A Review of Beef Jerky and Its Microbiological Characteristics

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Abstract. Because of its long shelf life, flavor, and health benefits, dried beef must be preserved if we are to fight the world's food shortage. Several factors, including urbanization, rising living standards, and shifting lifestyles, are driving up demand for processed beef products globally. Customers who purchase processed beef products can enjoy delicious, easy-to-prepare meals. Some common examples of air-dried meat products that are readily available in the market today are jerky, biltong, cured ham, and pastirma. This paper attempts to perform a review of the literature regarding the jerky's manufacturing processes and biochemical changes. To guarantee the safety of jerky products, it is essential to understand how microorganisms affect the preservation of flavor and to cater to consumers' preferences and health concerns. To provide a wider range of safer products and extend the shelf life of these items, future research should put a priority on improving the efficiency of jerky production.

1 Introduction

Although it has a limited shelf life, fresh meat is an extremely nutritious source of protein. As a result, people all over the world have created methods for dehydrating meat in order to preserve it and improve its flavor. Globally, a wide variety of dehydrated meat products are accessible. "Jerky" from North America, "carne-de-sol" from Brazil, "pastirma" from Turkey, "biltong" from South Africa, "kaddid" from North Africa, and "Cecina" from Spain are a few notable examples. There are not many instances like these [1]. Meat may be dried using a variety of techniques, including microwave, heat pump, refracting window, cold air, solar, hoover, ultrasonic, freeze-drying, and microwave drying. While these techniques are useful for drying meat, it should be remembered that higher temperatures have the potential to negatively impact important components within the meat, which would lower the overall quality of the dried meat. But it is important to remember that there are different kinds of dried meat products, depending on the kind of meat, the drying process, and the spices added [2].

Consider, for example, the dehydrated pork treats referred to as biltong, which enjoy widespread popularity in South Africa. The varieties mentioned are Springbok, Kudu, Gemsbok, and Ostrich [3]. In addition, biltong has a lengthy tradition of preparation, involving the drying of game meat by South Africans under the sun, and occasionally

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incorporating spices and vinegar derived from French Huguenot grapes into the dehydrated meat. This practise has been ongoing for a millennium [4]. Traditionally, the meat was dried for several weeks before delivery, and subsequently, the dried meat was wrapped in wrapping paper [2, 4]. Based on the results of a comparative investigation on the levels of fatty acids, iron, and peptides in dried ostrich meat, beef meat, and chicken meat, it was observed that dried ostrich meat had a fat content that was four times greater than beef meat and twice as much as chicken meat [3]. The utilisation of dehydrated meat as a practical and prevalent source of protein and taste is progressively gaining popularity in contemporary society. An illustration of this can be observed in the creation of expedient noodle meals that incorporate dehydrated chicken chunks [5]. Subsequent examination uncovered that the traditional approach of air drying was less effective than previously believed due to the substantial energy and time it demanded. According to their claims, increasing the temperature could reduce the duration and energy consumption of beef drying [5]. Conversely, it was asserted that higher temperatures would lead to a decrease in the meat’s flavour and the degradation of its nutritional elements. Additionally, it would result in a firmer texture of the finished product. Ultimately, the study determined that by considering the interaction between myofibrillar protein and water in lamb meat, it is feasible to air-dry the meat at lower temperatures and for shorter durations [6].

Inner Mongolia is renowned for its manufacture of various exquisite foods, such as Qinghai, dried meat, and yak. There are readily available dried beef items that are commonly produced and may be found in the market. These objects are manufactured using an ancient air-drying technique that has been inherited and practised for millennia [7]. Factors such as the kind of ruminant, the incorporation of spices, and the processing processes, such as traditional ways of air-drying, frying, and roasting, significantly influenced the results of the dried meat products [7]. The objective of the study was to examine the impact of these parameters on the development of heterocyclic aromatic amines [4], which are potentially carcinogenic compounds, in dried beef products. The results revealed that roasted meat had a greater abundance of heterocyclic aromatic amines [8] whereas deep-fried beef displayed the lowest proportion of HAAs. Simultaneously, the study discovered that spices have the capability to impede the creation of HAAs in beef items that were dried in the air. Additionally, the research revealed that dried meat sourced from Chinese yellow cows had elevated concentrations of HAAs in comparison to dried meat obtained from Aberdeen Angus cattle and Chinese yaks [7].

