alpha
Journal of Engineering and Applied Sciences
(AJEAS)
e-ISSN: 3023-6002

Alfa Mühendislik ve Uygulamalı Bilimler Dergisi
(2024) 2/3: 57 – 76

Review Article

DOI: 10.70988/ajeas.1495664

Received: 04/06/2024

Accepted: 10/09/2024

Published: 31/12/2024

Strategies for Reducing Salt in Meat Products

Hüdayi ERCOŞKUN [a], Fatma BAYRAKÇEKEN NİŞANCI [b,*]

[a] Çankırı Karatekin University, Faculty of Engineering, Department of Food Engineering, Çankırı, Turkiye
[b] Atatürk University, Faculty of Sciences, Department of Chemistry, Erzurum, Turkiye
* Corresponding author's e-mail address: fbayrakceken@atauni.edu.tr

Abstract

Meat and meat products stand as pillars of nutrition, offering essential nutrients for a balanced diet. However, the high salt content in processed meat raises concerns regarding excessive sodium intake and its associated health risks, such as hypertension and cardiovascular diseases. Addressing this issue necessitates reducing salt levels in processed meats while preserving their taste and quality. This article investigates the global and Turkish trends of elevated salt consumption, particularly driven by processed food intake. Given that meat products are significant contributors to dietary salt, various strategies have emerged to mitigate salt content without compromising flavor or quality. Through a comprehensive exploration of the health impacts of salt and innovative salt reduction methods in processed meat products, this article sheds light on the critical balance between health considerations and sensory preferences. By understanding and implementing effective salt reduction strategies, stakeholders can contribute to promoting healthier dietary habits without sacrificing the enjoyment and nutritional benefits of meat products.

Keywords: *Reduced Salt in Meat Products, Salt Reduction, Health*

Et Ürünlerinde Tuz Azaltma Stratejileri

Özet

Et ve et ürünleri, dengeli bir diyet için gerekli olan hayati besinleri sağlayarak insan sağlığı açısından temel gıda maddeleri arasında yer alır. Ancak, işlenmiş et ürünlerindeki yüksek tuz içeriği, aşırı sodyum alımıyla ilişkili olarak hipertansiyon ve kardiyovasküler hastalıklar gibi önemli sağlık riskleri oluşturur. Bu nedenle, bu ürünlerdeki tuz seviyelerinin azaltılması, lezzet ve kaliteyi koruyarak önemli bir öncelik haline gelmiştir. Bu makale, dünya genelinde ve Türkiye'de işlenmiş gıdalarla artan tuz tüketimi eğilimlerini incelemektedir. Et ürünlerinin, diyetle alınan tuzun önemli bir kısmını oluşturduğu göz önüne alındığında, tuz içeriğini lezzet veya kaliteyi tehlikeye atmadan azaltmak için çeşitli stratejiler geliştirilmiştir. Yüksek tuz alımının sağlık üzerindeki etkilerini ve işlenmiş et ürünlerinde tuz azaltma yöntemlerini inceleyen bu makale, sağlık ile duyusal tercihler arasındaki hassas dengeyi vurgulamaktadır. Bulgular, tuz azaltma stratejilerinin etkin bir şekilde uygulanmasının, et ürünlerinin besin değeri ve tüketim keyfini koruyarak daha sağlıklı beslenme alışkanlıklarının teşvik edilmesi açısından önemini ortaya koymaktadır.

Anahtar kelimeler: *Et Ürünlerinde Tuzun Azaltılması, Tuzun Azaltılması, Sağlık*

Citation: H. Ercoskun and F. Bayrakceken-Nisanci, "Strategies for Reducing Salt in Meat Products", AJEAS. (2024) 2(3): 57-76. http://dx.doi.org/10.70988/ajeas.1495664

1. Introduction

Attaining optimal growth, development, and overall well-being depends on the intake of a wide range of nutrients in adequate amounts. Among these vital nutrients, foods sourced from animals play a pivotal role in providing essential components for a balanced diet. Meat products, in particular, emerge as significant contributors, offering not only unique tastes but also a wealth of nutritional benefits. Rich in essential proteins, vitamins, and minerals crucial for bodily functions, meat products serve as indispensable elements in fostering overall health and balanced nutrition. Furthermore, the varied flavors and textures they offer enhance the culinary experience, solidifying their position as irreplaceable components of a well-rounded diet. This article explores the nutrient-rich profile of meat products, highlighting their biological value and their importance in promoting optimal health and balanced nutrition [1].

Meat and meat products stand out as significant sources of essential nutrients vital for overall health and well-being. Packed with amino acids and fat-soluble vitamins such as A, D, E, and K, they support diverse bodily functions crucial for optimal functioning. Additionally, these products boast a plethora of B-group vitamins, including B1, B2, B6, B12, and niacin, pivotal for energy metabolism and nerve function. Furthermore, their rich mineral content, comprising potassium, calcium, phosphorus, iron, zinc, and chlorine, ensures proper electrolyte balance, bone health, red blood cell formation, immune function, and metabolic processes. Incorporating meat and meat products into one's diet is paramount for obtaining these vital nutrients, thereby promoting overall health and well-being [2, 3].

