder components of beef emulsion. The test component (residual sausage casing [RSC]) was extracted from the cellulose casings after the sausages were thermally processed. Therefore, five different concentrations of the RSC constituent (0% RSC, 25% RSC, 50% RSC, 75% RSC, and 100% RSC) were used to create the beef emulsion model systems. Emulsion samples were examined for colour, texture profile analysis, cooking loss, emulsion stability and proximate composition. Overall, technological qualities and emulsion stability decreases with the increase in the amount of RSC component. While improving the sustainability of the sausage manufacturing process, small amounts of RSC component (25 percent RSC) could help maintain emulsion stability and optimum yield.

Economic losses have resulted from product recalls brought on by foodborne pathogen contamination of sausages. Furthermore, consumers' health is seriously threatened by food poisoning. Meat production facilities are frequently reported to be a source of *S. aureus* and to be contaminated with *Listeria monocytogenes*. Furthermore, the growth of bacteria that cause food spoilage, like *Lactobacillus* species and *Brochothrix thermosphacta*, which result in discolouration, gas and an unpleasant taste, frequently ruined meat products (Borch *et al*., 1996; Gounadaki *et al*., 2008; Gutiérrez *et al*., 2012; Batpho *et al*., 2017).

Modified casings. Microorganisms can readily contaminate sausages during every stage of production process including processing and packaging, storage, transportation, purchase, and consumption. In addition to incurring financial loss, deterioration in quality of sausages causes a major health risk to consumers. It is effective to use antimicrobial substances to deal with such microbial poisoning. Nisin is the most commonly employed bio preservative in the food processing industry. *Lactococcus lactis* strains are the ones that produce it. Nisin is the food additive that has been approved by the FAO and used in more than 50 nations. For cooked, RTE meat products that contain sauces, the maximum amount of nisin that is permitted to be added is 600 parts per million of the finished products. According to WHO GRAS Notice No. 000065, nisin is allowed to be used in casings and on cooked (RTE) meat products up to 276 ppm in the final product when used in casings and up to 220 ppm on cooked meat products because it is non-toxic to humans and stable in low acid and heat environments. Nisin exhibited antibacterial effectiveness against *Staphylococcus aureus*, *Listeria monocytogenes*, *Brochothrix thermosphacta*, *Lactobacillus* spp. and *Leuconostoc* spp (Cintas *et al*., 1998; Gill & Holley 2000; Li *et al*., 2005; Jin *et al*., 2009).

Study conducted by Batpho *et al*. (2017) demonstrates how to develop an antimicrobial casing by use the vacuum impregnation approach to incorporate nisin into a collagen casing, which inhibits foodborne microorganisms that cause food spoiling linked to RTE sausage that is kept at both abusive temperature (10ºC) and refrigerated (4ºC). Additionally, the casing's mechanical and physical characteristics were investigated to look into the meat processing industry's potential use. Incorporating or employing different sources of materials in the production of the casings can also improve the fundamental qualities of the sausages in addition to their microbiological quality.

Whey protein casings. Simelane & Ustunol (2005) examined the mechanical characteristics of edible films composed of heat-cured whey protein. Whey protein isolate (WPI) (5%, w/v), glycerol (3.3%, w/v), and candelilla wax (0.8%, w/v) were used for producing edible films. Curing with heat was done on two sets of films: one for 12 hours at 90°C and another for 24 hours at 80°C. Collagen and whey protein based edible films were subjected to a meat-processing protocol common to the production of polish sausages. During the multistage cooking procedure, the collagen films' TS (Tensile strength), % E (percentage elongation), and AM (apparent modulus) remained unchanged. The % E of the heat-cured Whey protein isolate films remained constant throughout the cooking process and was comparable to that of collagen films. When temperature, time, and relative humidity increased, WPI-based films' TS and AM decreased while their % E remained constant when compared to collagen films. Up to 70% RH, the films' moisture absorption was low; but, at 85% RH, it substantially increased. It was found that relative humidity reduced the films' TS. Films kept at 50% RH were 1/5 as strong as those kept at 75% RH. The study also indicated that more work needs to be done to enhance the characteristics of whey protein isolate based films in order to make them more "collagen-like."

