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Use of Plant Extracts from Family Moraceae to Extend the Shelf Life of Meat

BACHELOR'S THESISF

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Declaration

I, Karen Sovjáková, hereby declare that I have done this thesis entitled Use of Plant Extracts from Family Moraceae to Extend Shelf Life of Meat independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 16th April 2024

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Karen Sovjáková

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Abstract

Securing the preservation of meat is a crucial aspect of maintaining food safety and safeguarding its quality during storage. In recent years, there has been an increased interest in the exploration of natural compounds, particularly plant extracts, as alternative and non-toxic options to synthetic additives for meat preservation. This bachelor's thesis focused on using plant extracts derived from the Moraceae family, specifically focusing on plants from genera *Artocarpus*, *Dorstenia*, *Ficus*, and *Morus*, with the objective of extending the shelf life of meat. The central aspect of the study involved assessing the antioxidant characteristics of chosen plants within the specified genera, presented in a structured table format. The result of this study was the evaluation of table plants and the determination of the most promising candidates, particularly in the total amount of antioxidant substances present, which could be used with proper application to extend the shelf life of meat. Among the most promising candidates were *Artocarpus altilis*, *Artocarpus heterophyllus*, *Artocarpus lakoocha*, *Dorstenia ciliata*, *Dorstenia manni*, *Dorstenia psilurus*, *Ficus carica*, *Ficus lyrata*, and *Morus alba*. Additionally, the literature research included examining the characteristics and chemical properties of meat, along with exploring various preservation techniques beyond the use of antioxidants.

Key words: Antioxidants, Chemical compounds, Meat, Moraceae, Plant extracts, Preservation

Contents

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List of the abbreviations used in the thesis

AP	Aerobic Packaging
BHA	Butylated Hydroxy Anisole
BHT	Butylated Hydroxy Toluene
DPPH	2,2-diphenylpicrylhydrazyl
EOs	Essential Oils
GRAS	Generally Recognized As Safe
HHP	High Hydrostatic Pressure
MAP	Modified Atmosphere Packaging
MLP	*Morus alba* Leaf Powder
mpHHP	multi-pulse High Hydrostatic Pressure
NA	Not Available
PG	Propyl Gallate
PUFA	Poly Unsaturated Fatty Acids
SE	Soxhlet Extraction
SFE	Supercritical Fluid Extraction
spHHP	single-pulse High Hydrostatic Pressure
SWE	Subcritical Water Extraction
TBHQ	Tert-Butyl Hydro Quinone
UAE	Ultrasound-Assisted Extraction
VP	Vacuum Packaging
WBC	Water Binding Capacity
WHC	Water-Holding Capacity

1. Introduction

Meat and meat products are an important group of nutritionally rich foods. Meat is the main source of energy, proteins, vitamins, and also minerals. However, its constitution results in rapid spoilage and degradation if not preserved in time (Addis 2015). In recent years, there has been a significant increase in the popularity of natural products, especially in the food industry (Gyawali & Ibrahim 2014). That is why the use of plant extracts to extend the shelf life of meat is a very current topic. Prolonging the shelf life of meat is not only crucial for restraining food waste but also for meeting consumer expectations for fresh and top-grade products. Consequently, there is an expanding interest in exploring alternative approaches, including the utilization of natural plant extracts, that possess antimicrobial and antioxidant properties.

The family Moraceae, including genera such as *Ficus*, *Dorstenia*, *Artocarpus,* and *Morus*, has been acknowledged for its rich diversity of bioactive compounds (Clement & Weible 2009). These compounds, ranging from flavonoids and phenolic acids to tannins, possess various biological activities, including antimicrobial and antioxidant effects. Consequently, plant extracts derived from Moraceae species hold significant promise as natural preservatives for meat products (Duffal *et al.* 2003; Mbaveng *et al.* 2012). This bachelor's thesis aspires to delve into the potential of plant extracts sourced from the family Moraceae as effective agents for extending the shelf life of meat. Through a complete review of existing literature, this thesis aims to probe into the antimicrobial and antioxidant properties of extracts derived from Moraceae and their influence on meat preservation.

The results of this study could serve as a springboard for subsequent research attempts focused on directly applying plant extracts from the Moraceae family to meat. By applying the bioactive compounds present in Moraceae plants, the prospect of decreasing reliance on synthetic additives exists while at the same time enhancing the overall safety and quality of meat products. Furthermore, delving into plant-based preservation methods aligns with convincing trends favouring natural food ingredients, thereby addressing consumer preferences for healthier and more environmentally friendly food options.

2. Aims of the Thesis

The aim of the thesis was to map available literary sources and electronic information sources in order to determine the use of plant extracts from the Moraceae family to extend the shelf life of meat.

The specific objective was to compile information on plant extracts derived from the Moraceae family, with a focus on genera *Artocarpus*, *Dorstenia*, *Ficus*, and *Morus*, as potential natural additives for prolonging the shelf life of meat, and create tables featuring selected plants from these four genera, based on their chemical composition, economic significance, non-toxicity to human health, availability, and scientific prominence.

3. Methodology

Information on the topic was collected from specific internet databases such as cambridge.org, hindawi.com, intechopen.com, link.springer.com, sciencebiology.org, and sciencedirect.com. The most searched keywords were: preservation, antioxidants, chemical compounds, Moraceae, meat, flavonoids.

Summary tables of plants according to belongingness to genera *Artocarpus*, *Dorstenia*, *Ficus*, and *Morus* were compiled based on collected data and criteria. Criteria were as follows: chemical composition, economic significance, non-toxicity to human health, availability, and scientific prominence.

Finally, 9 most promising representatives from the compiled tables were selected and described in detail.

All sources were listed in the list of references.

4. Literature Review

4.1. Characteristics of meat

According to Lautenschlaeger & Upmann (2017) within the European Union, meat is, in principle, considered as skeletal muscle deriving from specified animal species, which may include edible offal and blood; the term meat does not include fish and seafood. Characteristics of meat include its nutritional composition, texture, flavour, colour, and water-holding capacity. Meat is primarily composed of protein, along with varying amounts of fat, vitamins, minerals, and water (Cobos & Díaz 2015). Texture can range from tender to tough depending on factors like cut, cooking method, and animal age. Flavour varies based on factors such as species, diet, and cooking techniques. The colour of meat is influenced by factors like myoglobin content and oxygenation state, appearing pink in poultry and red in beef (Mancini & Hunt 2005). Lastly, water-holding capacity refers to meat's ability to retain moisture during cooking and processing, impacting juiciness and tenderness (Pearce *et al*. 2011). Concerns regarding fat content and fatty acid profile in relation to meat consumption are notably influenced by the species of the animal and the feeding system (Pereira & Vicente 2013).

4.1.1. Types of meat

Meat classification involves systematically categorizing meat according to various criteria and establishing a framework for comprehending and organizing diverse meat types. This categorization considers factors like the animal's type, specific cuts, processing methods, preparation techniques, species, nutritional content, and other relevant aspects. Because of their composition and characteristics, meat obtained from slaughtered animals is categorized into two main types. Red meat, which includes beef, pork, and lamb, and white meat, which encompasses poultry (McAfee *et al*. 2010). For a more detailed characterization, the most important types of meat as a source of human nutrition were selected.

4.1.1.1. Beef

Beef stands out as a globally appreciated and adaptable meat, sourced primarily from cattle, especially cows. It is renowned for its robust flavour and nutritional richness, serving as a vital source of both macronutrients and micronutrients. Essential macronutrients found in beef include water, high-quality protein, and fats containing both saturated and unsaturated fatty acids. Additionally, beef provides critical micronutrients such as iron, zinc, selenium, and vitamins D and B-complex (Li 2017). Beef typically exhibits a characteristic brick red colour, which can vary depending on the age of the slaughtered animal. It appears pale red in young animals, darker in older ones, and particularly red in bulls. Additionally, the colour of the meat is affected by factors such as the animal's sex and its diet, with greater iron content in green fodder resulting in a darker red hue. The distinct taste and aroma of meat are influenced by the presence of volatile fatty acids, which are more pronounced in older animals. Juiciness and tenderness are closely linked to the taste profile of meat, with tenderness being influenced by the protein content in the muscle. Generally, meat from well-fed animals tends to be more tender compared to that from leaner animals (Zrcková 2011). The USA and Brazil stand as the top beef producers universally. Following closely, the European Union secures the third position in the ranking, producing 7.9 million tons of carcasses annually (Smith *et al.* 2018).

4.1.1.2. Mutton

Meat from sheep aged over one year, commonly known as mutton, is characterized by a more intense flavour, firmer texture, and darker hue compared to lamb. It typically posses higher fat content and a richer taste profile. Mutton exhibits fine fibres and a distinct aroma. When prepared properly, mutton is easily digestible and offers high nutritional value, containing complete proteins, potassium, sodium, and notably, iron. It is often recommended for individuals with anaemia and young children. On the other hand, lamb meat, sourced from young sheep aged between 5 and 12 months, is renowned for its tender texture, subtle flavour, and pinkish-red appearance. Considered a premium product due to its elevated cost, lamb is often regarded as a luxury item (Beriain *et al.* 2000).

4.1.1.3. Pork

Pork refers to meat derived from domestic pigs. The meat is pale pink to red. Due to its higher fat content compared to beef, pork has a greater energy value, making it somewhat more challenging to digest. The flavour profile of pork is influenced by the age of the animal and its diet. Pork from pigs fed with a higher milk content tends to have a lighter colour. The most desirable pork comes from younger cuts, characterized by fine fibres, tender texture, and a firm white fat layer. In contrast, meat from older cuts features tougher, coarser fibres and darker red coloration (Zrcková 2011).

4.1.1.4. Poultry

Poultry meat is popular worldwide, and its consumption continues to grow in both developed and developing countries. Poultry encompasses various domesticated birds commonly consumed for their meat, including chickens, turkeys, guinea fowl, ducks, and geese. Poultry meat is regarded as dietary due to its relatively lower muscle fibre content compared to meat from other livestock, resulting in a finer texture, tenderness, and ease of digestion (Barroeta 2007). It is abundant in animal proteins and generally contains lower fat levels, particularly in chicken and turkey, which offer reduced energy content. However, exceptions include goose and duck meat, known for their higher fat content. Among poultry meats, chicken receives the most attention, likely due to its lack of cultural or religious restrictions and its nutritional value (Magdelaine *et al.* 2008). Ducks, being waterfowl, possess a distinct physiology compared to other poultry. With a higher concentration of red muscle fibre than chicken meat, duck meat is classified as red meat. It enjoys widespread popularity and experiences robust demand, particularly in Asia (Ali *et al*. 2007). Duck meat is commonly acknowledged for its delicious flavour, abundance of amino acids, and polyunsaturated fatty acids (PUFA), while maintaining a relatively low-fat content. Notably, duck meat contains a significant amount of linoleic and linolenic acids in relation to its total PUFA content (Banaszak *et al*. 2020).