Salt holds a pivotal role in traditional cuisines worldwide, serving as an indispensable ingredient with multifaceted properties. Its ability to preserve food, enhance flavors, and mask undesirable tastes makes it a preferred choice in culinary practices. Additionally, its widespread availability and affordability contribute to its prominence in traditional dishes. In meat product production, salt functions not only as a preservative but also as a flavor enhancer and texture modifier. It aids in water retention, thereby maintaining moisture and inhibiting bacterial growth. However, excessive salt consumption has been associated with various health issues, including cardiovascular diseases, hypertension, and obesity. Despite its essential role in enhancing food quality, recent data advocate for moderating salt consumption to mitigate health risks associated with excessive sodium intake. The global and national average salt intake exceeds recommended limits, underscoring the urgency of reducing daily salt intake to promote cardiovascular health and overall well-being. Thus, while salt remains integral to culinary practices, its consumption must be balanced to ensure optimal health outcomes [4, 5].

A study conducted in Turkey revealed insightful data regarding sodium intake patterns, shedding light on the sources and distribution of dietary sodium. Surprisingly, 55.5% of daily sodium intake originates from foods, with bread and table salt emerging as prominent contributors at 31.9% and 12.6%, respectively. Notably, sodium derived from natural sources differs from that acquired through processed foods, with breakfast products constituting the highest sodium intake at 58%, followed by pickles at 17%, and meat and meat products at 12%. This delineation underscores the significant role of processed foods in overall sodium consumption. Understanding these nuanced patterns provides a foundation for targeted interventions aimed at reducing sodium intake and promoting healthier dietary choices in Turkey. By addressing the predominant sources of sodium and advocating for balanced nutrition, public health efforts can effectively mitigate the risks associated with excessive sodium consumption and foster improved health outcomes among the Turkish population [6].

The burgeoning consumer interest in healthier dietary options has incentivized manufacturers to innovate in the production of meat products with diminished sodium content. This reduction is accomplished through various methodologies, including the direct decrease of sodium chloride (NaCl) levels, substitution with alternative chloride salts like potassium chloride (KCl), calcium chloride ($CaCl_2$), or magnesium chloride ($MgCl_2$), and the adoption of flavor enhancers or novel processing techniques. This study endeavors to investigate the repercussions of sodium reduction on sensory perception and product attributes in meat and meat derivatives. Through the implementation of diverse sodium reduction strategies, producers aim to uphold product quality while aligning with consumer preferences for healthier selections [3,4,7].

2. Purposes of Using Salt in Meat Products

2.1. Taste

The perception of taste is mediated by chemosensory stimuli encountered during oral consumption. Taste buds, primarily situated on the tongue but also within the mouth and throat, function as the principal receptors for gustatory stimuli, facilitating flavor discernment. Age-related declines in taste acuity are common, leading to reduced ability to detect and appreciate food flavors [8]. Despite their uniform appearance, taste buds exhibit varied responses to sour, bitter, sweet, and salty tastes among individual taste receptor cells. Research indicates that each taste bud comprises 50 to 100 specialized receptor cells responsible for detecting distinct taste modalities. These cells are classified into four groups based on their functional properties.

Firstly, Type I cells, predominant within taste buds, primarily mediate salt taste perception, particularly along the lateral edges of the tongue. Secondly, Type II cells, equipped with receptor proteins facilitating bitter, sweet, and umami taste perception, are predominantly located in the anterior and posterior regions of the tongue. Thirdly, Type III cells, responsible for sour taste perception, are primarily found in the central regions of the tongue, triggered by the presence of hydrogen ions (H+) from acidic compounds in foods. Notably, the perception of sour taste varies across different receptor types. Lastly, Type IV cells' specific role in taste perception remains incompletely understood, necessitating further research for comprehensive understanding [9].

Ionic stimuli, such as sodium in salt, initiate a series of events upon interaction with ion channels in taste receptor cell membranes. These channels, permeable to salt cations (Na+), induce changes in the cell membrane's electrical potential and subsequent depolarization. This depolarization triggers calcium ion (Ca^{+2}) activation and neurotransmitter release. Activation of sodium channels by sodium ions leads to salt taste perception. This signal is then transmitted to the taste center in the brain for further processing and interpretation [10].

The taste characteristics of different salt types are influenced by their constituent anions. Sodium chloride (NaCl), bromide, and iodide salts evoke distinct taste perceptions, subject to individual variations in taste sensitivity and preference. Moreover, the reduction in salinity depends on the accompanying anion with the chloride ion. Sodium chloride notably influences salty taste perception, attributed to the impact of the Cl^- anion on receptor cells. Larger anions, such as those in bromide and iodide salts, exhibit restricted diffusion through cellular channels in taste receptors, rendering them less effective stimulants for salty taste compared to chloride ions [11-13].