Mubururu *et al*. (2014) developed sausage casings produced from the whey proteins. Whey, byproduct from producing cheese, can be developed into an edible film that is suitable for use as an alternative to sausage casing. The whey protein casings have very little microbial contamination in comparison to the natural casings. 10% (wt/wt) whey protein concentrate aqueous solutions were prepared and then heated to 75°C for one hour. After cooling the solutions to ambient temperature (below 30°C), a mutton cloth was used to filter the coagulant that had developed. Then, 0.1 M hydrochloric acid, 0.1 M sodium hydroxide, or both were utilized to bring down the pH to 7. Following the addition of the required amounts of 40g glycerol to plasticize the films, 9 g of formaldehyde and 0.05 g of calcium chloride added to crosslink the films. A thin deposit of film-forming solutions was casted on a plate followed by drying in a ventilated oven for 18 to 24 hours at 30°C. Whey protein-based films remain partially insoluble in water due to the presence of intermolecular disulphide linkages. After a 24-hour immersion, the plasticized casings were obviously not dispersed, and the solubility was found to be 38 ± 5%. Whey protein-based films are hydrophilic and show significant interaction between proteins due to non-covalent attractive forces like hydrogen bonds and hydrophobic interactions. The developed film contains 33 ± 1.5% moisture content.

Chitosan casings/films. Chitosan films and coatings have been demonstrated to improve the quality characteristics of fresh, processed and frozen food products by enhancing product appearance, reducing moisture loss, minimizing the discolouration, prolonging lipid oxidation and suppressing the growth of yeasts, moulds and bacteria (Gennadios *et al*., 1997; Shahidi *et al*., 1999; Cutter, 2006; Véronique, 2008). Chitosan has been used as a dip to improve the safety and quality of sausages. The shelf life of pig sausages stored at refrigerator temperature extended to fifteen days from seven days when it is provided with a chitosan dip (Véronique, 2008). An alternate approach to improve the quality and safety of sausages produced with chitosan. Apply a layer of chitosan to commercially available sausage casings using techniques like coating and laminating. The vacuum impregnation approach produced chitosan-coated cellulose casings with antibacterial qualities (Kaowkum *et al*., 2012).

Chitosan casings exhibit superior mechanical properties compared to traditional collagen casings (Adzaly *et al*., 2016). They possess higher tensile strength, meaning they are more resistant to tearing during the filling and handling processes. While their elongation at break is lower, indicating less flexibility, their overall performance under sausage manufacturing conditions is better (Adzaly *et al*., 2016). This suggests that chitosan casings are less prone to damage during processing, which can lead to reduced waste and improved production efficiency. Chitosan is a biodegradable and biocompatible material (Bangyekan *et al*., 2006). This means it breaks down naturally in the environment, reducing waste and minimizing its environmental impact. Its biocompatibility also suggests potential benefits for human health, even if further study is required to entirely understand these features. Chitosan possesses inherent antimicrobial properties (Bangyekan *et al*., 2006). It may enhance the safety of foods and enhance the shelf life of sausages. These characteristics can lower the chance of spoilage and improve product quality by preventing the growth of hazardous microorganisms.