4.1.1.5. Rabbit

The rabbit possesses numerous characteristics that theoretically make it an ideal animal for meat production. It has a short life cycle, a brief gestation period, remarkable prolificacy, and a high capacity for feed conversion (Cullere & Dalle Zotte 2018). In numerous European countries such as Malta, Cyprus, Italy, Czech Republic, Spain, Belgium, Luxembourg, Portugal, and France, as well as certain North African countries like Egypt and Algeria, rabbit meat is a regular part of the diet. In most of these nations, rabbit meat production plays an important role in the national economy. In addition to its high protein content, rabbit meat is also rich in essential amino acids (Dalle Zotte & Szendrő 2011).

4.1.1.6. Venison

Venison stands as an exceptionally prized organic food renowned for its unparalleled flavour, largely attributed to the animals' free-ranging lifestyle and diverse diet. Venison is the meat obtained from hunted game and has been a fundamental component of diets since ancient times. It encompasses a diverse array of animal species, including birds such as pheasant and mallard, ruminants like roe deer, deer, fallow deer, and mouflon, herbivores such as hares and wild rabbits, as well as monogastric animals like wild pigs (Bureš *et al.* 2018). Venison meat is tougher, dark red to reddish brown, has a low-fat content, a distinctive spicy taste and aroma typical of the game species in question. Compared to beef, it has a higher content of proteins and minerals (sodium, potassium, iron, phosphorus), and B vitamins (thiamine, riboflavin, and pantothenic acid) (Farouk *et al.* 2007).

4.1.2. The importance of meat in human diet

Meat has been a part of the human diet since prehistoric times, and its consumption has played a fundamental role in the evolution of the human species, especially in the development of the brain and intellectual abilities (Leroy *et al.* 2023). Even today, meat is one of the most popular and sought-after foods, whether for its taste or ability to satiate quickly. Due to the content of important proteins and vitamins, as well as iron, and phosphorus, meat is an irreplaceable ingredient for the human body in terms of nutritional value. Despite all the benefits and positive properties of meat, its excessive consumption can cause health problems, namely heart disease, Alzheimer‘s disease, some forms of cancer, and more (Tappel 2007). Hence, it is crucial to control the intake of meat in the human diet and strive for a balanced dietary pattern to prevent health issues (de Ridder *et al.* 2017).

4.1.3. Chemical properties of meat

Meat comprises approximately 70 to 75% water, 21% nitrogenous compounds (including 19% proteins and 1.5% nonprotein nitrogen compounds like nucleotides, peptides, creatine, and creatinine), 2.5 to 5% lipids, 1% non-nitrogenous compounds (such as vitamins and carbohydrates, with a minimal amount of glycogen transformed into lactic acid during the postmortem period), and 1% ash (containing potassium, phosphorus, sodium, chlorine, magnesium, calcium, and iron). The composition of meat varies due to several factors, including animal species, breed, sex, feeding, muscle type, and others (Cobos & Díaz 2015).

4.1.3.1. Water

In mammals, muscle tissue typically comprises around 75% water by weight, functioning as a conduit for transporting nutrients throughout the body. Water stands as the most abundant component in meat, its presence varying significantly based on the animal species and the meat's fat content. Pork typically contains less water, while beef and chicken exhibit higher water levels. While water may not hold much nutritional significance, it plays a crucial role in enhancing the sensory, culinary, and technological aspects of meat. Most of the water in muscle tissue is distributed within the muscle structure, encompassing the myofibrils, spaces between them, and between the myofibrils and the cell membrane (Offer & Cousins 1992). Various studies offer insights into the water content and viscosity of meat. One hypothesis suggests that the majority of water within muscle fibres is freely accessible, residing in crevices and pockets, while approximately 4% of the total water is less mobile, either weakly attached by electrostatic forces or tightly bound to muscle proteins (Poulanne & Halonen 2010). Muscle tissue possesses the capability to retain water through proteins, a phenomenon known as water-holding capacity (WHC). WHC is defined as the ability of meat and meat products to retain water during various stages such as cutting, grinding, pressing, transportation, storage, processing, and cooking (Pearce *et al.* 2011). Additionally, the term water binding capacity (WBC) is sometimes utilized. Typically, WHC denotes the inherent water-retaining ability of raw meat, whereas WBC signifies the water retained by the meat during processing, particularly in relation to heating (Kudryashov & Kudryashova 2023).

4.1.3.2. Protein

The primary constituents of meat are proteins, which serve various functions within the body and are classified into three groups based on their solubility in water and salt solutions, as well as their distribution within individual muscle structures (Tornberg 2005). Meat proteins are recognized as one of the richest sources of essential amino acids, containing all essential amino acids in balanced proportions, thereby providing significant nutritional value. Myofibrillar proteins are present within muscle cell fibres and composing myofibrils. They dissolve in diluted salt solutions but remain insoluble in deionized water. This group includes myosin, actin, troponin, tropomyosin, desmin, and titin. Actin and myosin, predominant among them, play direct roles in facilitating muscle contraction and relaxation. Myosin can account for up to 35% of the total protein volume in skeletal muscles, while actin is the prevailing protein in most eukaryotic cells (Choi & Kim 2009). Stromatic proteins are categorized as connective tissue proteins that do not dissolve in water or salt solutions. They are primarily found within the fibres of connective tissues, which envelop muscle structures within muscle tissue. Examples of stromatic proteins include collagen, elastin, reticulin, keratins, mucins, and mucoid. When heated, collagen undergoes swelling and gradually transforms into gelatine (gluten). The determination of stromal protein content typically relies on collagen content. Elastin plays a crucial role in maintaining the cohesion of muscle fibres in thermally processed meat. Keratins constitute a diverse group of proteins known for their mechanical and chemical resistance, as well as their flexibility (Bořilová *et al.* 2017). Sarcoplasmic proteins comprise 20 to 40% of the total proteins found in muscle tissue. These proteins are located in the cytoplasm of muscle cells and are soluble in water and weak salt solutions. They primarily consist of enzymes essential for diverse cellular functions and metabolic activities. Among them are haemoglobin and myoglobin pigments, responsible for the characteristic red colour of flesh and blood, as well as a variety of enzymes including myogen, myoalbumin, and x-globulin. Haemoglobin facilitates the transport of oxygen from the lungs to the body tissues and the removal of carbon dioxide from the tissues back to the lungs (Lopez-Enriquez *et al.* 2015).

4.1.3.3. Lipid

Lipids found in meat primarily consist of triglycerides and phospholipids. Triglycerides, acting as storage lipids, comprise three fatty acid molecules and one glycerol molecule. Meanwhile, phospholipids serve as structural components abundant in cell membranes (Mapiye *et al*. 2012). They are an important group of complex lipids whose molecule contains two fatty acids, glycerol and a phosphate group. Fat can be present as intermuscular fat, intramuscular fat, and subcutaneous fat. Whether in adipose tissue or muscle, fat contributes significantly to various aspects of meat quality and is essential to the nutritional value of meat. The firmness of meat is influenced by the level of saturated fatty acids present. Beef fat is more saturated than pork fat, which is also more saturated than poultry fat. It follows that cattle have tougher meat than pigs and poultry have the least tough meat. The melting point of beef fat is between 43 and 47 °C, while that of pigs is between 38 and 44 °C, and that of poultry is between 31 and 37 °C (Pereira & Abreu 2018).

4.1.3.4. Vitamins

Vitamins are essential organic compounds crucial for proper growth, development, and maintenance of the human body. Since the body cannot synthesize vitamins independently, they must be obtained through dietary intake. Vitamins are classified into two categories based on their solubility. Water-soluble vitamins include B-complex vitamins (thiamine, riboflavin, niacin, pyridoxine, choline, biotin, folic acid, cyanocobalamin, inositol, vitamin B6, and vitamin B12) and vitamin C. Fat-soluble vitamins include vitamin A, vitamin D, vitamin E, and vitamin K. The number of vitamins in meat is very diverse, as it depends on the type of animal and the type of feeding, however, meat serves as a rich source of vitamins, particularly those belonging to the B-complex group such as thiamine, riboflavin, niacin, vitamin B5, vitamin B6, and vitamin B12 and biotin (Ahmad *et al*. 2018).

Thiamine (vitamin B1) is involved in all key metabolic processes in the nervous system, heart, blood cells and muscles. It can help in the treatment of nervous diseases and improve mental alertness. Deficiency symptoms include fatigue, weakness, loss of appetite, irritability and depression, poor memory, indigestion. Its deficiency causes the disease beriberi. Riboflavin (vitamin B2) is important for the body's energy production and has antioxidant properties. Improves vision, supports healthy reproductive functions, protects against anaemia. Deficiency causes fatigue, burning sensations in the skin, cracks in the skin and mucous membranes. Niacin (vitamin B3) is necessary for the synthesis of sex hormones and for the normal functioning of the nervous system. Supports cellular respiration, and maintains healthy skin, nerves, tongue, and digestion. Deficiency symptoms include inflammation of the skin, diarrhoea, and dementia. Pantothenic acid (vitamin B5) supports wound healing, stimulates the immune system, lowers cholesterol, and prevents fatigue. Symptoms of deficiency are vomiting, convulsions, insomnia, and abdominal pain. Pyridoxine (vitamin B6) is necessary for the absorption of vitamin B12. It is needed for protein synthesis, for a healthy immune system and helps to reduce the symptoms of diabetes. Deficiency symptoms include anaemia, nervous disorders and skin problems. Cobalamin (vitamin B12) is necessary for the maintenance of the nervous system, improves memory, and supports the healthy growth of children. Deficiency manifests as tremors, pernicious anaemia and menstrual problems. Biotin prevents greying of hair, treats eczema and skin inflammations, reduces hair loss. Deficiency is manifested by fatigue and eczema (Akram *et al*. 2020).

4.1.3.5. Minerals

Mineral substances or minerals are chemical elements that are necessary for the proper growth, development, and function of the human body. Minerals are divided into two groups according to the amount needed by humans. Our body needs macrominerals in larger quantities and these include sodium, calcium, phosphorus, magnesium, potassium chloride, and sulphur. Microminerals are required in smaller amounts and include iron, zinc, iodine, copper, cobalt, manganese, selenium, and fluorine (Spada *et al*. 2010). Potassium is the most represented in meat, followed by phosphorus, sodium, and magnesium. At the same time, meat is also a good source of iron, zinc, and selenium (Ahmad *et al*. 2018).