2.2. Flavor

Salt plays a pivotal role in enhancing food flavor, especially within culinary traditions rich in heritage. Inadequate salt levels in food items can render them perceived as insipid by consumers. Additionally, salt not only amplifies food taste but also masks undesirable flavors, thereby augmenting overall palatability [14]. Sodium chloride represents the primary contributor to food salinity, serving as the benchmark for salinity measurement in substances. While Na^+ cations primarily govern salinity levels, other cations such as K^+, Li^+, NH_4^+, and Ca^{2+} also influence taste through salinity. The prevalent use of NaCl in foods, compared to mineral salts like $CaCl_2$, KCl, and $MgSO_4$ is attributed to its costeffectiveness, widespread availability, and flavor-enhancing properties. Furthermore, salt provides the added advantage of regulating enzymatic activity in foods and promoting the growth of microorganisms conducive to the formation of aromatic compounds [15].

Substitutes like calcium chloride, potassium chloride, and phosphate, utilized to reduce salt content in foods, may introduce bitter, metallic, and astringent tastes, along with undesirable color and structural alterations in the product. Diminishing sodium chloride levels in meat products can activate proteolytic enzymes, resulting in undesired softness due to endopeptidase activity, while exopeptidase activity may produce undesirable tastes and odors [16].

2.3. Protective Properties of Salt and Its Effect on Microbial Stability

Indeed, sodium chloride (NaCl) assumes a crucial role as an additive in meat and meat products, primarily functioning to lower water activity. The salting process serves two key objectives: enhancing flavor and effectively inhibiting microbial proliferation within the food matrix [17]. The heightened salt concentration in foods induces alterations in cellular metabolism through osmotic pressure effects, leading to the leaching of water-soluble components, such as vitamins and minerals inherent in the natural structure of meat products. Consequently, this can lead to a notable decrease in the nutritional value of foods. Additionally, relying solely on salt in processed foods for preservation purposes is insufficient; it necessitates supplementation with other preservation techniques, such as drying or osmotic dehydration, to effectively prolong shelf life and ensure food safety [18]. Salt indeed plays a critical role in preventing spoilage by reducing the water activity (aw) value of microorganisms and pathogens in food below the threshold necessary for their growth. The aw value denotes the water availability in food for various enzymatic reactions, metabolic activities, and microbial proliferation. Each microorganism possesses a specific aw value at which it can thrive.

In the context of meat and meat products, aw values typically range from 0.99 to 0.70. For instance, salami and sausages exhibit aw values between 0.857 and 0.993, while sausage may range from 0.72 to 0.90. These values significantly impact the proliferation of bacteria responsible for food spoilage and foodborne illnesses. Common spoilage bacteria in meat products include Bacillus, Clostridium, Pseudomonas, and Escherichia [19]. A decrease in the water activity (aw) value of foods can correspondingly lead to a reduction in shelf life. Lowering the salt level in products necessitates adjustments to other parameters to maintain the antimicrobial effect and ensure shelf stability. A significant reduction in NaCl levels without implementing additional protective measures can compromise the product's shelf life. Therefore, it becomes imperative to employ alternative antimicrobial strategies or preservation techniques to compensate for the decreased salt content and uphold product quality and safety standards [20].

2.4. Salt and Health

In recent years, there has been a conspicuous surge in consumer demand for healthier food options, propelled by heightened awareness of nutritional concerns. Among these concerns, consumers increasingly prioritize products with reduced salt content in their diets. Research has delineated that excessive salt intake correlates with adverse health outcomes, encompassing cardiovascular diseases, renal dysfunction, elevated blood pressure, hypertension, and related cardiovascular complications [21,22,23]. Globally and domestically, the average salt consumption among individuals typically ranges from 9 to 12 grams per day, with a worldwide average estimated at 12 grams per day [21]. Studies conducted by SALTurk in 2011 revealed that our country's average salt consumption varies, with an estimated intake of 18 grams per day. SALTurk is a research initiative dedicated to studying salt consumption patterns and associated health implications within the Turkish population [24]. The recommended daily salt intake for a typical adult is approximately 5 grams per day to maintain optimal health. However, historical data suggests that salt consumption in ancient times was significantly lower, around 1.5 grams per day. Presently, salt intake has escalated to an alarming range of 9 to 18 grams per day for many individuals, approximately three times higher than the recommended level. This stark disparity underscores the urgent need for the implementation of the "Excessive Salt Reduction Program" initiated by the Ministry of Health in Turkey [25].

2.5. Effect of Salt Consumption on Hypertension

Hypertension manifests in individuals with heightened salt consumption, defined by diastolic blood pressure ≥90 mmHg and systolic blood pressure ≥140 mmHg. Societies exhibiting daily sodium intake surpassing 5.75 grams are prone to hypertension, indicating a significant role of salt intake in its pathogenesis. Notably, chloride ions, alongside sodium, contribute to the development of hypertension. Dysfunctions in sodium and chloride ion homeostasis prompt volume expansion and elevation of blood pressure. Interestingly, blood pressure remains unaffected when solely ingesting sodium citrate or ammonium chloride, underscoring the unique hypertensive effects of sodium and chloride ions in combination [26].