Adzaly *et al*. (2016) investigated the performance of a new chitosan casing (CH casing) under conventional sausage production conditions. The purpose of the study was to verify the novel chitosan casing's commercial viability that contained Tween 80 (0.2%

w/w), glycerol (50% w/w), and cinnamonaldehyde (2.2% w/v) under conventional sausage producing conditions. Both collagen (control) and chitosan casings were filled with meat batter, which was followed by cooking. Collagen showed less effective ($P \le 0.05$) barrier properties for oxygen, moisture, liquid smoke, and UV light than the chitosan shell. The chitosan casing revealed higher ($P \le 0.05$) tensile strength, reduced elongation at break and tensile energy to break and superior transparency. Prior to cooking, the CH casing had higher moisture content than the collagen casing (29% vs. 13%), however after cooking, it was lower (8–9% vs. 24%). When it came to UV protection, the CH casings exceeded the collagen casings. Before the sausages were processed, the CH casing's tensile strength (TS) was less than that of the collagen casing but the reverse outcome was seen once the sausages were processed. This implies that whereas the collagen casings require greater attention after cooking, the CH casings demand more attention prior to cooking. These results suggest that the produced chitosan casing may be used as an improved or alternative for the collagen casing currently used in sausage production.

CONCLUSION AND FUTURE SCOPE

Over time, the usage of natural casings has expanded beyond goat intestines. The sub-mucosal layer of the small intestine of sheep, goats, cattle, pigs, and occasionally horses, was the main source of natural casings. Man-made alternatives to natural casings are synthetic sausage casings. Designed to satisfy the increasing demand for sausages, these casings come in a range of materials, including cellulose, collagen, and plastic, and offer a number of benefits over natural ones, including uniqueness in size and shape, availability, and storage properties. Despite advancements to satisfy market demands, consumer preference remained concentrated on natural casings due to the remarkable taste, softness, and texture of natural casings are well known. The use of natural casings to enhance the sausage's taste constitutes one of its most evident features. The meat gets a deeper, more intense flavour as a result of the casings' ability to breathe, which lets the flavours of cooking and smoking penetrate through. Therefore, choosing the right casing, whether it's natural sheep casing or synthetic films requires a thorough comprehension of its mechanical, structural, and consumer preference, as well as the variables influencing these attributes. As a conclusion to this review, we propose that there is a great deal of room to include new edible substitutes for the natural casings. Furthermore, it can open the door to sustainability by utilizing byproducts or discards like whey protein, chitosan, collagen as a source of raw materials.

Acknowledgement. I express my gratitude to my supervisor for the unwavering assistance and guidance, in the manuscript preparation process.
Conflict of Interest. None.

REFERENCES

Adzaly, N. Z., Jackson, A., Kang, I. and Almenar, E. (2016). Performance of a novel casing made of chitosan under traditional sausage manufacturing conditions. *Meat Science*, *113*, 116-123.

Adzaly, N. Z., Jackson, A., Villalobos-Carvajal, R., Kang, I. and Almenar, E. (2015). Development of a novel sausage casing. *Journal of Food Engineering, 152,* 24–31.

Angele, P., Abke, J., Kujat, R., Faltermeier, H., Schumann, D., Nerlich, M. and Mueller, R. (2004). Influence of different collagen species on physico-chemical properties of crosslinked collagen matrices. *Biomaterials*, *25*(14), 2831-2841.

Bangyekan, C., Aht-Ong, D. and Srikulkit, K. (2006). Preparation and properties evaluation of chitosan-coated cassava starch films. *Carbohydrate polymers*, *63*(1), 61-71.

Barbut, S. (2015). *The science of poultry and meat processing*.

Batpho, K., Boonsupthip, W. & Rachtanapun, C. (2017). Antimicrobial activity of collagen casing impregnated with nisin against foodborne microorganisms associated with ready-to-eat sausage. *Food Control*, *73*, 1342-1352.

Bolívar-Monsalve, J., Ramírez-Toro, C., Bolívar, G. and Ceballos-González, C. (2019). Mechanisms of action of novel ingredients used in edible films to preserve microbial quality and oxidative stability in sausages-A review. *Trends in Food Science & Technology, 89,* 100-109.

Borch, E., Kant-Muermans, M. L. and Blixt, Y. (1996). Bacterial spoilage of meat and cured meat products. *International Journal of Food Microbiology*, *33*(1), 103-120.

Bradley, R. (2002). Report on the safety of sheep intestine and natural casings derived therefrom in regard to risks from animal TSE and BSE in particular. *Report prepared for the tse/bse ad hoc group of the scientific steering committee*, *7*.