Potassium is one of the most important minerals in the human body, it plays an important role in the conduction of nerve impulses, energy production, nucleic acid and protein synthesis, and muscle contraction. Deficiency symptoms include vomiting, muscle weakness and pain, extreme fatigue, and low blood pressure. Phosphorus is essential for the structure and function of the organism. It is present in the body in the form of phosphates and helps in the process of bone mineralization and the formation of bone structure. Activates B-complex vitamins and participates in the formation of RNA and DNA. Deficiency symptoms include weakness, anaemia, joint pain, loss of appetite, mental confusion, and more. Sodium is involved in maintaining fluid balance in the body, regulates acid-base balance and the transmission of neuromuscular impulses. Its deficit usually does not occur, only with diarrhoea or excessive sweating. Deficiency is then manifested by weakness, fatigue, exhaustion of the body and muscle spasms. Magnesium is essential for many biochemical processes in the human body, including the metabolism of nucleic acids and proteins. It is important for hormonal activity and cell regeneration. Deficiency is manifested by weakness, fatigue, hyperactivity in children, and palpitations. Iron acts against anaemia, increases the energy level in the body, and has an anti-tumour effect. Deficiency is manifested by fatigue, insomnia, paleness, and anaemia. Zinc strengthens the immune system, counteracts hair loss, treats acne and other skin disorders. Deficiency symptoms are growth retardation, lethargy, delayed wound healing, and decreased appetite. Selenium stimulates the immune system. Maintains healthy skin, hair, and vision, and protects against heart and circulation diseases. Deficiency manifests itself in fatigue, weakness, liver dysfunction and dandruff formation (Akram *et al*. 2020).

4.1.4. Meat spoilage

Meat is prone to rapid spoilage if not preserved. Fresh meat obtained from healthy animals typically carries a limited number of microorganisms at the point of slaughter and is nearly sterile. However, potential contamination may occur during meat processing procedures. It is imperative that meat processing follows slaughtering promptly, ideally within thirty minutes of the animal being killed, to minimize microbial proliferation. Failure to adhere to this timeline allows microorganism levels to increase. The speed at which meat spoils depends on both external and internal factors. External factors encompass temperature, moisture content, oxygen exposure, and the quantity and variety of microorganisms present on the meat. Internal factors consist of meat properties such as water activity, fat content, the stress level of the animal, and pH, which elevated level can create favourable conditions for bacterial growth, among other influences. From the perspective of meat spoilage, lipid oxidation, also known as rancidity, and microbial and enzymatic spoilage are crucial concepts (Addis 2015).

4.1.4.1. Lipid oxidation

During lipid oxidation, unsaturated fatty acids react with molecular oxygen, yielding hydroperoxides as the initial oxidation product. While hydroperoxides are odourless, their instability causes rapid decomposition, resulting in the formation of numerous secondary compounds such as hydrocarbons, aldehydes, ketones, alcohols, esters, and acids. These compounds contribute to unpleasant odours and deterioration in the taste of meat. Moreover, the oxidation process diminishes the nutritional value of the meat by causing the loss of essential fatty acids and vitamins. Additionally, lipid oxidation generates many toxic compounds (Ross & Smith 2006).

4.1.4.2. Microbial spoilage

Under normal conditions, meat together with meat products is an ideal environment for the growth of various microflora, which can also include pathogens. The most common genera of bacteria found in meat spoilage are *Staphylococcus*, *Bacillus*, *Campylobacter*, *Clostridium*, *Listeria*, *Salmonella*, etc. Fungal species found in meat include *Cladosporium*, *Geotrichum*, *Penicillium*, and *Mucor*, while yeasts include *Candida* spp. and *Cryptococcus* sp. The optimal pH range for the growth of spoilage bacteria in meat is typically between 5.5 and 7.0. Within this pH range, microbial growth can lead to various undesirable effects such as slime formation, degradation of structural components, odours, and changes in appearance (Dave & Ghaly 2011).

4.1.4.3. Enzymatic spoilage

Following the slaughter of animals, natural enzymatic processes occur within their muscle cells, contributing to meat spoilage. This period, during which enzymes remain active, is known as autolysis or the spontaneous decomposition of meat. During autolysis, complex compounds such as carbohydrates, fats, and proteins gradually break down into simpler substances and eventually into final decomposition products like water, carbon dioxide, or ammonia. Autolysis is an endogenous process. Concurrently with autolysis, proteolysis, which is the breakdown of meat for consumption, occurs. Proteolysis takes place within the muscles of slaughtered animals simultaneously with autolysis but at varying speeds and intensities. Autolysis is most intense immediately after slaughter and gradually decreases over time, whereas proteolysis is not evident during the initial postmortem period. Proteolysis is primarily driven by microorganisms and microbial enzymes, making it an exogenous process (Ghaly *et al*. 2010).

4.2. Techniques of meat preservation

Meat preservation involves employing various techniques to treat and handle meat, aiming to prevent or greatly reduce spoilage caused by microorganisms, which can lead to the deterioration of quality, edibility, or nutritional value. Preservation typically entails measures to inhibit the growth of bacteria, fungi, and other microorganisms, while also slowing down the oxidation of fats that may cause rancidity (Amit *et al*. 2017).

4.2.1. Traditional methods

Ancient preservation techniques were crafted ingeniously, relying on fundamental resources readily available. These methods encompass sun-drying, heat treatment, or immersing in a solution containing salt, water, and sometimes sugar and spices to extend the longevity of food items (Pittia & Antonello 2015).

4.2.1.1. Drying

One of the fundamental techniques in food processing is the preservation of foods through heating. Drying, which involves evaporating free water from a product by applying heat, can be considered as the process of dehydration. Dating back to ancient times, drying stands as one of the oldest methods employed for food preservation. Sun drying, a natural and commonly employed method for food preservation, has evolved alongside novel drying techniques facilitated by advanced equipment. While sun drying relies on natural processes, employing heat from the sun, drying with artificial heat sources such as fire or specialized dryers constitutes an artificial approach to dehydration. The primary objective of drying food is to prolong its shelf life by lowering water activity. This reduction in water activity effectively retards microbial growth and enzyme activity. Additionally, drying facilitates a decrease in the weight and volume of the food, resulting in reduced transportation and storage expenses. Drying can lead to the loss of certain vitamins and nutrients, while also concentrating the nutrients in the remaining mass. The dehydration process typically retains more quality and nutrients compared to sun drying. Before drying meat, certain pretreatment methods are employed to optimize results. These techniques encompass blanching, utilizing sulphur dioxide to maintain texture, flavour, and vitamin levels, salting or curing, dipping in sulphite to aid in dehydration and enhance drying quality, and cooking, which effectively eliminates microorganisms and reduces water-holding capacity (Dhakal 2022).

4.2.1.2. Pickling

The pickling method is a traditional and globally popular method of pickling meat in vinegar or edible oil with the addition of salt and spices. Thanks to the reduced pH, the shelf life of the product is extended by up to three months. Meat pickles are ideal for storage at room temperature and ready for immediate consumption (Arun *et al.* 2007). This method is widely used in tropical countries where high spoilage of meat is a serious problem. Refrigeration or freezing during storage is often used to prevent the growth of microorganisms, but this consumes a lot of energy. Pickling meat is therefore an alternative method of meat preservation that is inexpensive and at the same time helps to improve the taste and texture of the meat. Acetic acid is often used to pickle meat, which lowers the pH of the pickle to a range of 4.04 to 4.17, limiting microbial growth or possible survival of undesirable organisms and ensuring product stability at room temperature. The definition of a pickled food is established as a low-acid food that has a maximum pH of 4.6 or less and a water activity greater than 0.85 (Hafiz *et al.* 2013). In the Orient, especially in countries such as Nepal, India and some countries of the East, pickled meats and vegetables are also used due to their property to aid digestion by stimulating the flow of gastric juice (Gadekar *et al.* 2010). Meat pickles are often eaten with bread or rice but can also be used as snacks. Certain cuts of meat are more suitable for pickling than others. For example, beef brisket, pork shoulder, chicken thighs and turkey breast are considered ideal because they have the right ratio of fat and muscle. Marbling in the meat absorbs the brine well, which makes the final product tastier (Bhusal *et al.* 2017).

4.2.1.3. Fermentation

Food fermentation has been practiced for centuries, initially relying on the spontaneous action of unknown microorganisms found naturally in food and the surrounding environment. In modern commercial fermentation processes, lactic acid bacteria are predominantly utilized in starter preparations due to their beneficial technological effects. Commonly used starter cultures for various fermented sausages typically include slightly acidifying bacteria species such as *Lactobacillus* (*L.*) *sakei*, *L. curvatus*, *L. plantarum*, *Pediococcus* (*P.*) *acidilactici*, and *P. pentosaceus*. Meat fermentation stands as one of the oldest methods of food preservation, characterized by a low-energy biological acidification process that imparts unique flavours, colours, and textures to the final product. The transformation of muscle into fermented meat products is driven by homo- or heterofermentative starter cultures or naturally occurring "wild" microorganisms that facilitate pH reduction (Neffe-Skocińska *et al*. 2016). Salt serves as the primary additive in fermented meat products. Typically added at levels ranging from 2% to 4%, it promotes the growth of lactic acid bacteria while simultaneously inhibiting the proliferation of various undesirable microorganisms. Basic sugars like glucose serve as fermentation substrates that are easily metabolized by all lactic acid bacteria. The amount of sugar present affects the speed and degree of acid production, and enhances flavour, texture, and overall product yield. The recipe often includes different types of spices, such as mustard, ginger, cardamom, cinnamon, paprika, garlic, various types of pepper, and nutmeg. Spices are added for flavour, but also for their antioxidant properties and ability to stimulate the growth of lactic bacteria. Temperature, duration, and relative humidity combinations vary significantly in industrial production settings. Typically, higher fermentation temperatures and water activity levels lead to accelerated lactic acid production. In Europe, fermentation temperatures span from 5 to 26°C, with lower temperatures common in the Mediterranean region and higher temperatures prevailing in northern Europe. The composition of the final product is primarily influenced by several key factors, including the composition and proportions of the raw materials employed, the processing techniques applied, and the extent of drying (Ockerman & Basu 2014).