2 Materials and methods

2.1 Research Method

This literature study makes use of a research strategy that seeks to employ a methodical approach to conduct an in-depth analysis of dried meat. According to [9], a systematic review is defined as "a scientific process that is governed by a set of explicit and demanding rules that are oriented towards demonstrating comprehensiveness, immunity from bias, and transparency and accountability of technique and execution." According to Wright, et al. [10], A systematic review is characterized as a "review of the evidence on a formulated question that uses explicit and systematic methods to extract and analyze data from the studies that are included in the review, as well as to identify, select, and critically appraise relevant primary research." Furthermore, the review incorporates systematic reviews. We were able to obtain excellent papers from online journals and conference proceedings by using a search on Scopus. Each item is relevant to beef jerky products, and the associated effects and modifications are examined to guarantee the attainment of a trustworthy
comprehension. [11]. For the purpose of limiting the scope of the evaluation, the systematic review process is characterized by a number of criteria [12]. In these reviews, a general overview of a subject was provided, and the author relied on their own expertise. However, they did not try to synthesis all the relevant published information, nor did they describe how the papers that were included had been identified and synthesized. The problem with these kinds of reviews is that they do not give readers the ability to monitor and evaluate the judgments that are made, and they leave it up to the researcher to decide what should be included and what should not be included. In addition, these evaluations frequently do not include an express evaluation of the quality of the include studies. Because of this, there is a possibility that the findings of the review will be biased. In order to address these concerns and the numerous possible sources of bias that can arise throughout the process of locating, selecting, synthesizing, and reporting primary studies, researchers recommended treating the review process as a scientific process in and of itself, which eventually evolved into the systematic review method [9].

2.2 Criteria for Inclusion

The review process began with the development of the inclusion criteria, which covered both qualitative and quantitative studies [13, 14]. If a study does not meet the inclusion criteria, it will not be reviewed. The inclusion criteria are the standards that are used to assess a subject's significance in a study that is included in the review. It is critical to choose articles that address the research question with an appropriate study design. It might be necessary to determine the study dates as well as a chronology of the issue or problem under investigation.

Table 1. Criteria of inclusion.

<table>
<thead>
<tr>
<th>No.</th>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Topic</td>
<td>In the papers (journal articles and conference proceedings), there are themes of discussion that pertain to beef jerky products, the consequences that are linked with them, and the changes that have occurred.</td>
</tr>
<tr>
<td>2.</td>
<td>Period</td>
<td>There is a connection between the research articles (papers) that were published between the years 2015 and 2023 and the topic that is being examined.</td>
</tr>
<tr>
<td>3.</td>
<td>Research Base</td>
<td>Quantitative and qualitative empirical research are also covered in the papers (articles).</td>
</tr>
<tr>
<td>4.</td>
<td>Transparency</td>
<td>Clearly indicating the sample size, instruments, and analysis should be a part of the research procedure (prior research).</td>
</tr>
<tr>
<td>5.</td>
<td>Reliability/Validity</td>
<td>In accordance with the nature of research and the publishing in the scientific community, the findings of the study must be legitimate and credible.</td>
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The purpose of the literature search that serves as the foundation for this evaluation is to locate papers that have the potential to contribute to the accomplishment of the study objectives. Documents published between the years 2000 and 2023 are the only ones that fall under the purview of the search for this systematic review. A search for relevant literature was conducted using the following keywords: beef jerky. The search was conducted through the online journal databases that are indexed by Scopus (Routledge, Taylor & Francis, Springer, and Elsevier).

It is necessary to follow the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards in order to acquire a systematic review of high quality [13].
To facilitate more effective review reporting, these rules include both checklists and flow charts. The literature was located and vetted by a process that consisted of five parts [15]: The establishment of inclusion criteria (see Table 1) in order to guarantee that it is subjected to a comprehensive review. Literature that did not meet these criteria was not included in the review; (2) a search was conducted for related literatures in online journal databases that were indexed by Scopus (Routledge, Taylor & Francis, Springer, and Elsevier). According to the criteria for inclusion, the studies that were discussed in this literature were determined to be suitable; (3) The limitations of the findings in the literature that was published between the years 2015 and 2023; (4) Carry out a wider investigation of the literature that fits the inclusion criteria and is kept for research; (5) Carry out literature analysis in order to construct critical reviews of beef jerky products, the associated effects, and changes; (6) Draw conclusions based on the final analysis that has been carried out and validated by the current study.

3 Results and discussion

The findings of the literature search yielded a total of 196 papers. The authors conduct a more in-depth analysis of the paper, determines whether the articles contain a dried meat topic, and then classifies the document in accordance with the inclusion criteria. In conclusion, 41 papers that were pertinent were chosen based on an estimation of which group was the most prevalent (see Table 2 for further information).