2.6. Effect of Salt Consumption on Cardiovascular Disease

High blood pressure, or hypertension, stands as a significant contributor to global mortality and morbidity, particularly concerning cardiovascular health. It represents a primary risk factor, implicated in approximately 50% of deaths due to coronary heart disease and a staggering 60% of fatalities attributed to stroke. Beyond its impact on mortality, hypertension significantly affects adult populations by leading to disability and reduced quality of life. The relationship between blood pressure and cardiovascular disease risk is unequivocal. As blood pressure levels increase, so does the risk of developing cardiovascular conditions such as coronary artery disease, heart attack, and stroke. Conversely, interventions aimed at lowering blood pressure exert a profound effect on mitigating the risk associated with these diseases. Strategies targeting blood pressure reduction, including lifestyle modifications and pharmacological interventions, yield substantial benefits in terms of cardiovascular health outcomes, underscoring the importance of blood pressure management in disease prevention and management [27].

Scientific investigations examining the impact of salt reduction on cardiovascular disease remain relatively limited in number. However, findings from available studies underscore the critical importance of moderating salt intake in mitigating cardiovascular risks. For instance, in a notable study, salt consumption exceeding 5 grams per day was associated with a significant increase in cardiovascular disease risk, surpassing 17%, and an even higher risk of stroke, exceeding 23%. In response to these findings, numerous countries have implemented initiatives aimed at reducing salt content in foods. Emerging evidence from research endeavors indicates that salt reduction interventions yield significant health benefits. Specifically, such interventions have been shown to lower systolic blood pressure by up to 10 mm Hg, resulting in a substantial reduction in mortality rates from both stroke and coronary heart disease, ranging from 75% to 80%. Moreover, these interventions have been associated with an impressive increase in life expectancy, with studies reporting an additional 5 to 6 years of life on average. These findings underscore the critical role of salt reduction initiatives in promoting cardiovascular health and enhancing longevity. Further research efforts are warranted to elucidate the precise mechanisms underlying the cardiovascular benefits of salt reduction and to inform evidence-based public health strategies aimed at reducing salt intake on a global scale [28].

2.7. Effect of Salt Consumption on Kidney Disease

Sodium serves a critical role in regulating blood pressure and fluid balance within the human body. However, excessive dietary salt intake can lead to adverse health outcomes. For example, heightened salt consumption is associated with increased urinary calcium excretion and reduced calcium levels in bones. This calcium loss from bones elevates the risk of developing kidney stones and osteoporosis, a condition characterized by decreased bone density and increased fragility. Additionally, excessive salt intake can adversely affect kidney health. In individuals with kidney-related conditions, excessive salt consumption accelerates the excretion of albumin and proteins from the body, exacerbating kidney damage and compromising renal function. Therefore, maintaining appropriate salt intake levels is crucial for promoting optimal kidney health and overall well-being [29, 30].

Indeed, research has elucidated a significant association between kidney failure and hypertension. Kidney disease and hypertension frequently coexist, with uncontrolled blood pressure contributing to the deterioration of other organs, including the kidneys. Atherosclerotic disease, characterized by the accumulation of various substances on the inner walls of vessels supplying the heart, can perpetuate long-term hypertension and exacerbate kidney function decline alongside uncontrolled blood pressure. In fact, hypertension is prevalent in a significant majority of chronic kidney disease patients, estimated at 80-85%. This interplay between hypertension and kidney dysfunction underscores the intricate relationship between cardiovascular health and renal function, emphasizing the importance of comprehensive management strategies to mitigate the risks associated with these interconnected conditions [31].

2.8. Effect of Salt Consumption on Stomach Health

High salt intake has been implicated in the pathogenesis of infections and diseases, particularly in the gastrointestinal tract. One notable mechanism by which excessive salt consumption exerts its deleterious effects is through the induction of hypergastrinemia, an abnormal elevation of gastrin hormone levels. This hormonal imbalance can lead to the proliferation of Helicobacter pylori bacteria within the gastric mucosa, a known risk factor for various gastric diseases, including gastritis and peptic ulcer disease. Importantly, emerging evidence suggests an escalating correlation between salt consumption and the incidence of stomach cancer. The detrimental impact of salt on gastric health is further compounded by the prevalence of processed meat products, canned foods, and fast food in modern dietary habits. These foods often contain high levels of salt as a preservative or flavor enhancer, thereby exacerbating the destructive effects of salt on the stomach lining. Consequently, a concerted effort to reduce salt intake, particularly from processed and fast foods, is crucial for mitigating the risk of gastric infections and diseases, including stomach cancer. Adopting dietary practices that prioritize whole, unprocessed foods and limit salt-rich processed foods is imperative for promoting gastric health and reducing the burden of gastrointestinal diseases [32].