4.2.1.4. Thermal technology

Heating is likely the most economical and efficient preservation method available. Its primary objective is to eliminate most pathogens and spoilage microorganisms, along with deactivating enzymes to thwart spoilage and the proliferation of undesirable microflora. Certain heat treatment methods yield self-stable foods with extended shelf lives, often obviating the need for additional special storage conditions (Guerrero-Legarreta & García-Barrientos 2012). Commercially speaking, a food is deemed commercially sterile if it lacks *Bacillus stearothermophilus* or *Clostridium perfringens* (Lawson *et al*. 1994). While the principles of heat transfer are uniform across all thermal technologies, each serves a distinct purpose. These technologies, categorized based on treatment severity, include scalding, cooking, pasteurization, and sterilization. (Hanson 1990). Scalding, typically conducted at a temperature of around 65°C, is applied to tissues before freezing, drying, or preservation. Its primary aim is to deactivate enzymes, thus preventing alterations in colour, taste, and nutritional value due to enzyme activity. Cooking serves the main purpose of enhancing sensory quality. Given that cooked meat has a longer shelf life compared to raw meat, cooking can also be viewed as a preservation technique. During cooking, microorganisms are eradicated, and enzymes are deactivated. This process leads to changes in the meat's colour, texture, and flavour, while also enhancing its digestibility. Depending on the method of heat application, cooking techniques include oven cooking, roasting, grilling, frying, boiling, and steaming. While pasteurization effectively eliminates pathogenic vegetative cells, spores, and heat-resistant microorganisms may still survive. Hence, this method is often combined with another preservation technique, such as refrigeration or the use of chemical additives. Sterilization entails the absence of viable microorganisms in the product. However, in food processing, this definition isn't entirely applicable. Therefore, terms like "commercial sterility," "bacteriologically inactive," or "partially sterile" are employed in the food industry. This process involves heating food to temperatures of around 85°C or higher. By heating sealed jars in steam, the food undergoes cooking and pasteurization simultaneously (Guerrero-Legarreta & García-Barrientos 2012).

4.2.2. Present methods

Modern preservation methods have evolved from traditional practices, leveraging both historical wisdom and contemporary advancements. These methods often involve sophisticated equipment and technologies, building upon the foundations laid by traditional techniques.

4.2.2.1. Ionising radiation

Ionizing radiation serves as an efficient, non-thermal technique employed to reduce or eliminate foodborne pathogens, including *Salmonella* spp., in both raw and cooked meat. Irradiation is typically implemented as the concluding step in processing. Packaged food products can in some cases still be contaminated, ionizing radiation can therefore significantly reduce the pathogenic microflora of the product after packaging. This preservation process can be combined with the use of natural antibacterial compounds, such as extracts from spices and herbs, or different packaging systems (Szczawińska 2017). Three types of ionizing radiation are available for use, namely gamma rays emitted by radionuclides (such as cobalt-60 and cesium-137), X-rays generated from machine sources operating at or below the 5 megaelectron volt (MeV) energy level, and electrons generated from machine sources operating at or below the 10 MeV energy level (Codex 1983). The measurement of radiation is expressed in units called kiloGrays (kGy). In conjunction with ionizing radiation, terms like radurization, radicidation, and radapterization are closely associated. Radurization involves a significant reduction in the number of saprophytic microorganisms, leading to an extension of the product's shelf life, with doses typically ranging from 0.75 to 2.5 kGy. Radicidation is employed to eliminate bacterial pathogens, with doses ranging from 2.5 to 10 kGy. Radapterization aims to achieve a sterilization effect by ensuring the complete removal of spore-forming substances in food, with doses typically ranging from 10 to 40 kGy (Szczawińska 2017).

4.2.2.2. High hydrostatic pressure

High hydrostatic pressure (HHP) treatment is administered either before or after product packaging to enhance the microbiological safety and shelf life of the product. This preservation method entails subjecting the product to isostatic pressure at room temperature, typically ranging between 100 and 600 MPa. The pressure chamber is filled, sealed, degassed, and pressure is applied through pumps using a liquid, typically water (Hugas *et al*. 2002). As high temperatures are not required during this process, the sensory and nutrition characteristics of the product remain largely unaltered, which is highly desirable for the market (Garriga *et al*. 2004). HHP stands as one of the most advanced non-thermal technologies commercially available on the global market. It finds extensive use in various products including sliced meat, fruit jellies and jams, fruit juices, salad dressings, raw oysters, ham, guacamole, and more (García-Gimeno & Izquierdo 2020). In the HPP treatment, the process involves compression to the target pressure, maintaining this pressure for a specific duration, and then decompression to atmospheric pressure. As only one compression cycle occurs in this method, it is referred to as single-pulse high hydrostatic pressure (spHHP). However, there exists another method where multiple compression cycles occur throughout the process, known as multi-pulse high hydrostatic pressure (mpHHP). While mpHHP is more effective in deactivating harmful organisms compared to spHHP, it is significantly more expensive, making it impractical for commercial use (Buzrul 2015).

4.2.2.3. Packaging

Packaging encompasses various functions aimed at preserving, maintaining, and safeguarding products from environmental factors while also promoting user-friendliness and ease of closure (Robertson 2012). It serves to shield products from deterioration during storage and distribution, protecting them from mechanical, chemical, physical, and biological influences. Additionally, packaging helps maintain the product's properties and enhances its visual appeal, thereby enticing customers to make purchases. In meat packaging, synthetic materials like plastic films or foils are commonly utilized, often in conjunction with outer packaging such as cardboard boxes. Three primary types of meat product packaging include aerobic (AP), vacuum (VP), and modified atmosphere packaging (MAP). AP is primarily employed for raw meat, where the meat is wrapped in stretch film on polystyrene trays and sealed securely using a heat-sealing wrapping machine. This type of packaging is gas-permeable, ensuring hygienic protection without improving the durability of the product, which is guaranteed by the cold chain. Typically, meat packaged aerobically has a shelf life of about 3 to 4 days until noticeable odours and discoloration develop (Cenci-Goga *et al.* 2020). VP is a preservation technique involving the removal of air from the packaging environment. The procedure involves placing the product, already packaged in a specialized bag, into a vacuum chamber fitted with a vacuum pump to extract air (Rubio *et al.* 2006). However, it's important to note that the device typically cannot eliminate 100% of the air. Realistically, it removes around 75 to 85%, or at most 90%, from the package. The fundamental concept of MAP is to eliminate oxygen either through a barrier film or by adjusting the gaseous atmosphere around the meat. The primary gases employed in MAP are carbon dioxide (CO2), oxygen (O2), and nitrogen (N2) (Gurunathan *et al*. 2022).

4.2.2.4. Herbs and spices

While considered part of traditional meat preservation techniques, the resurgence of interest in natural ingredients devoid of synthetic additives underscores the relevance of herbs and spices in contemporary preservation methods. As such, they are worthy to be included within modern preservation practices. Plants provide a diverse range of products, with herbs and spices being particularly notable. Their utilization dates back to ancient times, aiding in balancing food compositions and extending shelf life by combatting antimicrobial activity. These natural additives are categorized as Generally Recognized as Safe (GRAS) and serve multifaceted roles similar to chemical additives (Makwana *et al.* 2015). The primary contributor to the biological activity of plants, particularly in spices and herbs, is their volatile constituents, commonly known as essential oils (EOs). These oils are chemically composed of more than seventy different compounds, including terpenes and polyphenolic compounds. Approximately 80% of the content in herbs and spices consists of these volatile compounds. These substances are known for their effective role in inhibiting microbial growth (Sultanbawa 2011). The EOs derived from herbs such as oregano, rosemary, thyme, clove, lemon balm, ginger, coriander, and marjoram have shown the best antimicrobial effects in meat and meat products so far (Aminzare *et al*. 2016; Barbosa *et al*. 2009). One of the key properties of EOs and their components is their hydrophobic nature, making their penetration into bacterial cell membrane lipids and mitochondria easier. This process disrupts their structure and increases permeability, leading to the leakage of ions and cellular contents. While bacteria may tolerate limited leakage, it impacts their bio-viability. Extensive leakage of cellular contents or ions and essential molecules ultimately leads to cell death (Bagamboula *et al*. 2004; Burt 2004). Contemporary technologies utilized to enhance the microbial and sensory attributes of meat and meat products encompass encapsulating extracts within nanoemulsions. Extracts and EOs are directly incorporated into the meat batter during the manufacturing process of meat products to leverage their antimicrobial properties (Aminzare *et al*. 2016).

4.2.3. Importance of plant antioxidants in meat preservation

In the processing of meat and meat products, antioxidants are often incorporated to inhibit lipid oxidation. Plant extracts have great antioxidant activity due to the high content of phenolic compounds. Phenolic compounds are known as secondary metabolites in plant samples and can inhibit or slow oxidation while being oxidized in the process (Lattanzio *et al.* 2009). Therefore, plant polyphenols and EOs are recognized as the primary natural sources of bioactive compounds used to extend the shelf life of meat and meat products. Synthetic antioxidants such as butylated hydroxy anisole (BHA), butylated hydroxytoluene (BHT), tert-butylhydroquinone (TBHQ), propyl gallate (PG), and nitrites are currently in limited use. It has been found that they can cause health risks due to their toxicity, thus the demand for their use has decreased considerably (Karre *et al.* 2013). Based on aromatic ring structures, phenolic compounds are divided into phenolic acid (hydroxybenzoic and hydroxycinnamic acids), flavonoids (anthocyanins, flavonols, flavones), diterper tannins (hydrolyzable and condensed tannins), stilbenes, curcuminoids, coumarins, lignans, and others (phenolic alkaloids, phenolic terpenoids, phenolic glycosides, volatile oil) (Falowo *et al.* 2014). Plant extracts are derived from plant materials through the use of various solvents and extraction methods. The extraction process aims to achieve optimal yield and quality of the desired compounds. Numerous techniques are employed to obtain antioxidants from plants, including supercritical fluid extraction (SFE), Soxhlet extraction (SE), ultrasound-assisted extraction (UAE), subcritical water extraction (SWE), and others. During the solvent extraction process, the plant materials are cleaned, washed, dried, and ground into a fine powder. Various types of solvents are used for these purposes, such as acetone, methanol, pure ethanol, 70, 80, 90% ethanol, dimethyl sulfoxide, and water (Shah *et al.* 2014). One of the antioxidant activity testing methods is the DPPH method. The DPPH test is based on the ability of a stable free radical 2,2-diphenylpicrylhydrazyl to react with hydrogen donors. In this test, after reduction by an antioxidant or radical, the solution turns from purple to light yellow. This method is chosen because it is easy, fast, and has sensitive levels that can analyse many samples (Molyneux 2004).