Table 2. Distribution of article publications.

<table>
<thead>
<tr>
<th>Research Areas</th>
<th>Publication Year</th>
<th>Number of Papers</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef Jerky and Dried Meat Products</td>
<td>2007-2023</td>
<td>25</td>
<td>[3, 4]; [2, 16]; [5, 7, 17-19]; [20, 21]; [8, 22]; [23, 24]; [25]; [26, 27]; [6]; [28]; [29]; [30]; [31]; [25]; [32]</td>
</tr>
<tr>
<td>Additive substances and their effect</td>
<td>2007-2022</td>
<td>8</td>
<td>[33]; [34]; [35]; [36]; [37]; [38]; [39]; [40]</td>
</tr>
<tr>
<td>Beef Jerky Processing and Storage</td>
<td>2020-2021</td>
<td>2</td>
<td>[41]; [42]</td>
</tr>
<tr>
<td>Microbiological characteristics</td>
<td>2008-2019</td>
<td>6</td>
<td>[32]; [43]; [44]; [45]; [46]; [47]</td>
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3.1 Beef Jerky and Dried Meat Products

The different types of dried meat have become well-known in many areas due to the various drying techniques. A thorough investigation of the product’s components, physiochemical and biochemical changes, safety concerns, and health benefits is imperative due to the vast diversity of dried meat products originating from different cultures. The microbiological characteristics of dried meat products are therefore significant. This is since the main goal of drying meat is to preserve it by stopping the growth of dangerous bacteria. In relation to this topic, state-of-the-art technology intended to raise the efficiency of the meat drying process will be demonstrated.
3.1.1 Biltong

It is common practice in South Africa to consume biltong, which is a dried meat product made from ostrich. When it comes to dried meat products like biltong, the absence of a heat lethality phase raises doubts about whether or not the processing of biltong can effectively minimize the number of microbial pathogens available [28]. Despite the fact that commercial biltong manufacturers make use of hot air dryers, the meat that is traditionally marinated is often dried outside throughout the winter months [48]. In addition, drying with hot air demands a significant amount of both time and effort. IRHAD, which stands for infrared and hot air drying, is an alternative method that helps dry meat during the process of preparing biltong.

There are no laws in place for the manufacturing of biltong in South Africa, despite the fact that it is believed to have originated there as a result of early Dutch settlers' attempts to preserve meat [28]. The increasing demand for biltong in the United States and the United Kingdom has resulted in the failure of an attempt to export the product directly from South Africa. Up until relatively recently, it was difficult to export biltong from South Africa to industrialized nations that have stringent rules on food safety. This was the case unless the biltong was produced at a facility that had achieved HACCP approval or to the standards of the European Union. According to the data from Gavai, et al. [28], a basic biltong method has the potential to minimize four important groups of foodborne pathogens, eventually leading to the creation of a snack food that is made of dried beef protein that is safe to consume.

3.1.2 Dried Chicken

Recently, there has been an increase in the number of consumers who are interested in snack items that are dried meats. Dietitians' recommendations that individuals consume more protein while consuming fewer carbohydrates in their meals have been a driving force behind this trend. As a result of the acceleration of life, particularly in Western societies, there has been an increase in the need for food that is ready to eat and requires little effort to prepare. This has led to a wider variety of meat snacks and meals available on the market. Meat snack sticks have been designed as premium-quality products with a high nutrient content as well as a high value as a quick and "on the go" food product. These sticks are also aimed primarily at young people who are physically and mentally active, as well as professional athletes [3]. Chicken is another popular choice for meat snack sticks, although beef is the most prevalent type of meat utilized in these sticks. One of the distinguishing characteristics of beef meat is its high levels of protein, iron, and vitamin B [49]. On the other hand, chicken meat is low in fat and high in high-quality protein and polyunsaturated fatty acids [50].