3. Meat and Salt

Meat and its derivatives constitute a prized component of the human diet, esteemed for their sensory attributes, nutritional richness, and digestibility. However, the perishable nature of meat necessitates meticulous storage to avert spoilage. Consequently, an array of preservation methods has been devised, giving rise to a diverse spectrum of meat products. These products are crafted by incorporating various seasonings to impart distinct tastes, flavors, and appearances. Traditional delicacies across diverse cultures, such as sausage, pastrami, and roasted meat, have evolved from the necessity to prolong the shelf life of meat. Through adept seasoning and preservation techniques, these products not only extend the longevity of meat but also augment its culinary allure. Hence, meat products serve as a testament to human innovation in transforming a perishable commodity into enduring culinary delights that enrich our gastronomic heritage [33]. Indeed, the quality of meat is pivotal in eliciting consumer satisfaction. Several parameters contribute to the overall quality of meat, encompassing its composition, tenderness, water retention capacity, taste, aroma, as well as considerations pertaining to spoilage and contamination.

The nutritional value of meat varies based on its composition, encompassing factors such as protein content, fat composition, and micronutrient profiles. Furthermore, characteristics like tenderness and juiciness significantly influence the eating experience and consumer satisfaction. Water retention capacity is another critical aspect, affecting the succulence and texture of meat products. Additionally, the sensory attributes of meat, including taste and aroma, profoundly impact consumer acceptance. The presence of off-flavors or odors, indicative of spoilage or contamination, can significantly detract from meat quality and consumer perception. Thus, ensuring high standards across these parameters is essential for delivering meat products that meet consumer expectations and contribute to overall satisfaction and well-being [34].

Tenderness stands as a crucial factor influencing consumer appreciation of meat products. Influenced by various factors such as animal age, gender, species, presence of connective tissue, nutritional status, pre-slaughter conditions, and enzymatic reactions during meat maturation, it is a key determinant of meat quality. Tenderness, characterized by ease of chewing and absence of toughness, is highly valued in meat products. Factors such as animal age, gender, species, and distribution of connective tissue influence tenderness development, along with nutritional status and pre-slaughter conditions. Furthermore, enzymatic reactions during meat aging significantly contribute to tenderness, involving the breakdown of muscle proteins, softening meat texture, and enhancing palatability. Ensuring optimal tenderness is paramount for delivering high-quality meat products that meet consumer expectations and contribute to overall satisfaction [35].

Salting is a time-honored preservation method integral to the production of dried meat products. It serves multiple critical functions, including enhancing water retention capacity and inhibiting microbial growth by reducing water activity [36]. The salting process effectively lowers the water activity of meat to levels below 0.95, creating an inhospitable environment for microbial proliferation and enhancing product safety and shelf life. Salt concentration in salted and dried meat products typically falls within the range of 4.3% to 4.5%, crucial for inhibiting microbial growth and ensuring product preservation [38]. Salt exerts a multifaceted influence on chemical and biochemical reactions within meat products, modulating processes such as lipolysis, proteolysis, and lipid oxidation, which impact product properties including color, flavor, and texture. Salt serves as a versatile ingredient in meat processing, acting not only as a preservative but also as a modulator of reactions that contribute to product quality and sensory characteristics [39, 40].

Salting of meat products can be achieved through two distinct methods: wet salting and dry salting, each playing critical roles in enhancing flavor, preservation, and overall quality. Dry salting, employed in the preparation of dried and cured meat products, involves evenly distributing salt over the meat's surface to ensure uniform coverage and penetration. Wet salting, on the other hand, involves immersing the meat in a salt solution or brine to facilitate thorough salt penetration. Both methods cater to diverse culinary preferences and processing requirements, enhancing the quality and preservation of meat products [40-42].

The penetration rate of salt into meat is influenced by factors such as salt dissolution on the meat surface and the concentration of the solution, which may vary depending on muscle type. Salt inhibits proteolytic enzymes, softening the meat and affecting its textural properties. The curing process in meat products involves the addition of additives such as salt, nitrite, and nitrate, along with spices, enhancing properties such as aroma, flavor, texture, taste, and color. Curing extends the shelf life of meat products, ensuring their preservation over time [43-45].

The curing process stands as the predominant method employed to impart juiciness, crispness, and consistency to final meat products. During curing, various compounds such as sodium chloride, sodium lactate, sodium phosphate, polysaccharides, and gums are favored for their functional roles. Sodium chloride, a commonly utilized ingredient in foods, facilitates the retention of water within the meat structure, both from the curing solution and inherent to the meat's natural composition [46].

In the initial stage of bacon production, alongside salt, nitrite or nitrate is essential for curing purposes [47, 48]. Sole reliance on salt during the salting process is unfavorable as it can result in a hardened texture and undesirable dark coloration of the meat. To counteract these undesirable effects, nitrite or nitrate compounds are incorporated alongside salt. This addition not only imparts the desired color and aroma to the meat but also extends its preservation period while limiting the occurrence of oxidative rancidity [49].