4.3. Characteristics of the family Moraceae

The Moraceae family, differently called the mulberry family or fig family, includes trees, herbs, climbers, or shrubs. Plants of the Moraceae family typically have simple, alternate leaves with various shapes, including ovate, elliptic, lanceolate, or palmate. The leaves may be serrated or entire, and many species have prominent veins. Flowers are often arranged in dense, spherical clusters known as heads or spikes. The flowers are typically small, unisexual, and lack petals, but they are surrounded by specialized bracts that may be colourful and conspicuous. The fruit varies widely in size, shape, and colour. Many species produce fleshy fruits, which are often consumed by animals and humans alike. One of the distinguishing features of Moraceae plants is their milky sap, known as latex, which is often present in the stems and leaves. Plant latex serves as a valuable source of pharmaceuticals, pesticides, and immune allergens. It is used as a disinfectant, anticoagulant, anti-inflammatory, and antioxidant agent. This natural substance contains plenty of unique compounds, primarily defense molecules, which act as barriers, safeguarding plants against microbial threats and herbivores (Tripathi & Upadhyay 2021). The family is widely distributed across tropical and subtropical regions of the world, with many species adapted to different ecological niches. Numerous species within the Moraceae family hold considerable economic value. Fruits such as figs, mulberries, and breadfruit are prized as food sources, while plants like rubber trees are specifically grown for their latex, a crucial component in rubber manufacturing (Berg & Eggli 2023).

4.3.1. Classification of the family Moraceae

Moraceae represents a family of higher dicotyledonous plants within the Rosales order, including 38 genera and more than 1100 species (Leite *et al*. 2018). Classification within the family Moraceae is based on various morphological characteristics, including leaf shape, flower structure, and fruit type. Some of the well-known genera within the Moraceae family include *Artocarpus*, *Dorstenia*, *Ficus*, and *Morus* (Clement & Weible 2009).

4.3.1.1. Genus *Ficus*

The genus *Ficus*, commonly known as fig trees, comprises around 850 species, representing a diverse group of plants with distinct characteristics. Their leaves are typically alternate, and simple, with margins that can be smooth or toothed, and they vary in shape from ovate to elliptic, with textures ranging from glossy to matte. Figs, the fruit of *Ficus* trees, are notable for their unique structure - a type of inverted flower lining the inside of a fleshy, pear-shaped structure called a syconium. These figs come in a range of colours, including green, yellow, purple, and black, depending on the species and ripeness. *Ficus* trees exhibit a variety of growth habits, including shrubs, vines, and large trees, with many species characterized by aerial roots that grow downward from branches, providing additional support and absorbing moisture. Native to tropical and subtropical regions worldwide, *Ficus* trees thrive in diverse habitats, from rainforests and dry forests to savannas and coastal areas. Some species are also cultivated as ornamental plants in temperate regions. Beyond their ecological importance, *Ficus* trees hold cultural and religious significance in numerous societies, often considered sacred and associated with myths, rituals, and spiritual beliefs. Additionally, figs have been cultivated for their edible fruit for millennia, remaining a nutritious food source consumed in various parts of the world (Lansky & Paavilainen 2010).

The following Table 1. demonstrates ethnobotanical and chemical data of the plants from the genus *Ficus.* In some instances, specific information, mostly local names for certain species, may not be available. In these cases, the corresponding box is marked as "not available" (NA).

Table 1. Ethnobotanical and chemical data of the genus *Ficus*

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
1.	*Ficus auriculata*	Elephant ear fig tree	Timla, Gular, Tremal	India, China, Nepal	Leaves	Kaempferol; quercetin; myricetin; betulinic acid; lupeol; stigmasterol; bergapten; scopoletin; β-sitosterol-3-O-β-dglucopyranoside	1.2.
2.	*Ficus benghalensis*	Banyan fig	Barh, Aala, Marri Chettu	India	Aerial roots	Saponins; tannins; glucoside; flavonoids; β-Sitosterol-α-d-glucose; meso-inositol	3.
3.	*Ficus capensis*	Cape fig	Umukuyu	Tropical Africa and the Cape Islands	Stem bark	Alkaloids; balsams; carbohydrates; flavonoids; free anthraquinones; tannins; glycosides; terpenes; resins; sterols; saponins; glycosides	4. 5. 6.
					Leaves	Carvacrol; α-caryophyllene; caryophyllene oxide; linalool; 3-tetradecanone; geranylacetone; 3,7,11-trimethyl-3-hydroxy6; 10-dodecadiene-1-yl acetate; hexahydrofarnesyl acetone	
4.	*Ficus carica*	Common fig	Incir	Western Asia, Mediterranean	Dried fruit	Alkaloids; flavonoids; coumarins; saponins; rennin; caoutchouc; resin; albumin; cerin; sugar; terpenes	7. 8. 9. 10.
					Latex	Diastase; esterase; lipase; catalase; and peroxidase; malic acid	
					Leaves	Psoralen; bergapten; rutin; quercetin; luteolin; ferulic acid; taraxasterol; coumarins; saponins	
					Pulp	Chlorgenic acid	
					Peel	Quercitin-3-O-rutinoside; psoralen	

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
5.	*Ficus cordata*	Namaqua fig	Melkboom, Namakwavy	Namaqualand	Stem bark	Pentacyclic triterpenes 8,26-cyclo-urs-21-en3β, 20β-diol; 3β-acetoxy-8, 26-cyclo-ursan-20β-ol; 3-friedelanone; oleanolic acid; betulinic acid; lupeol acetate; α and β amyrine; 3,5,7,4′-tetra hydroxyl flavones	11.
6.	*Ficus deltoidea*	Mistletoe fig	Mas Cotek, Serapat Angin, Telinga Beruk	Malayan Archipelago	Leaves	Triterpene; conrauidienol; dihydroflavonol; conrauiflavonol; 3,4',5-trihydroxy-6'',6''-dimethylpyrano[2,3-g] flavone; β-amyrin acetate; 6β-hydroxystigmasta-4,22-dien3-one; 8-prenyl apigenin; betulinic acid; ursolic acid; luteolin; catechin; epigallocatechin; orientin; β-sitosterol glucoside	12. 13.
7.	*Ficus lyrata*	Fiddle leaf fig	Banjo fig	Central and West Africa	Stem bark and leaves	Lupeol acetate; arabinose; α and β amyrine; *α* -amyrinacetate; 3*β*-acetoxy-20-taraxasten-22-one; 3*β*-acetoxy-11*α*-methoxy-12-ursene; 3-O--L-arabinopyranosyl-4-hydroxybenzoic acid; 3,4-dihydroxy benzoic acid; stigmastane-3,6-dione; stigmasterol; *β*-sitosterol	14.
					Fruit	Catechin; luteolin-6.8-C-diglukoside; rientin; arabinose; β-amyrins; β-carotene; glycosides; β-setosterols	
8.	*Ficus microcarpa*	Chinese banyan	Gajumaru	Tropical Asia, Australasia, and Pacific regions	Aerial roots Leaves	Friedelin; lupeol; oleanolic acid; ursolic acids Catechin; epicatechin; isovitexin	15. 16.
9.	*Ficus palmata*	Punjab fig	Anjiri, Heibam, Pepri	Pakistan, northern India, Afghanistan	Stem bark	Cetyl behenate; lupeol; α-amyrin acetate	17. 18.

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
10.	*Ficus polita*	Wild rubber tree	Umkhiwane, Umphumela	Tropical Africa	Roots	Betulinic acid; ursolic acid; trihydroxy-stilbene-3; 5-O-βd-diglucopyranoside; euphol-3- ocinnamate; lupeol; taraxar-14-ene	19.
11.	*Ficus religiosa*	The Peepal tree	Ashud, Ashvattha, Jari, Piplo	India, Sri Lanka	Bark	Bergapten; bergaptol; lanosterol; leucocyanidin-3-Oβ-glucopyranosid; leucopelargonidin-3-Oβ-d-glucopyranoside; leucopelargonidin-3-O-α-lrhamnopyranoside; lupeol; acetyl behenate; acetate; tannin; wax; saponin	20. 21. 22. 23. 24.
					Fruit	Kaempferol; quercetin; myricetin; undecane; tridecane; tetradecane; α-thujene; α-pinene; β-pinene; α-terpinene; limonene	
					Leaves	Eugenol; 2-phenylethyl alcohol; benzyl alcohol; hexenol; n-hexanol; phytol; phenol; salicylaldehyde; phenylacetaldehyde; allyl caproate; linalool; n-nonanal; adipoin; methylcyclopentane, 2-dione; itaconic anhydride	
12.	*Ficus retusa*	Indian laurel fig	Phrapsi Thapsi	India, China	Leaves	1,2-Benzenedicarboxylic acid-dibutyl ester; phenol; 4-(2aminopropyl); butyrolactone	25. 26.
					Aerial parts	Luteolin; afzelechin; catechin; vitexin; β-sitosterol acetate; β-amyrin acetate; moretenone; β-amyrin; β-sitosterol; friedelenol	
13.	*Ficus sagittifolia*	Fiddle leaf fig	NA	Sub-Saharan West Africa	Stem bark	Genistein; 2′-hydroxygenistein; 2R-eriodictyol; erycibenin A; moracin P; peucedanol; dihydrophaseic acid	27.

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
14.	*Ficus sycomorus*	Sycamore fig	Teen al-Jamal	Africa (Nile Delta region)	Whole plant	Quercetin; quercetin 3-O-lrhamnopyranosyl (1-6)-β-dglucopyranoside; quercetin 3-O-β-d-glucopyranoside (isoquercitrin); quercetin 3,7-O-αl-dirhamnoside; quercetin; 3-O-β-d-galactopyranosyl(1-6)-glucopyranoside; β-Sitosterol-3-β-dglucopyranoside; gallic acid	28. 29.
15.	*Ficus pumila*	Creeping fig	Bata, Jalar, Lata	Japan	Leaves and stem	Amyrin acetate; α-amyrin acetate; lupeol; β-amyrin; α-amyrin; rhoiptelenol; 3α-hydroxyisohop-22(29)-en-24-oic acid; lupenyl acetate; ursolic acid; betulinic acid	30. 31.
16.	*Ficus tsiela*	Bat tree	Chela, Ichi, Koyali, Pipri	India, Sri Lanka	Whole plant	Gallic acid; lupeol; carbohydrates; glycosides; saponins; resins; fat; flavonoids; tannins; and phenolic compounds. Alkaloids and steroid are absent	32. 33.