In comparison to dried beef, dried ostrich and chicken meat had higher ratios of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA), which suggests that proper PUFA: SFA ratios could be beneficial in the prevention of coronary heart disease [3]. The study did, however, suggest that the use of spices could be helpful in maintaining the appropriate ratio. This is since herbs and spices could prevent the oxidative process of extremely high levels of PUFA in dried beef products that have a long shelf life. Additionally, dried beef products include a high concentration of nutrients, including iron, zinc, and magnesium for example. According to another piece of information, dried ostrich has twenty times more iron than dry chicken and twice as much as dried beef.
3.1.3 Jerky

Jerky is a traditional meat product that is dried and fermented. It is made by slicing whole meat, marinating it, and then drying it. Jerky is commonly used in traditional cuisine. Jerky made from beef is a well-known dish because of the signature flavour and texture that it possesses. Beef jerky is often created with raw beef meat that has been sliced into strips, mixed with salt, sugar, and spices, and then air-dried for approximately one month [29]. In general, beef jerky is made like this. It is the spontaneous fermentation of the meat that takes place during the air-drying process that is responsible for the fermented flavour that is present in beef jerky. The majority of the bacteria that are part of the fermentation process for beef jerky come from the raw materials, the environment around them, and the processing facilities themselves, which results in the formation of a distinct microbial population [29, 30]. The moisture content of foods with intermediate moisture content, also known as semi-dried foods, is normally between 20% and 50%, and the water activities of these foods range from 0.70 to 0.85. The moisture content of these foods varies depending on the degree of drying and any chemicals that are used to inhibit the growth of microbes within the food [31].

3.1.4 Kitoza

Kitoza, a traditional beef product from Madagascar, is an essential component of the cuisine of Madagascar [51]. Kitoza is a product of the Malagasy people. A mixture of garlic, pepper, and ginger is used to season the strips of meat, which are often beef but can also be pig. The next step is to sun-dry them and/or smoke them in the kitchen, either above the stove until they are ready to be consumed or in smoking units. Refrigerated kitoza is stored at room temperature. It is eaten either raw or fried as a snack, or it is used in recipes that are created. The preparation of kitoza is no longer limited to the household; butchers and a few small factories are also responsible for its production. In Madagascar, where chilling techniques are still expensive and uncertain, there is a significant opportunity for meat products that can maintain their consistency at room temperature and are prepared using straightforward methods. One example of such a product is kitoza. Kitoza is a sort of dish that is made from alternate, dried, or smoked meat. Among the recipes that are made from beef that has not been minced, biltong is the one that most closely resembles salted and dried beef kitoza.

3.1.5 Sucuk

Sucuk is a type of dry-fermented sausage that is commonly made in Turkey [21]. It is often produced with cow flesh, water buffalo, and/or mutton flesh, and beef fat [20, 21]. Sheep tail fat can alternatively be used in the recipe. Because of their specific organoleptic properties, fermented meat products offer a wide range of meat products [20]. The fermentation stage is an essential phase in creating the product qualities. In terms of sensory qualities, the combination of cultures (Lactiplantibacillus plantarum and Staphylococcus xylosus) showed the greatest results at fermentation temperatures [21].

Sucuk's main additive is salt, which is added at a rate of 2-2.5%. Nitrate and nitrite are exploited as antimicrobials, colorants, and antioxidants [20]. In addition, nitrate and nitrite are occasionally employed in tandem. Lactic acid bacteria can easily utilize saccharose or glucose as a fermentation substrate. Sucuk is commonly created using black and red pepper, cumin, allspice, and garlic as spices. Then, the batter is put into air-dried bovine small intestines [20].
3.1.6 Pastirma

The pastirma, which is well-known for its distinctive flavour, is the dry-cured beef product that is the most popular in Turkey. It is a raw meat product that has been cured and constructed from the whole muscle that has been taken from the carcasses of cattle and water buffalo [20]. One carcass can produce sixteen or more meat chunks that are suitable for pastrami. There are a few different kinds of pastirma that are produced, and each one is named after the location from which the muscles and muscle parts that are used as raw material are gathered (for example, şekerpare, kuşgömu, bohca, kurek, srt, and so on). Consequently, the texture and qualitative characteristics of the various types of pastirma are different from one another [20]. Typically, the production of pastrami takes place in natural settings, where the temperature of the air and the relative humidity of the air might change according on the climate and the weather conditions.