The excessive use of salt in meat products for preservation and the resultant health concerns have prompted consumers to seek meat products with reduced salt content. Over 70% of dietary salt intake is derived from processed foods, with meat products contributing over 20% to this total [3]. Efforts to mitigate salt consumption in Turkey include regulatory measures to reduce salt content in processed foods and the mandatory labeling of salt content on food packaging.

The maximum salt amounts allowed by the Food Codex in Turkey are as in Table 1 below [50].

Table 1. Maximum salt amounts allowed by the Food Codex in Turkey [50].

MEAT TYPE	SALT CONTENT
Bacon	Dry matter maximum 10% by mass
Roasting	Maximum 3% by mass
In ham	Maximum 3% by mass
Chicken Doner	Maximum 2% by mass
Mince	Maximum 2% by mass

The World Health Organization (WHO) advocates for a daily sodium intake of less than 2 grams, equivalent to 5 grams of salt, per individual. In line with this recommendation, endeavors are underway to diminish the salt content present in meat products [51]. Although the intrinsic salt content of meat products is not inherently harmful to human health, the processing of such products often leads to an elevation in their salt content. For instance, while fresh beef tenderloin meat typically contains 50 mg of sodium per 100 grams, beef burger meat may contain 396 mg of sodium per 100 grams due to processing.Table 2 shows the sodium and sodium chloride amounts contained in meat and meat products in the National Food Composition data system [52].

Table 2. Amount of sodium and sodium chloride contained in meat and meat products [g/100 g edible part] [52].

MEAT TYPE (100g)	Sodium (mg)	Salt (mg)
Raw products		
Beef tenderloin meat	50	124
Sheep loin meat	65	163
Beef tenderloin meat	49	123
Chicken leg meat	82	205
Offal beef kidney	192	481
Turkey leg meat	72	179
Trout	120	299
Processed Products		
Beef burger meat	396	800
Sausage veal	889	2223
Bacon	2799	6996
Salami turkey	938	2345
Doner Chicken meat raw	653	1631
Doner minced meat	800	2001
Sausage	971	2428

3.1. Use of Salt in Meat Products

Salt serves a pivotal role in enhancing the flavor profile and textural attributes of meat products, augmenting existing flavors while imparting desired textural properties. Its contribution to the development of textural properties in meat products is multifaceted, involving the swelling of proteins, which enhances their binding capabilities and water retention capacity. Typically, a concentration of 2% salt is utilized in meat products [53]. Deviating from this threshold by using less than 1.4% salt in meat products can compromise their cooking efficiency, necessitating the supplementation of additional protein to maintain product integrity. Notably, in meat products containing 2% salt, approximately 79% of the total sodium content is derived from the salt added during processing [54].

3.2.Use of Salt in Emulsion Products

Meat products such as salami and sausage stand as prominent examples of food items crafted through emulsion technology, a process integral to their production. The preparation of these products revolves around the principle of establishing a continuous phase, achieved by chopping meat in a dough cutter alongside salt, while knives rotate at high speeds with the assistance of blades. Concurrently, ice or water is added to the environment to facilitate the extraction of proteins dissolved in the saline solution. Subsequently, oil is gradually incorporated into this phase to form an oil/water emulsion [55]. The emulsion is then encased in either natural or artificial casings and subjected to smoking and cooking processes to yield a stable final product [56].

Salt serves as a crucial additive in emulsion-type meat products, such as salami and sausage, playing multiple roles in product formulation and quality. Firstly, salt augments viscosity in emulsion products, thereby influencing their texture and consistency. Additionally, it exerts a bacteriostatic effect, contributing to product safety and shelf life extension [57]. Through its ability to enhance the water retention capacity of emulsion products, salt mitigates the loss of juiciness during cooking. Within the formulation, chloride ions (Cl-) present in the salt formulation permeate the myofilaments, causing them to swell, while sodium ions (Na+) cluster within the filaments, collectively increasing water retention capacity [58,59]. During the creation of salami dough, salt plays a pivotal role in facilitating emulsion formation by extracting myofibrillar proteins dissolved in the saline solution [58, 59].

The solubility of key proteins such as actin and myosin, which significantly influence emulsion formation, varies depending on factors such as pH, salt solubility, and temperature. The efficient utilization of dissolved proteins in emulsion products is paramount, as it profoundly impacts product stability, viscosity, absorption capacity, and overall yield of salami and sausage [60, 61].

3.3. Use of Salt in Bacon Production

Pastrami, a well-known cured meat product, is derived from the salting, pressing, drying, and curing of meat extracted in whole pieces from specific sections of the beef carcass [62, 63]. Among these stages, the curing process stands out as pivotal in pastrami production. During curing, the meat undergoes treatment with a blend of salt, nitrite, nitrate, and sugar. Subsequently, the cured meat undergoes drying, typically through one or two pressing cycles at specific weights. Once the moisture content of the meat reaches a predetermined level, the necessary curing and drying procedures are executed to impart the distinct taste, flavor, and texture characteristic of pastrami [64].