1. (Mehra & Tandon 2021) 2. (El-Fishawy *et al*. 2011) 3. (Aswar *et al*. 2008) 4. (Esievo *et al*. 2018) 5. (Oyeleke *et al*. 2008) 6. (Salem *et al*. 2013) 7. (Badgujar *et al*. 2014) 8. (Vaya & Mahmood 2006) 9. (Aref *et al*. 2010) 10. (Jeong *et al*. 2009) 11. (Poumale *et al*. 2008) 12. (Bunawan *et al*. 2014) 13. (Omar *et al*. 2011) 14. (Ramadan *et al*. 2009) 15. (Riefner 2016) 16. (Chiang & Kuo 2002) 17. (Mubashir & Shah 2011) 18. (Al-Qahtani *et al*. 2023) 19. (Kuete *et al*. 2011) 20. (Rutuja *et al*. 2015) 21. (Al-Snafi 2017) 22. (Rajiv & Sivaraj 2012) 23. (Makhija *et al*. 2010) 24. (Poudel *et al*. 2015) 25. (Aly *et al*. 2013) 26. (Sarg *et al*. 2011) 27. (Taiwo *et al*. 2023) 28. (Mohamed *et al*. 2010) 29. (El-Sayed *et al*. 2010) 30. (Kitajima *et al*. 1994) 31. (Qi *et al*. 2021) 32. (Hakiman *et al*. 2012) 33. (Bunawan *et al*. 2014)

Table 1. shows that *Ficus carica* and *Ficus lyrata* have demonstrated significant potential for meat preservation due to the abundance of beneficial chemical compounds found in nearly all parts of these plants, allowing for comprehensive utilization. Numerous studies have shown that both the fruits and leaves of the Common fig possess a range of biological properties, primarily attributed to the presence of phenolic compounds. These properties encompass anticancer, antibacterial, antioxidant, and anti-inflammatory effects (Solomon *et al*. 2006; Vaya *et al*. 2006). According to Teixeira *et al*. (2006) and their study, the phytochemical analysis reveals that the aqueous extract of ripe dried fruit of *F. carica* contains enough phenolic compounds, which could be used for preventing meat spoilage. Due to the lack of studies, *F. carica* can be suggested for future more detailed investigation in its application directly to meat to increase its preservation.

On the other hand, extracts from *F. lyrata* were already tested on the chicken carcass and according to Wira *et al*. (2020), the results indicated that the fruit extract of *F. lyrata* is not toxic up to a concentration of 15000 mg/kg BW, affirming its safety for application. Implementing of the fruit extract to preserve chicken carcasses extends the shelf life by up to 12 hours, resulting in decreased pH to 5.59, lowered meat temperature by up to 24.3 °C, and absence of initial decay detected until 12 hours. *F. lyrata* was subjected to testing against pathogens including *Escherichia coli*, *Pseudomonas aeruginosa*, and *Bacillus subtilis*, revealing antimicrobial activity in its fruit extract. Among these microbes, *B. subtilis* exhibited the most significant inhibitory effect. This could be attributed to its status as a gram-positive bacterium, making it more susceptible to antimicrobials compared to the gram-negative bacteria *E. coli* and *P. aeruginosa*, which are generally more resistant (Jagathambal *et al*. 2011). In another study, leaves of *F. lyrata* were examined concerning broiler chicken meat. The inclusion of *F. lyrata* leaf extract effectively manages microbial growth in broiler chicken. While soaking treatment in *F. lyrata* leaf extract does not entirely eliminate microbial presence, it does inhibit microbial growth, resulting in lower levels compared to untreated samples (Djali *et al*. 2019).

4.3.1.2. Genus *Dorstenia*

The genus *Dorstenia* encompasses approximately 117 accepted named species of flowering plants, distributed from Central to South America, Africa, and even Asia (Peniche-Pavía *et al*. 2018). These plants are typically characterized by their succulent or herbaceous nature, with some species exhibiting shrub-like growth habits. One notable characteristic of *Dorstenia* species is their unique inflorescence structure. The flowers are often inconspicuous and are surrounded by specialized bracts, forming a structure known as a hypanthodium. This complex arrangement plays a crucial role in pollination, attracting specific pollinators such as flies or ants. *Dorstenia* plants are adapted to various habitats, including rocky areas, forests, and savannahs. They often thrive in well-drained soils and are resilient to drought conditions. Some species of *Dorstenia* have cultural or medicinal significance in certain regions, where they may be used in traditional medicine or as ornamental plants (Misiewicz & Zerega 2012).

The following Table 2. demonstrates ethnobotanical and chemical data of the plants from the genus *Dorstenia.*

Table 2. Ethnobotanical and chemical data of the genus *Dorstenia*

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
1.	*Dorstenia arifolia*	Sapling-leaved dorstenia	NA	Brazil	Leaves	α-amyrin; β-amyrin; α-amyrin acetate; β-amyrin acetate; α-amyrin octanoate; β-amyrin octanoate; glutinol; glutinyl acetate; taraxeryl acetate; lupenyl acetate; lanosta-8,24-dien-3-yl acetate; psoralen	1.
2.	*Dorstenia barnimiana*	Barnim's dorstenia	NA	Burundi, Cameroo, Ethiopia, Kenya	Roots	Alkaloids; flavonoids; phenols; saponins; tannins	2.
3.	*Dorstenia barteri*	Wild pear	Mbongo	Cameroon, Congo, Gabon	Twigs	Bartericins A, B, C, D; stipulin; kanzonol B; 3'-(2-hydroxy-3-methylbut-3-enyl)-4,2',4'-trihydroxychalcone, β-sitosterol and its 3-β-D-glucopyranosyl derivative	3.
4.	*Dorstenia brasiliensis*	Brazilian dorstenia	Carapiá	Argentina, Bolivia, Brazil	Roots	Smyrindiol; dorstenic acid A and B; isopimarane-type diterpenoid; bartericin A, B; stigmasterol; isobavachalcone, 4-hydroxylonchocarpin, dorsmanin F, 6,8-diprenyleridictyol, quercetin; quercitrin; amentoflavone; psoralen; bergapten; umbelliferone	4.
5.	*Dorstenia ciliata*	Hairy dorstenia	Efiok, Ewe Abamoda	Cameroon, Gabon, Nigeria	Aerial parts	Ciliatins A, B; stipulin; 8-prenylapigenin; 6-prenylapigenin; luteolin; canniflavone; dinklagin C; poinsettifolin A	5. 6.
6.	*Dorstenia contrajerva*	Snakewort	Contrajeva	From South Mexico to Venezuela	Aerial parts	Bergapten; 4-[[3-(4,5-dihydro-5,5-dimethyl-4-oxo-2-furanyl)butyl]oxy]-7H-furo[3,2-g]; benzopyran-7-one; bergaptol; catechin; epicatechin	7.

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
7.	*Dorstenia convexa*	Convex dorstenia	NA	Cameroon, Congo, Zaïre	Twigs	Lupane triterpenes; betulonic acid; platanic acid; betulinic acid; 3,20-dioxo-30-norlupan-28-oic acid; lupenone; and 29-norlupan-3,20-dione; ubiquitous lupeol; β-sitosterol glucopyranoside	8. 9.
8.	*Dorstenia dinklagei*	Dinklage's dorstenia	NA	Angola, Cameroon, Congo, Gabon, Zaïre	Twigs	α-amyrenonyl acetate; 3β-acetoxy-1β,11α-dihydroxy-olean-12-ene; α-amyrin acetate; β-acetoxy-6α-hydroxy-11-oxoisobauerene (dinklagenonoate)	10.
9.	*Dorstenia elliptica*	Elliptical dorstenia	NA	Cameroon, Congo, Gabon	Twigs	3-(3,3-dimethylallyl)-4,2′,4′-trihydroxylchalcone, psoralen, bergapten, *O*-[3-(2,2-dimethyl-3-oxo-2*H*-furan-5-yl)butyl]bergaptol, β-sitosterol; β-D-glucopyranoside	11.
10.	*Dorstenia foetida*	Stinking dorstenia	Ogberi, Maningo, Akukon	Nigeria, Cameroon, and Ghana	Leaves	5-(2,3-epoxy-3-methyl-butoxy)-chalepensin; 5-methoxy-3-(3-methyl-2,3-dihydroxybutyl)-psoralen-diacetate; 5-methoxy-3-[3-(*β*-D-glucopyranosyloxy)-2-acetyloxy-3-methyl-butyl]-psoralen; psoralen; bergapten; isopimpinellin; phellopterin; 5-methoxychalepensin; turbinatocoumarin	12.
11.	*Dorstenia gigas*	Gigantic dorstenia	Kartab	Socotra Island	Twigs and leaves	Swietenocoumarin B; furanopinnarin; dimethoxychalpensin; isoimperatorin; cnidilin; oxypeucedanin; byakangelicin; isopimpinellin; swietenocoumarin; 5-methoxychalepensin; turbinatocoumarin; malonylturbinatocoumari; phellopterin	13.

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
12.	*Dorstenia mannii*	West African dorstenia	Oko-omoba, Obianwu	Cameroon, Congo, Equatorial Guinea, Gabon, Nigeria	Twigs and leaves	Dorsmanin A, B, C, D, E, F, G; 6-prenylchrysoeriol; 6,8-diprenyleriodictyol; 5,6-7,8-*bis*-(2,2-dimethylchromano)-3′,4′-dihydroxyflavanone; 6-prenyl-8-(2-hydroxy-3-methylbut-3-enyl)-5,7,3′,4′-tetrahydroxyflavanone	14. 15.
13.	*Dorstenia picta*	NA	NA	Cameroon, Congo, Gabon, Nigeria	Leaves and twigs	Coumarin; bergapten; psoralen; β-sitostero; β-sitosterol glucopyranoside; oleanolic acid	16.
14.	*Dorstenia psilurus*	Common dorstenia	NAA	Angola, Cameroon, Congo, Gabon, Malawi	Roots	Dorsilurins F, G, H, I, J, K; artelasticin; quercetin; gallic acid; ascorbic acid; flavonoids; phenolics	17. 18.

1. (Fingolo *et al*. 2013) 2. (Derebe *et al*. 2021) 3. (Ngameni *et al*. 2004) 4. (Bieski *et al*. 2012) 5. (Peniche-Pavía *et al*. 2018) 6. (Ngadjui *et al*. 2002) 7. (Caceres *et al*. 2001) 8. (Omisore *et al*. 2005) 9. (Poumale *et al*. 2011) 10. (Vouffo *et al*. 2008) 11. (Abegaz *et al*. 2004) 12. (Heinke *et al*. 2011) 13. (Peniche-Pavía *et al*. 2018) 14. (Dufall *et al*. 2003) 15. (Ngadjui *et al*. 1999) 16. (Vouffo *et al*. 2008) 17. (Tabopda *et al*. 2008) 18. (Somaida *et al*. 2020)

Among the plants listed in Table 2., *Dorstenia ciliata* and *Dorstenia psilurus* deserve special mention. Both plants were mentioned in the study by Kansci *et al.* (2003), where they were observed to be used as ingredients for food preservation and as recipes in traditional Cameroonian medicine. Additionally, they exhibited robust anti-radical activity when assessed using the DPPH test. The research revealed that the leaf extract of *D. ciliata* demonstrated slightly superior anti-radical activity compared to the root extract of *D. psilurus*. Furthermore, a new phenolic compound, 6-prenylapigenin, was identified in *D. ciliata*, although its anti-radical activity was found to be weaker compared to the extracts. A different study focused on another significant plant from the genus *Dorstenia*, named as *Dorstenia mannii*. Mbaveng *et al.* (2012) demonstrated the antioxidant activity of prenylated flavonoids extracted from this plant. The prenylated compounds tested included dorsmanin A, B, C, D; 6,8-diprenyleriodictyol, as well as dorsmanin E, F, and G. These compounds, along with the crude methanol extract, underwent examination for their antimicrobial effects against various bacteria and yeasts, including strains of *Candida albicans*, *Enterobacter aerogenes*, *E. coli*, *Klebsiella pneumoniae, Providencia stuartii*, and *P. aeruginosa*. The findings revealed that dorsmanin C and G effectively inhibited the growth of all microorganisms studied, encompassing mycobacteria, yeast, and gram-negative bacteria, while other compounds displayed selective activities.