3.1.7 Kadid

A well-known cuisine that is generally cooked in the Maghreb (which includes Morocco, Algeria, and Tunisia) following "Aid Al Adha" [8] is called Kadid Guedid or Kadid. This dish is made with salted and sun-dried pork. In addition, it can be prepared using a wide range of red meats, including camel, as well as any part of the carcass. In addition, the preparation of Kadid differs from one place to another, mostly because of the varieties of materials that are utilized, the salting and drying methods, and the uses that are utilized for the product. It is for this reason that the final appearance and colour are not always the same. When raw flesh is prepared in the traditional manner, it is first sliced into thin strips and then blended with salt and spices. After that, the salted segments are made to dry in the sun by being hung out in the open air. It is possible to salt the meat in brine or dry, and the amount of salt that is applied is determined by the amount of flesh that is utilized. On the other hand, the addition of spices (fresh garlic or garlic powder, hot red pepper, coriander, and mint) is mostly since the region has traditionally used some of these ingredients. When it comes to the chemical, microbiological, and sensory properties of the guedid. Based on the study by Chabbouh, et al. [22], the seasoning process, which is a step in the processing of kadid meat that affects the flavour of the final product, changed the physicochemical and microbiological properties of the salted meat and sped up the rate at which it dried out. It is also recommended that convective curing be performed at a temperature of thirty degrees Celsius to make Kadid that has the same qualities as the traditional product.

3.1.8 Cecina

Produced in the North-western region of Spain, traditional Spanish beef Cecina is a meat product that is dry-cured, has a medium moisture content, and is ready to eat [23]. A European geographical indicator quality badge has been bestowed upon Cecina de León, a beef Cecina that has been certified and is produced in the province of León on the Spanish mainland. There is meat in this product that comes from cows that weigh more than 400 kilos. The silver side and top round, both of which originate from the hind legs, are the cuts of beef that are considered for consumption. In addition to this, the cuts are dry-salted and then suspended in ripening chambers for a period of many months. Meat Cecina is dry-smoked for several days while it is maturing. Lorenzo, et al. [24] demonstrated that the length of salting influenced the physicochemical parameters, free fatty acid profile, and free amino acid profile of dry-cured foal "Cecina." In addition, a longer period spent salting is associated with a decrease in the release of free amino acids and free fatty acids. In conclusion, although it would be interesting to conduct a sensory analysis to establish the preferences of the
customer, it is possible to declare that "Cecina’s" treated with salt for a short length of time would have features that are sufficient. Additionally, since they contain less salt, they have the potential to serve as a good replacement for other salted meat products, such as beef "Cecina" or dry-cured swine ham, both of which are popular in Spain and other countries in the Mediterranean region.

3.1.9 Carne-de-sol

Despite having a shelf life of only three to four days at room temperature due to its light salinity and partial sun drying, carne-de-sol is consumed in great numbers in Salinas, which is located in Northeast Brazil [2]. Carne-de-sol beef is a semi-dehydrated product that has particular sensory qualities. It is typically made under unclean conditions, which results in a product that has a shelf life of three to five days at room temperature when it is produced with high levels of sodium chloride [25]. For carne-de-sol beef, the absence of technical requirements allows for a wide range of product formations that are based on regional tastes. This, in turn, results in a diversity of salt chloride concentrations. Assis, et al. [32] state that because the Carne-de-sol is a handcrafted item, there is a wide range of variations in terms of manufacture, physicochemical composition, and microbiological efficacy. The socioeconomic relevance of sun-dried meat in the region is enormous, which justifies the need to better understand its characteristics to assist in the formulation of regional public policies the purpose of which is to ensure the product's sanitary control.

3.1.10 Dendeng

Although it is more commonly referred to as Minangkabau in Indonesia, the Dendeng West Sumatra Province is well-known for the variety of cuisines that it offers. As a result of the fact that traditional Minangkabau dishes are often created using herbs and spices that are readily available in the area, it is challenging to recreate these dishes in other locations or countries. Because of this, traditional cuisine possesses a variety of characteristics. Minangkabau cuisine includes dendeng as one of its classic dishes. There is no substitute for the authentic Minangkabau dish known as dendeng [26, 27]. Additionally, there are two types of dendeng: dendeng lambok, which is a wet variety, and dendeng kariang, which is a dry kind. Dendeng is mostly composed of beef slices that have been sliced very thinly and referred to as silverside. Dendeng is also made with goat and rabbit meat in some locations. These beef slices have been prepared with a variety of herbs and spices. Producers in the dendeng industry frequently make use of components such as coriander, garlic, galangal, pepper, tamarind, and spices including cinnamon, cumin, and lime [52]. Another prevalent ingredient is salt. Fry the dendeng kariang to enhance its colour, flavour, aroma, and texture. Before being fried, the beef slices are sun-dried till the water content reaches 10%-15%. According to Rini, et al. [26] this process results in raw dendeng kariang. Furthermore, to consume raw dendeng kariang, it is necessary to sauté it in vegetable oil until it acquires a brown colour, a crisp texture, and a distinct aroma.