The salt utilized in the curing process significantly influences the transformations occurring during pastrami production, exerting numerous beneficial effects on product development in meat processing. In particular, the elevated salt concentration present in whole-piece products like pastrami contributes to microbial stability by modulating intracellular and extracellular osmotic pressures, leading to the removal of intracellular water and subsequent reduction in water activity. Additionally, salt influences flavor by enhancing its solubility in meat proteins. At higher salt concentrations, the bacteriostatic effect of salt is further accentuated. Moreover, an increase in the amount of salt utilized in pastrami production correlates with an elevation in the dry matter content of the final product. Typically, the salt content in pastrami products ranges from 5% to 6%. However, in bacon production, consumer preferences may dictate a reduction in salt content to less than 3% [64, 65].

3.4. Use of Salt in Kavurma Production

Kavurma, a traditional meat product, involves a meticulous process of preparing and preserving meat from bovine and ovine animals. The meat, cut into small pieces not exceeding 7cm, undergoes seasoning with salt and internal fat before being roasted in specialized cauldrons at dry temperatures. Subsequently, the roasted meat is meticulously packaged, either in its own oil or with the internal fat procured from the butchered animals, ensuring complete coverage with a protective layer of fat. This method of preparation and preservation dates back to eras preceding the advent of refrigeration technology, underscoring its historical significance in food preservation practices [66].

Unique among meat products, kavurma stands as a prime example of meat being cooked in pieces, a characteristic that distinguishes it within the processed food landscape. Roasting plays a pivotal role in enhancing the durability of the meat while preserving it in oil, contributing to its longevity and availability in times when refrigeration was not accessible. Within the meat industry, the production of products preserved in fat remains limited, highlighting the rarity and distinctive nature of kavurma and similar products [67].

Salt emerges as a critical additive in the production of kavurma, imparting several benefits to the final product. Beyond its antimicrobial properties, salt contributes significantly to the taste and flavor profile of the roasted meat, enhancing its overall sensory appeal [56]. Thus, salt plays a multifaceted role in the preparation of kavurma, influencing both its safety and sensory attributes.

3.5. Use of Salt in Sucuk Production

The preparation of sucuk, a popular sausage product, involves a series of meticulous steps to ensure its quality, flavor, and safety. Initially, meat pieces sourced from the breast, leg, and shoulder regions of beef carcasses are meticulously separated from coarse fat and connective tissues. These meat portions are then combined with tail fat and meat fat, following a specific ratio (10% tail fat, 10% meat fat, 80% beef), to form the sausage dough. Subsequently, the sucuk dough is subjected to a resting period at -20˚C for a day to optimize its texture and consistency.

During the formulation stage, salt, garlic, and a blend of spices are meticulously incorporated into the sausage dough to impart distinctive flavor profiles. Additionally, sodium nitrite is introduced into the mixture to enhance coloration, contributing to the visual appeal of the final product. Once the sausage dough is thoroughly blended, it is carefully filled into artificial intestines with a diameter of 38 mm, ensuring uniformity and consistency in the final sucuk product [68, 69].

Salt, prominently featured as an additive in sucuk production, serves a multitude of functions that significantly influence the quality and characteristics of the sausage. Primarily, salt plays a crucial role in enhancing the water retention capacity of the sausage dough, thereby contributing to its succulence and juiciness. Moreover, salt influences the coloration of the sausage, contributing to its visual appeal. Beyond its sensory attributes, salt also facilitates fat binding properties in the sausage, ensuring optimal texture and consistency. Importantly, salt contributes to the safety and shelf life of the sucuk product by reducing water activity, thereby inhibiting microbial growth and spoilage [70]. Thus, salt emerges as a multifunctional ingredient in sucuk production, influencing both its sensory attributes and safety parameters.

3.6. Use of Salt in Minced Meat and Meatballs

Sodium chloride, commonly known as table salt, plays a pivotal role in shaping the sensory attributes of ground meat or meatballs, exerting multifaceted effects on their texture, flavor, and overall quality. In the preparation of meatball dough, transglutaminases, enzymes utilized to catalyze protein cross-linking, are employed to augment gel formation and enhance the yield of meatballs [71]. Sodium chloride, a key ingredient in this process, serves to mitigate cooking losses and refine texture, thereby optimizing the sensory experience of products such as ground meat and meatballs. Its presence enhances the cohesiveness of the dough, facilitating the harmonious distribution of moisture and fat within the meatballs, thus contributing to their succulence and juiciness [72].

Moreover, supplementary components like soy protein, caseinates, and other functional additives are incorporated into meat products to enhance their technological properties, including those of meatballs. Sodium chloride, in conjunction with these additives, plays a pivotal role in bolstering binding properties, augmenting hardness, optimizing cooking efficiency, and intensifying flavor profiles in ground meat and meatball formulations. Through its influence on various physicochemical parameters, sodium chloride contributes to the overall sensory appeal and palatability of meatball products [3].