In another study, three compounds (6,8-diprenyleriodictyol, dorsmanin C and dorsmanin F) were compared to the common, non-prenylated flavonoid, quercetin. The prenylated flavonoids were found to be potent scavengers of the stable free radical in DPPH test and are more potent than BHT. Unlike quercetin, they did not show any pro-oxidant activity, which is highly desirable. The data presented here are highly significant, especially considering the medical relevance of the examined microorganisms. Thus, the comprehensive findings of this study offer compelling evidence that both the crude extract of *D. mannii* and certain of its compounds could serve as valuable natural antimicrobial and antioxidative agents for meat preservation (Duffal *et al.* 2003; Mbaveng *et al.* 2012).

4.3.1.3. Genus *Artocarpus*

The genus *Artocarpus* comprises approximately 50 species of flowering trees and shrubs distributed across tropical regions such as Bangladesh, Burma, Indonesia, China, Sri Lanka, Thailand, Philippines, parts of Africa, Australia, Brazil, and Florida. These plants are renowned for their diverse and economically important fruits, as well as their cultural significance in various parts of the world (Jagtap & Bapat 2010). One distinctive characteristic of *Artocarpus* species is their large, compound fruits known as syncarps. These syncarps, which develop from the aggregation of numerous individual flowers, vary in size, shape, and flavour among different species (Hari *et al*. 2014). *Artocarpus* trees are typically evergreen or deciduous, with simple, alternate leaves that can vary widely in size and shape. Some species have deeply lobed or serrated leaves, while others have smooth-edged foliage. These plants are often cultivated for their edible fruits, which serve as important food sources in many tropical countries. Additionally, various parts of *Artocarpus* trees, including the bark, roots, and leaves, may have medicinal properties and are used in traditional medicine practices. In addition to their economic and medicinal significance, *Artocarpus* species are valued for their timber, which is used in construction and woodworking. The wood of certain species is prized for its strength, durability, and attractive grain patterns (Jagtap & Bapat 2010).

The following Table 3. demonstrates ethnobotanical and chemical data of the plants from the genus *Artocarpus.*

Table 3. Ethnobotanical and chemical data of the genus *Artocarpus*

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
1.	*Artocarpus altilis*	Breadfruit	Sukun, Beta, Kapiak, Kuru	South Pacific, Southeast Asia	Peels	Alkaloids; flavonoids; phenols; tannins; glycosides	1. 2.
					Bark	Prenylated stilbenoids	
					Cortex	Artocarpin; norartocarpetin; cycloartocarpin; artonol B; cyclomorusin; artoflavone A; cyclogeracommunin; and artonin M; prenylated stilbenoids; flavonoids; isocycloartobiloxanthon; furanocyclocommunin	
					Fruits	Flavonols; tannins; catechins; monoterpenes	
					Leaves	Phenols; flavonoids; prenylated aurone; cycloaltilisin 7; artocarpaurone; prenylated chalcones; prenylated flavanones; triterpens; hexadecanoic acid; cis-13-octadecenoic acid; and cinnamic acid	
					Root and seeds	Prenylflavonoids; triterpenoids	
2.	*Artocarpus camansi*	Breadnut	Kelur, Pakau, Kapiak, Mei kakano	New Guinea, Moluccas, Philippines	Leaves and stem	Friedelinol; squalene; β-sitosterol; stigmasterol; phytol; polyprenol; cycloartenol	3.
					Peels	Steroids; triterpenoids	
3.	*Artocarpus dadah*	Gombang tree	NA	Borneo, Laos	Bark and twigs	3-(γ,γ-dimethylallyl)resveratrol; 5-(γ,γ-dimethylallyl)oxyresveratrol; 3-(2,3-dihydroxy-3-methylbutyl)resveratrol; 3-(γ,γ-dimethylpropenyl)moracin M; oxyresveratrol; catechin; afzelechin-3-O-α-l-rhamnopyranoside; epiafzelechin; dihydromorin; catechin; engeletin; dadahols A and B	4.

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
4.	*Artocarpus heterophyllus*	Jackfruit	Kathal	Western Ghats	Flowers	Carotenoids; flavonoids	5. 6.
					Leaves	Chromones; flavonoids; catechin; chlorogenic acid;	
					Roots	Free 6- or 8-prenylated substituted flavones; free 8-geranyl substituted flavones; free 3- prenylated substituted flavones	
					Bark and pulp	Flavonoids; phenols; saponins; (epi)catechin; glycosides	
					Seeds	Flavonoids; tannins; steroids; glycosides; saponins; anthraquinones; phenols	
5.	*Artocarpus hirsutus*	Wild jack	Hesava, Anjili, Perpela	India	Stem	Sterols; triterpenoids; flavonoids; tannins; saponins	7.
					Leaves	Glycosides; alkaloids; sterols; triterpenoids; flavonoids; tannins; saponins	
					Fruits	Alkaloids; flavonoids; glycosides; saponins; terpenoids	
6.	*Artocarpus kemando*	Squirrel's jack	Bodut, Dusun, Kudu	Malaya, Sumatera, Thailand	Stem bark	Artomandin; artoindonesianin C; artonol B; artochamin A; β-sitosterol	8.
7.	*Artocarpus lakoocha*	Monkey fruit	Tampang, Badhal, Myankdok	Bangladesh, Bhutan, Cambodia, Vietnam	Bark	Lakoochanone; lakoochanosides; catechin; moracin C; integrin; cycloartenone; engeletin; isogemichalcone B; morachalcone A; heterophyllene B; albanin A; moracin M; artocarpesin; artocarpin; norartocarpin; resveratrol; artocarpanone; oxyresveratrol	1. 9.
					Leaves	Flavonoids; phenols; tannins; eicosane; diethyl phthalate; 9-octyl eicosane	
					Fruits	Flavonoids; tannins; terpenoids; saponins; glycosides; alkaloids; steroids; quercetin; kaempferol	

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
8.	*Artocarpus lanceifolius*	Keledang tree	Keledang, Timakon, Kaliput	Indonesia	Bark	Artoindonesianins Z-4; artonin E; 12-hydroxyartonin E; artobiloxanthone; cycloartobiloxanthone	10.
9.	*Artocarpus integer*	Chempedak	Sonekadat, Kathar, Chakka	India, Sri Lanka	Leaves and bark	Epiafzelechin; epicatechin; 3β-hydroxy-7α-methoxy-24β-ethylcholest-5-ene; isobavachalcone; kuwanon J; integrin; morachalcone A; apigenin; scopoletin; ferulic acid; luteolin; artonin F; heteroflavanone A; cudraflavone C; cyclocommunol	11.
10.	*Artocarpus odoratissimus*	Marang	Terap, Johore jak	Southeast Asia	Roots	Pinocembrin and pinostrobin; α-amyrin acetate and ß-amyrin acetate	12.
					Bark	Traxateryl acetate and hexyl dodecanoate	
					Leaves	β-Sitosterol and stigmasterol	

1. (Chaurasia S & Pandey A. 2023.) 2. (Sikarwar *et al*. 2014) 3. (Tsai *et al*. 2013) 4. (Su *et al*. 2002) 5. (Jagtap *et al*. 2010) 6. (Zheng *et al*. 2014) 7. (Nayak *et al*. 2017) 8. (Ee *et al*. 2011) 9. (Bhattacharya *et al*. 2019) 10. (Musthapa *et al*. 2009) 11. (Shah *et al*. 2016) 12. (Yen *et al*. 2017)

According to Table 3., *Artocarpus heterophyllus* appeared as the best candidate. It contains a large amount of antioxidant substances, among which artocarpin is worthy of mention. Artocarpin was initially discovered in the root of *A. heterophyllus* and subsequently found in species like *A. altilis* and *A. lakoocha*. Several studies have provided insights into the artocarpin content in extracts derived from various solvents and Artocarpus species. Known for its cytotoxic, anti-inflammatory, antioxidant, and antimicrobial properties, artocarpin could be tested to prolong shelf life of meat (Chan *et al*. 2018; Wang *et al*. 2022).

Additionally, *A. heterophyllus*, unlike other members of the genus, was also investigated when directly applied to meat. Jackfruit seed extract, recognized as a natural preservative, demonstrates the ability to extend the shelf life of meat without any adverse effects. These extracts offer potential for enhancing the shelf life of stored meat under natural conditions, without compromising its quality or taste. Research by Ramli *et al*. (2021) highlights the strong antibacterial properties of jackfruit seed extract. Analysis using DPPH reveals that *A. heterophyllus* seed extract possesses satisfactory radical scavenging capacity, effectively neutralizing free radicals generated during meat oxidation. This research suggests that jackfruit seed could serve as a promising source of natural antioxidants. Nevertheless, further studies are necessary to elucidate the specific structures contributing to observed bioactivities and to investigate the in vivo antioxidant and hypoglycemic effects.

Another study examined total water extract, ethyl acetate, and aqueous fractions from the leaves of *A. heterophyllus*, assessing their phenolic content, antioxidant, and antibacterial activities against foodborne pathogens such as *Bacillus cereus, Enterococcus faecalis, E. coli*, *Listeria monocytogenes*, *Salmonella typhimurium*, *Salmonella enterica*, and *Staphylococcus aureus*. *A. heterophyllus* has shown antimicrobial activity against certain foodborne pathogens and also exhibited notable antioxidant activity. These findings suggest that *A. heterophyllus* could serve as a promising source of polyphenols as functional components, which could be utilized in the development of functional foods with health-promoting properties (Loizzo *et al*. 2010).