Charulatha, V. and Rajaram, A. (2003). Influence of different crosslinking treatments on the physical properties of collagen membranes. *Biomaterials*, *24*(5), 759-767.

Chen, X., Zhou, L., Xu, H., Yamamoto, M., Shinoda, M., Kishimoto, M. and Yamane, H. (2020). Effect of the Application of a Dehydrothermal Treatment on the Structure and the Mechanical Properties of Collagen Film. *Materials*, *13*(2), 377.

Cintas, L. M., Casaus, P., Fernández, M. F. and Hernández, P. E. (1998). Comparative antimicrobial activity of enterocin L50, pediocin PA-1, nisin A and lactocin S against spoilage and foodborne pathogenic bacteria. *Food Microbiology*, *15*(3), 289-298.

Dibaba, A. B. (2019). The risk of introduction of swine vesicular disease virus into Kenya via natural sausage casings imported from Italy. *Preventive Veterinary Medicine*, *169*, 104703.

Djordjevic, J., Pecanac, B., Todorovic, M., Dokmanovic, M., Glamoclija, N., Tadic, V. and Baltic, M. Z. (2015). Fermented sausage casings. *Procedia Food Science*, *5*, 69-72.

Feng, C. H., Drummond, L., Zhang, Z. H. and Sun, D. W. (2014). Evaluation of innovative immersion vacuum cooling with different pressure reduction rates and agitation for cooked sausages stuffed in natural or artificial casing. *LWT-Food Science and Technology*, *59*(1), 77-85.

Gabiatti, C., Mejia, S. M. V., Lim, L. T., Bohrer, B., Rodrigues, R. C., Prentice, C. and Bohrer, B. M.