3.2 Additive Substances and Their Effect

It is common practice to incorporate chemicals into the preparation of dried meat and meat products in order to achieve the correct colour or to serve as preservatives [6]. While washing sheep meat, beef jerky, and chicken, potassium sorbate, which is a common preservative, is either added to the meat or utilized in the washing process. One of the functions of potassium sorbate is to act as a preservative by lowering or decreasing the activity of microorganisms. This allows animal products to have a longer shelf life. It is common practice to include salt,
spices, and additives in dried meat products, in addition to the meat itself, which is the fundamental component of these commodities. These additional components can facilitate the processing of meat, enhance the meat's sensory attributes, and lengthen its shelf life. It is possible for essential oils to be in liquid form, even though most of the additional constituents are solid (powder or coarsely pulverized). The additional components not only contribute to the enhanced flavour and safety of the finished meat products, but they also have the potential to contribute to the health benefits of the meat products. Ku, et al. [35] demonstrated that the restructured jerky that contained glutinous rice flour, potato starch, soybean, and acorn powder was able to effectively reduce the amount of moisture content, water activity, thiobarbituric acid reactive substances (TBARS), and damp yield. According to the results of the sensory evaluations, the product samples that contained 9% glutinous rice flour, potato starch, and chestnut powder had the highest overall approval. An addition of soybean powder at a concentration of five percent, on the other hand, has the highest overall acceptance. Because of this, it has been suggested that the addition of glutinous rice flour, potato starch, soybean powder, and acorn powder could potentially function as fat substitutes, so presenting consumers with a new type of jerky.

Various strains of Salmonella and Listeria monocytogenes are vulnerable to the effects of antimicrobial agents [33, 36]. It has been shown that adding potassium sorbate along with other elements like pH, aw, and temperature is an effective way to thermally inactivate Salmonella species [34]. The meat was washed with potassium sorbate, which reduced the microbiological activity of L. monocytogenes and increased the product's shelf life by two days. [33]. Because it helps to preserve the flesh, potassium sorbate is a preservative that is typically used on meat. Furthermore, nitrite is a common preservative found in meat-containing products. In the fight against Clostridium botulinum, nitrite performs a role that is analogous to that of potassium sorbate in terms of its bacteriostatic, bacteriocidal, and anti-botulinum properties. An excellent example of this would be its use in cured meat products, where it functions as a potent inhibitor of C. botulinum and other anaerobic microbes [37]. Nitrite is used as a coloring agent in meat products in addition to being a potent heme oxidant. The distinctive red color of meat products is caused by nitrite, which acts as an oxidizing agent on the heme in preserved meat products [37, 38]. Nitrite, when used as a curing agent, has been shown to improve the scent of dry-fermented sausage products. This has been proved through demonstration. The existence of odour-active chemicals such as hexanal, heptanal, and 1-octen-3-ol, which were previously believed to be responsible for the scent of dry fermented sausages [39], demonstrates this reality. However, even though food additive nitrates and nitrites were found to be positively associated with breast and prostate cancer risks, respectively [40], the addition of nitrite and nitrate is necessary for the purpose of serving as a colouring agent and a preservative for meat products. Although these findings need to be verified by the conduct of additional prospective studies on a broad scale, they offer fresh perspectives within the framework of a heated discussion concerning the prohibition of these food additives.

3.3 Beef Jerky Processing and Storage

A method that is useful for preserving flesh is the preparation of jerky. Although hot-air drying is a standard method for producing jerky, it is not without its drawbacks, which include textures that are overly harsh, lipid oxidation, and high energy costs [41]. The development of novel processing methods is required to improve the quality of jerky as well as its ability to maintain its quality over time. Consumer demands, such as those pertaining to nutrition, natural goods, human well-being, and concerns regarding safety and health, have been a driving force behind recent developments in the curing of meat and meat products [6]. As a result, to maximize the health benefits for consumers and bring about both quantitative
and qualitative changes in the composition of dehydrated meat products, creative strategies have been developed and implemented in the processing, preparation, production, storage, and distribution systems. Utilizing omics techniques, which include, among others, transcriptomics, proteomics, metabolomics, and genomics, is another aspect of state-of-the-art technology. These techniques are useful for learning vital details about the product and for evaluating the quality of dried meat and meat products. The application of omics technology has the potential to increase knowledge of the expression of genes, proteins, and metabolites (hydrophilic and lipophilic), metabolic and biochemical processes, and underlying candidate biomarkers to assess meat quality [6]. This is even though the dried meat source contains a wide variety of animal species, breeds, sexes, and quality traits. To certifying mixed livestock products, the sequencing of the next generation (NGS) could be applicable. The quality of meat has been the subject of a great number of omics investigations. Dehydrated flesh, on the other hand, has been the subject of little investigation. It is necessary to conduct additional study to evaluate the quality and safety of dehydrated beef using omics information technology.