4.3.1.4. Genus *Morus*

The genus *Morus*, commonly known as mulberries, includes approximately 24 species of deciduous trees and shrubs. These plants have a wide distribution across Asia, Europe, North America, South America, and Africa and are highly valued for their edible fruits, ornamental characteristics, and cultural significance (Ercisli & Orhan 2007). One characteristic feature of *Morus* species is their distinctive foliage. The leaves are typically alternate, simple, and serrated, with varying shapes and sizes depending on the species. Mulberry leaves are an important food source for silkworms, which are cultivated for silk production, making *Morus* trees economically significant in sericulture (Gurjar *et al*. 2018). The fruits of *Morus* trees, known as mulberries, come in a variety of colours, including black, red, purple, and white, depending on the species and cultivar. Mulberries are sweet and juicy, often consumed fresh or used in jams, jellies, pies, and other culinary preparations. They are also rich in vitamins, minerals, and antioxidants, contributing to their nutritional value. *Morus* species are generally hardy and adaptable, thriving in a range of soil types and climatic conditions. They are often cultivated as ornamental trees in gardens and landscapes due to their attractive foliage, colourful fruits, and shade-providing canopy. In addition to their culinary and ornamental uses, *Morus* trees have been used in traditional medicine for their various health benefits. Extracts from different parts of the plant, including the leaves, bark, and roots, are believed to possess medicinal properties and have been used to treat various ailments in folk medicine practices (Chen *et al*. 1995).

The following Table 4. demonstrates ethnobotanical and chemical data of the plants from the genus *Morus.*

Table 4. Ethnobotanical and chemical data of the genus *Morus*

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
1.	*Morus alba*	White mulberry	Bái Sāng	China	Fruits	Rutin; isoquercitrin; rutoside; morin; isoquercetin; quercetin; kaempferol; taxifolin hexoside; dihydrokaempferol-hexoside; morusin; chlorogenic acid; 4-hydroxycinnamic acid	1. 2.
					Leaves	Isoquercitrin; rutin; quercitrin; astragalin; skimming; chlorogenic acid	
					Twigs	Kuwanon G; morusin mulberroside A; oxyresveratrol; 4-hydroxycinnamic acid	
					Root bark	Taxifolin; kuwanon G; morusin; mulberroside A; oxyresveratrol; chlorogenic acid	
2.	*Morus australis*	Korean mulberry	Kiskuri, Nuni	East and Southeast Asia	Leaves	Quercetin; kaempferol; rutin; cyanidin; delphinidin; pelargonidin derivatives; caffeic acid; ferulic acid and chlorogenic acid	3.
					Root bark	Australone A; morusin; kuwanon C; betulinic acid; beta-amyrin; quercetin; ursolic acid	
3.	*Morus cathayana*	Chinese mulberry	Hua Sang	China	Root bark	Quercetin; kaempferol; rutin; myricetin; luteolin; australone B; morusin; mulberroside A; moracin C; mulberrofuran G; mornigrol D; albafuran C; sanggenols F; cathayanon A, B	4.
4.	*Morus indica*	Indian mulberry	Shahatut, Tuti	Sub-tropical Himalayan region	Leaves and roots	Ascorbic acid; tocopherol; b-carotene; glutathione; *N*-methyl-1-Deoxynojirimycin; Kwanon G, H; Moracin A-Z; Albanins A-H; γ-aminobutyric acid, *L*-asparagine; *L*-arginine; *L*- lysine; choline; Mulberrofuran I	5. 6.

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
5.	*Morus insignis*	Andean mulberry	Mengkudu hutan, Pokok tut	Central and South America	Leaves	Mulberrofuran U and moracin M-3-O-β-D-glucopyranoside; β-sitosterol; β-sitosterol-3-O-β-glucopyranoside; ursolic acid; moracin M; kaempferol-3-O-β-glucopyranoside and quercetin-3-O-β-glucopyranoside	7.
6.	*Morus laevigata*	Large white fruit	Mora, Morera	NA	Fruit	Citrulline; hydroxyproline; free amino acids	7. 8.
7.	*Morus macroura*	Himalayan mulberry	Shatoot	NA	Stem	Guangsangons A-N; albafuran C; Kwanon J, X, Y; Mulberrofuran G, K, J	7. 9.
8.	*Morus mongolica*	Mongolian mulberry	Huang sang, Kuwa	China, Japan, Korea	Stem and root	Pyranoflavanone; sanggenol L; sanggenol M; 2-arylbenzofurans with isoprenoid units; mulberrofurans W−Z	10.
9.	*Morus nigra*	Black mulberry	Moral negro, Kara dut	Western Asia to the eastern Mediterranean	Fruits	Cyanidin-hexoside; cyanidin-pentosyl-hexoside; cyanidin-rhamnosyl-hexoside; cyanidin-sambubiosyl-rhamnoside; cyanidin-sambubiosyl-glucoside; petunidin-pentoside; peonidin-hexoside; kaempferol-rhamnoside, kaempferol-hexoside; kaempferol- rhamnosyl-hexoside; kaempferol-dihexoside; quercetin-rhamnoside; quercetin-hexoside; quercetin-rhamnosyl-dihexoside; rutin; morin; quercetin; kaempferol; apigenin-hexoside; apigenin-dihexoside); chlorogenic acid	11. 12. 13. 14. 1.
					Leaves	Cyanidin; quercetin; rutin; kaempferol; catechin; caffeic acid; coumaric acid; syringic acid	
					Twigs	Morunigrols A, B, C, D; cudraflavone B; morusin; moracin C and P; morunigrines A and B	
					Roots bark	Kuwanon L, G and H; morusin; chalcomoracin; norartocarpetin; oxyresveratrol	

(continued)

	Scientific name	English name	Local name	Area of origin	Plant part	Phytochemical compounds	Sources
10.	*Morus rubra*	Red mulberry	Murier	North America	Fruits	Cyanidin 3,5-diglucoside; cyanidin 3-glucoside; cyanidin 3-rutinoside; pelargonidin 3-glucoside; peonidin 3-glucoside; rutin; isoquercitrin; rutoside; morin	15. 16.
					Leaves	Isoquercitrin; rutin; quercitrin; astragalin; skimming; chlorogenic acid	
11.	*Morus serrata*	Himalayan mulberry	NA	Assam, Pakistan	Root	β-Amyrin acetate; betulinic acid; cerylalcohol; quercetin; morin	6. 17.

1. (Zelová *et al*. 2014) 2. (Memete *et al.* 2022) 3. (Liao *et al*. 2017) 4. (Wei *et al*. 2016) 5. (Roy *et al*. 2010) 6. (Boro *et al*. 2021) 7. (da Silva Almeida *et al*. 2012) 8. (Wang *et al*. 2015) 9. (Farrag *et al*. 2017) 10. (Kang *et al*. 2006) 11. (Zorzi *et al*. 2020) 12. (Figueredo *et al*. 2018) 13. (Qu *et al*. 2021) 14. (Mascarello *et al*. 2018) 15. (Koca *et al*. 2008) 16. (Gundogdu *et al*. 2011) 17. (Janakirama *et al*. 2021)

Among the plants from the table 4., *Morus alba* has shown a large amount of flavonol groups that can be used to fight oxidation and thus extend the shelf life of meat. Furthermore, an enhancement in pork quality was noted upon incorporating 15% *M. alba* leaf powder (MLP) into the pig's diet. This supplementation led to an increase in intramuscular fat content, pH levels, meat colour, and antioxidative capacity. The addition of 15% MLP proved to be the most promising concentration, maintaining growth, intake, and carcass performance, while also mitigating oxidative stress and improving blood metabolites (Zhu *et al*. 2019). Additionally, MLP exhibited the capability to improve lamb meat's redness, quality, and shelf life (Ouyang *et al*. 2020). According to Zhang *et al*. (2016), extracts from *M. alba* leaves can effectively prevent the oxidation of oxymyoglobin and metmyoglobin, thus preserving the colour of refrigerated beef. Additionally, these leaf extracts significantly decrease peroxide and thiobarbituric acid reactive substances values while enhancing superoxide dismutase and glutathione peroxidase activities during beef storage. This indicates that mulberry leaves possess the ability to reduce lipid oxidation reactions. Consequently, *M. alba* leaves serve as a beneficial supplement for ruminants and pigs and act as natural antioxidants, thereby preserving meat colour and enhancing quality and shelf life, crucial aspects in the food industry.

One of the remarkable substances appears to be morusin, as it has potential as an additive for meat preservation. It belongs to the group of flavonoids and occurs naturally in plants such as *M. alba*, *M. nigra* etc. Several studies have demonstrated morusin's anticancer, antioxidant, anti-inflammatory, and antimicrobial properties. Notably, it exhibits antibacterial and antifungal effects, particularly against Gram-positive bacteria of the genera *Bacillus*, *Enterococcus*, and *Staphylococcus* (Majinda *et al*. 2011; Panek-Krzyśko *et al*. 2021). According to Pang *et al*. (2019), morusin demonstrates antimicrobial properties against foodborne pathogens. Their study revealed that morusin exerts a potent antibacterial effect by disrupting the architecture of cell membranes and inhibiting the phosphatidic acid biosynthesis pathway in *S. aureus*. However, further research and an extended observation period are necessary to determine the maximum efficacy of *M. alba* leaf extract on meat quality and preservation. This will ensure determining the appropriate dosage required for the desired shelf life, thereby preventing economic losses in the food-processing industry (Chen *et al*. 2021).

5. Conclusions

In conclusion, the utilization of plant extracts from the family Moraceae presents a promising avenue for extending the shelf life of meat products. Through a thorough exploration of the antimicrobial and antioxidant properties of extracts from particular plants, as well as their application in meat preservation, this bachelor's thesis has shed light on their potential efficacy in the food industry.

The findings of this literature research indicate that plant extracts from species, such as *A. altilis*, *A. heterophyllus*, *A. lakoocha*, *D. ciliata*, *D. manni*, *D. psilurus*, *F. carica*, *F. lyrata*, and *M. alba* contain bioactive compounds capable of inhibiting microbial growth and oxidative deterioration in meat. These compounds, including phenolic compounds, flavonoids, and tannins, demonstrate significant antimicrobial and antioxidant activities, thereby could enhancing the preservation of meat products. In some cases, the addition of these extracts has been shown to prolong the shelf life of meat, reduce microbial contamination, and maintain product quality. However, many representatives have not yet been studied more in the industry, despite the fact that they show important antioxidant properties.

Therefore, for future research, it is recommended to practically include these representatives by directly applying their extracts to meat. At the same time, further investigation to optimize extraction methods, determine optimal concentrations, and assess consumer acceptance, could be suggested. By harnessing the natural bioactive compounds found in Moraceae plants, the food industry can strive towards safer, healthier, and more sustainable meat preservation practices. Overall, this thesis contributes to the growing body of research on natural preservatives for meat products and underscores the potential of Moraceae plant extracts as viable alternatives to synthetic additives.

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