(2020). Enzymatically treated spent cellulose sausage casings as an ingredient in beef emulsion systems. *Meat and Muscle Biology*, *4*(1).
Gennadios, A., Hanna, M. A. and Kurth, L. B. (1997). Application of edible coatings on meats, poultry and seafoods: a review. *LWT-Food Science and Technology*, *30*(4), 337-350.
Gill, A. O. and Holley, R. A. (2000). Inhibition of bacterial growth on ham and bologna by lysozyme, nisin and EDTA. *Food Research International*, *33*(2), 83-90.
Gounadaki, A. S., Skandamis, P. N., Drosinos, E. H. and Nychas, G. J. E. (2008). Microbial ecology of food contact surfaces and products of small-scale facilities producing traditional sausages. *Food microbiology*, *25*(2), 313-323.
Guan, D., Yang, X., Tao, J., Zhan, F., Qiu, Y., Jin, J. and Zhao, L. (2025). Novel biodegradable polyamide 4/chitosan casing films for enhanced fermented sausage packaging. *Food Packaging and Shelf Life*, *47*, 101444.
Gutiérrez, D., Delgado, S., Vázquez-Sánchez, D., Martínez, B., Cabo, M. L., Rodríguez, A. and García, P. (2012). Incidence of Staphylococcus aureus and analysis of associated bacterial communities on food industry surfaces. *Applied and Environmental Microbiology*, *78*(24), 8547-8554.
Hamann, D., Puton, B. M. S., Comin, T., Colet, R., Valduga, E., Zeni, J. and Cansian, R. L. (2022). Active edible films based on green tea extract and gelatin for coating of fresh sausage. *Meat Science*, *194*, 108966.
Harper, B. A. (2013). *Understanding interactions in wet alginate film formation used for in-line food processes* (Doctoral dissertation, University of Guelph).
Harper, B. A., Barbut, S., Lim, L. T. and Marcone, M. F. (2012). Microstructural and textural investigation of various manufactured collagen sausage casings. *Food Research International*, *49*(1), 494-500.
He, L., Mu, C., Shi, J., Zhang, Q., Shi, B. and Lin, W. (2011). Modification of collagen with a natural cross-linker, procyanidin. *International Journal of Biological Macromolecules*, *48*(2), 354-359.
Heinz, G. and Hautzinger, P. (2007). *Meat processing technology for small-to medium-scale producers*. FAO. Bangkok, Thailand openknowledge.fao.org
Henderson, W. F. and Dietrich, H. E. (1926). Cellulose Sausage Casings1. *Industrial & Engineering Chemistry*, *18*(11), 1190-1194.
Hood, L. L. (1987). Collagen in sausage casing. In: Advances in Meat Research, Vol. 4.
Irklei, V. M. (1990). Basic trends in technology of manufacturing cellulose films and casings. Fibre Chemistry, 181-187.
Jelsma, T., Wijnker, J. J., van der Poel, W. H. and Wisselink, H. J. (2021). Intestinal Viral Loads and Inactivation Kinetics of Livestock Viruses Relevant for Natural Casing Production: A Systematic Review and Meta-Analysis. *Pathogens*, *10*(2), 173.
Jin, T., Liu, L., Zhang, H. and Hicks, K. (2009). Antimicrobial activity of nisin incorporated in pectin and polylactic acid composite films against Listeria monocytogenes. *International Journal of Food Science and Technology*, *44*(2), 322-329.
Kaowkum, P., Boonsupthip, W., Thumanu, K. and Rachtanapun, C. (2012). Preliminary Antimicrobial casing Incorporated with Chitosan by Vacuum Impregnation. *Italian Journal of Food Science/Rivista Italiana di Scienza degli Alimenti*, *24*(4).
Knipe, C. L. (2024) Sausage casings. In M. Dikeman & C. Devine (Eds.), Encyclopedia of meat sciences (3rd ed., pp. 440–445). Ohio State University, Columbus. OH, United States.
Koolmees, P. A., Tersteeg, M. H. G., Keizer, G., Van Den Broek, J. and Bradley, R. (2004). Comparative histological studies of mechanically versus manually processed sheep intestines used to make natural sausage casings. *Journal of Food Protection*, *67*(12), 2747-2755.
Kutas, R. (1987). Great sausage recipes and meat curing. The Sausage Maker Inc. New York.
Li, T., Tao, J. and Hong, F. (2005). Study on the inhibition effect of nisin. *The Journal of American Science*, *1*(2), 33-37.
Liu, F., Yu, Z., Wang, B. and Chiou, B. S. (2023). Changes in structures and properties of collagen fibers during collagen casing film manufacturing. *Foods*, *12*(9), 1847.
Long, K., Cha, R., Zhang, Y., Li, J., Ren, F. and Jiang, X. (2018). Cellulose nanocrystals as reinforcements for collagen-based casings with low gas transmission. *Cellulose*, *25*(1), 463-471.
Luchansky, J. B. and Call, J. E. (2004). Evaluation of nisin-coated cellulose casings for the control of Listeria monocytogenes inoculated onto the surface of commercially prepared frankfurters. *Journal of Food Protection*, *67*(5), 1017-1021.
Meatmagnate.com (2025) South Australia. https://meatmagnate.com/sausage-casing/. Accessed 20 April 2025.
Mercadante, A. Z., Capitani, C. D., Decker, E. A. and Castro, I. A. D. (2010). Effect of natural pigments on the oxidative stability of sausages stored under refrigeration. *Meat Science*, *84*(4), 718-726.
Mubururu, B., Moyo, D. N. and Muredzi, P. (2014). Production of artificial sausage casings from whey proteins. *International Journal of Nutrition Sciences*, *3*, 30-38.
Ockerman, H. W. (1996). Chemistry of meat tissue.
Onishchenko, V., Pak, A. O., Goralchuk, A., Shubina, L., Bolshakova, V., Inzhyyants, S. and Domanova, O. (2021). Devising techniques for reinforcing glued sausage casings by using different physical methods. *Eastern-European Journal of Enterprise Technologies*, *1*(11), 109.
Pearson, A. M., Gillett, T. A., Pearson, A. M. and Gillett, T. A. (1996). Casings, extenders, and additives. *Processed meats*, 291-310.
Rivas, F. P., Cayre, M. E., Campos, C. A. and Castro, M. P. (2018). Natural and artificial casings as bacteriocin carriers for the bio preservation of meats products. *Journal of Food Safety*, *38*(1), e12419.
Rust, R. E. and Knipe, C. L. (2014). Sausage casings. In M. Dikeman & C. Devine (Eds.), Encyclopedia of meat sciences (2nd ed., pp. 235–240). Ohio State University, Columbus. OH, United States.
Sanders, D. A., Belyea, R. L. and Taylor, T. A. (2000). Degradation of spent casings with commercial cellulases. *Bioresource Technology*, *71*(2), 125-131.
Savic, Z. (2012). Advances in the manufacture of sausage casings. In *Advances in meat, poultry and seafood packaging* (pp. 377-405). Woodhead Publishing.
Serio, A., Laika, J., Maggio, F., Sacchetti, G., D’Alessandro, F., Rossi, C. and Paparella, A. (2020). Casing contribution to proteolytic changes and biogenic amines content in the production of an artisanal naturally fermented dry sausage. *Foods*, *9*(9), 1286.
Shahidi, F., Arachchi, J. K. V. and Jeon, Y. J. (1999). Food applications of chitin and chitosans. *Trends in Food Science & Technology*, *10*(2), 37-51.