Kim, et al. [41] investigated the novel processing methods that have been developed to improve the quality of jerky and its capacity to be stored for an extended period. Texture modification and shelf-life extension are the two categories of technology that are available. Drying technologies that make use of superheated steam, mid-infrared radiation, microwave radiation, vacuum, and integrated drying methods can increase the rate of evaporation and improve the structure of the meat. Furthermore, the introduction of humectants results in an improvement in the thickness of the texture. By inhibiting lipid oxidation and microbiological growth, natural antioxidants and processing technology can lengthen the shelf life of jerky. This benefits consumers. The use of humectants, antioxidants, or further processing to manufacture and preserve jerky can improve its textural characteristics and shelf life [41]. In conclusion, modern processing technologies can remove moisture more effectively than traditional methods.

When it comes to processed beef, Bhat, et al. [42] looked at the possibility of using pulsed electric fields as a sodium-reduction technique. Manufacturing beef jerky with different percentages of sodium chloride, including 2.0%, 1.2% (T1), and 1.2%, combined with PEF processing (T2), served as a model for the experiment. Through the modulation of salt diffusion and sodium delivery, they hypothesized that the PEF therapy would increase saltiness, which would then result in a more pleasant impression of saltiness during chewing. As a result, PEF has the potential to be an innovative method to produce meat products high in sodium.

### 3.4 Microbiological characteristics of jerky

The presence of microorganisms in dried meat and meat products is a significant aspect that plays a role in defining the quality of the production processes and the products themselves. Numerous parameters, such as the aw values, which indicate the relative moisture balance or available water ratio that encourages the proliferation of microorganisms, have an impact on the microbial activities that occur in dried meat [6]. Table 3 provides a summary of the microbiological characteristics of jerky and dry beef products via a variety of processing processes. The microbiological characteristics of meat products have been the subject of extensive research to guarantee the creation of food products that are safe for human consumption.
Table 3. The table summary of microbiological characterization of jerky and dry meat products from various processing conditions.

<table>
<thead>
<tr>
<th>Dried Meat/Meat Products</th>
<th>Tested microorganisms</th>
<th>Findings</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carne-de-sol</td>
<td><em>Salmonella</em> spp. and <em>Staphylococcus aureus</em></td>
<td>Two samples (5%) tested positive for <em>Salmonella</em> spp., while 16 (40%) tested positive for <em>Staphylococcus aureus</em> with levels more than $10^3$ CFU/g.</td>
<td>[32]</td>
</tr>
<tr>
<td>Biltong</td>
<td><em>Escherichia coli</em></td>
<td>Five (2.8%) of the 180 meat and meat products tested positive for E. coli.</td>
<td>[43]</td>
</tr>
<tr>
<td>Jerky</td>
<td></td>
<td>Until 15 days of storage, total plate counts in beef jerky samples were lower than in pork jerky samples, however total plate counts in PPM jerky were significantly lower than other jerky types at 30 days of storage (P 0.05). PPM jerky's low microbiological levels are connected to its low moisture content and aw.</td>
<td>[44]</td>
</tr>
<tr>
<td>Kitoza</td>
<td><em>Lactic acid bacteria and coagulase-negative staphylococci</em></td>
<td>Lacrimal acid bacteria and coagulase-negative staphylococci were the two populations that were found to be codominant, with average counts of 6–7 log colony-forming units per gram. Although there were instances in which good hygiene standards were insufficient, samples were not contaminated with <em>Salmonella</em>, <em>Clostridium perfringens</em>, or <em>Bacillus cereus</em>, and just one instance of <em>Listeria monocytogenes</em> was known to have occurred. The presence of <em>Staphylococcus aureus</em> was occasionally discovered in salted and dried items, with greater numbers than those reported in salted and smoked products.</td>
<td>[51]</td>
</tr>
<tr>
<td>Sucuk</td>
<td><em>Staphylococcus/ Micrococcus and Enterobacteriaceae</em></td>
<td>Bacterial loads changed significantly during fermentation (P 0.05). Microbial counts for Total mesophilic aerobic bacteria (TMAB) and Lactic acid bacteria (LAB) revealed that the bacterial load remained steady throughout the first 2-3 days of fermentation before dropping significantly (P&lt;0.05) after heat treatment.</td>
<td>[45]</td>
</tr>
<tr>
<td>Pastirma</td>
<td><em>Micrococcus/ Staphylococcus</em></td>
<td>Pastirma's microflora is dominated by <em>Micrococcus</em>, <em>Staphylococcus</em>, and lactic acid bacteria.</td>
<td>[46]</td>
</tr>
<tr>
<td>Origin</td>
<td>Bacteria/Strains</td>
<td>Description</td>
<td>Reference</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Pastirma</td>
<td>Micrococcus/Staphylococcus and lactic acid bacteria</td>
<td>Micrococcus/Staphylococcus and lactic acid bacteria were more abundant in the short form of pastirma. The number of Enterobacteriaceae was below the detection limit (2 log CFU/g) in all forms of pastirma.</td>
<td>[47]</td>
</tr>
<tr>
<td>Cecina</td>
<td>Micrococcaceae, lactic acid bacteria, and enterobacteria</td>
<td>Curing period had a substantial (p&lt;0.05) effect on microbial characteristics, with microbial numbers decreasing (p&lt;0.05) from day 210 to day 360. Total viable count, Micrococcaceae, and lactic acid bacteria reduced (p&lt;0.05) between days 210 and 360, presumably due to the inhibitory effect of low aw values. There were positive and significant correlations between aw and total viable count (r = 0.60, p 0.05), Micrococcaceae (r = 0.94, p 0.05), and lactic acid bacteria (r = 0.88, p 0.05); and moisture and total viable count (r = 0.78, p 0.05), Micrococcaceae (r = 0.90, p&lt;0.05), and lactic acid bacteria (r = 0.83, p&lt;0.05). There was no enterobacteria found.</td>
<td></td>
</tr>
<tr>
<td>Dendeng</td>
<td>Lactobacillus plantarum</td>
<td>The study indicated that the addition of L. plantarum resulted in improved chemical and microbiological quality, and that it might be used for commercial manufacture of fermented goat meat dendeng. The findings of the study indicated that there was no significant difference in the bacterial content of sliced and ground beef jerky (P &lt; 0.05). The average bacterial content of sliced rabbit meat was 1.6×10⁶ CFU/g, while the bacterial content of ground rabbit meat was 2.9×10⁶ CFU/g. The use of ground meat does not appear to have any impact on the overall bacterial counts, as indicated by this.</td>
<td>[53] [54]</td>
</tr>
</tbody>
</table>

### 4 Conclusion and Future Perspectives

Dehydrating fresh beef extends its shelf life and adds unique flavors to the finished product, jerky. There are many different types of dried meats that can be found all over the world. To obtain its distinct qualities, each of these dehydrated meats is produced through a different combination of processes. Based on its type of meat content, processing methods, and place of origin, dried flesh can be categorized. In order to produce dried meat products, drying is an essential step in the process. This is because it has the ability to alter the nutritional
makeup, texture, and flavor profiles of dehydrated meat. Using the right drying methods and conditions is crucial to producing long-lasting and high-quality dried meat. These factors are mostly determined by the kind of meat being processed. To improve the quality of the dehydrated meat, non-meat ingredients are added. These ingredients serve as preservatives and pigments. Amplification of taste, enhancement of sensory qualities, inhibition of microbes, improvement of food safety, and reinforcement of health benefits are some of these factors. However, in order to guarantee the quality and safety of the products, it is feasible to increase the quantity of each ingredient in accordance with the particular type of dehydrated meat. Meat and meat products that have been dehydrated can be evaluated for safety and quality using microbiological analysis. Meanwhile, the microbiological characteristics of dried meat primarily examined the factors that governed its microbiological stability and storage circumstances. It is frequently seen that LAB, Staphylococcus spp., and Salmonella spp. might be present in meat products. All these bacteria are significant. To avoid microbiological contamination of the product, it is essential to initially identify the critical constraints and subsequently optimize each processing step and condition in alignment with these variables. Furthermore, it is crucial to keep in mind that the conversion of fresh flesh into dried meat results in alterations to the biochemical makeup of the meat. The application of omics approaches has been extensively studied and researched to decrease excessive sodium content. PEF has the potential to be a cutting-edge technique for producing sodium-rich beef products. Nevertheless, to expand the production of jerky on the market, it is important to thoroughly understand and address every aspect of food safety while also innovating new methods for food processing and storage.

References


46. A. Akköse, G. Kaban, M. Murat Karaoğlu, and M. Kaya, "Characteristics of pastırma types produced from water buffalo meat," (in English), *Kafkas Universitesi Veteriner