Simelane, S. and Ustunol, Z. (2005). Mechanical Properties of Heat-cured Whey Protein-based Edible Films Compared with Collagen Casings under Sausage Manufacturing Conditions. *Journal of Food Science*, *70*(2), E131-E134.

Simonova, I., Drachuk, U., Halukh, B., Basarab, I., Koval, H. and Nutskovskyi, Y. (2024). Innovative approaches to improving the barrier properties of natural sausage casings. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: *Food Technologies, 26*(102), 21-29.

Sreenath, H. K. and Jeffries, T. W. (2011). Interactions of fungi from fermented sausage with regenerated cellulose casings. *Journal of Industrial Microbiology and Biotechnology, 38*(11), 1793-1802.

Sreenath, H. K. and Koegel, R. G. (2008). Bioconvertion of spent cellulose sausage casings. *Enzyme and microbial technology*, *43*(2), 226-232.

Suurs, P. and Barbut, S. (2020). Collagen use for co-extruded sausage casings–A review. *Trends in Food Science & Technology*, *102*, 91-101.

Véronique, C. O. M. A. (2008). Bioactive packaging technologies for extended shelf life of meat-based products. *Meat science*, *78*(1-2), 90-103.

Wang, B., Shi, D., Yu, Z., Liu, F. and Zhong, F. (2020). Improvement on properties of collagen casing films by aging treatment after oil coating. *Food Packaging and Shelf Life*, *25*, 100519.

Wu, Y. C., Chi, S. P. and Christieans, S. (2014) Casings. Handbook of fermented meat and poultry. Oct 2:89-96. Handbook of fermented meat and poultry. In *Handbook of Fermented Meat and Poultry* (pp. 217-225).

Yan, X., Yang, L., Zhang, Y., Han, W. and Duan, Y. (2022). Effect of collagen casing on the quality characteristics of fermented sausage. *Plos One*, *17*(2), e0263389.

Yemenicioğlu, A. (2024). Recent developments shaping the future of antimicrobial edible food packaging: a review. *International Journal of Food Science and Technology, 59*(12), 9646-9665.

Zając, M., Pająk, P. and Skowyra, G. (2021). Characterization of edible collagen casings in comparison with the ovine casing and their effect on sausage quality. *Journal of the Science of Food and Agriculture*, *101*(14), 6001-6009.

How to cite this article: Ancy Thomas and Blossom K.L. (2025). Traditional and Modern Approaches to Sausage Casing: A Review. *Biological Forum, 17*(7): 168-181.