Furthermore, the sensory perception of saltiness in meatballs is intricately modulated by the interplay of other ingredients and spices employed in their formulation. While sodium chloride imparts a distinct saltiness to the product, its perception is influenced by the taste and aroma of complementary ingredients, thus shaping the overall flavor profile of meatballs. This intricate interaction underscores the importance of sodium chloride in meatball production, where its sensory effects are finely balanced with those of other constituents to achieve desired flavor outcomes.

3.7. Salt Reduction Strategies in Meat Products

The gradual reduction of salt content in meat and meat products offers a promising strategy to mitigate sodium intake without compromising consumer acceptance. Research investigating gradual salt reduction has revealed that sensory adaptation occurs, wherein consumers acclimate to the reduced salt levels, perceiving the products as possessing normal salinity [73]. The successful implementation of this approach is exemplified by the United Kingdom, where a gradual reduction strategy led to a notable decrease of 20-30% in the salt content of processed food products over a span of three years [74]. However, this strategy is not without its challenges, particularly concerning taste sensitivity. Approximately 25% of individuals exhibit heightened sensitivity to taste, rendering it challenging to reduce salt content without detection by consumers [15].

Moreover, achieving salt reduction on an industrial scale across all products poses logistical complexities. Despite consumer acceptance of reduced-sodium products, achieving substantial salt reduction without compromising taste remains elusive. Reduced salt levels in foods can lead to the emergence of undesirable bitter tastes and a shortened shelf life [75, 76]. The reduction of salinity in meat and meat products corresponds to a decrease in perceived saltiness and product taste intensity.

To address these challenges, various approaches to reducing sodium content in meat and meat products, particularly processed meats, have been explored:

1. Decreasing the amount of sodium chloride used in meat products.
2. Substituting sodium chloride with alternative chloride salts such as potassium chloride (KCl), calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$).
3. Incorporating flavor-enhancing and masking agents to mitigate the loss of saltiness when reducing salt content.
4. Optimizing the physical structure of salt to enhance its functionality.

5. Employing novel processing techniques to achieve salt reduction while maintaining product quality and sensory attributes [3, 16].

3.8. Salt Substitutes Used Instead of Salt

Potassium chloride (KCl) is a widely utilized salt substitute aimed at reducing the sodium content of foods. However, a 50:50 blend of sodium chloride and potassium chloride has been reported to impart bitterness and diminish salty taste perception. Moreover, individuals with heart failure, chronic renal failure, and type I diabetes may exacerbate their existing health conditions with elevated potassium intake [77]. By partially substituting salt with KCl, the sodium content in meat products can be lowered. Mixing chloride salts in meat processing is a common method to achieve sodium reduction. Notably, Pansalt® is a patented product composed of nearly half the sodium chloride replaced with magnesium sulfate, potassium chloride, and L-lysine hydrochloride. Lysine hydrochloride aids in sodium excretion, enhances product salinity, and masks the taste of magnesium and potassium. Other commercially available mixtures include Morton Lite Salt®, Losalt, and Saxa So-Low salt [3].

In a study comparing turkey ham, veal ham, and bacon produced with a mixture of 40% potassium chloride and 60% sodium chloride (Morton Lite Salt®) with control groups, no significant differences in sensory attributes were observed [3]. Another investigation focused on producing beef patties using low-sodium salts, including Pansalt®, sodium chloride, and no added salt. Results indicated that meatballs containing Pansalt® exhibited higher water retention capacity, likely attributed to the presence of magnesium sulfate and potassium chloride [78].

Studies have demonstrated that replacing sodium chloride with other salts at a rate of 25-40% does not noticeably alter taste perception. However, increasing potassium chloride levels may enhance acidic, spicy, and salty tastes [79]. Additionally, incorporating 50% potassium chloride in cooked hams can improve binding and sensory properties. In another study, hams prepared with 70% sodium chloride + 30% magnesium chloride or potassium chloride were comparable in taste, crispness, flavor, and acceptability to those made with 100% sodium chloride [80].

Regarding bacon production, substituting 15% of salt with KCl yielded acceptable textural properties, while replacing 30% of salt with KCl resulted in undesirable chewiness and hardness [81]. Phosphates are also employed to reduce sodium chloride content in meat products. Phosphates enhance cooking efficiency and water retention by releasing negatively charged portions of meat proteins. The synergistic effect of salt and phosphates allows for a reduction in salt content without compromising taste. The addition of sodium polyphosphate can decrease NaCl content in cooked salami and sausages to 1.4% and in cooked hams to 1.7% without sacrificing taste [82].

3.9. Flavor Enhancers and Enhancers

Taste masking and flavor enhancement are strategies employed to reduce sodium consumption in foods, utilizing additives such as monosodium glutamate (MSG), lactate, edible seaweed, yeast extracts, and nucleotides. These enhancers activate receptors in the mouth and throat, preventing flavor loss resulting from reduced salt levels [84]. A study substituting part of the table salt with MSG (Ajiplus) in Singaporean dishes observed a decrease in spice aroma, umami, sweetness, chicken flavor, and saltiness when salt levels were reduced by 40%. However, addition of flavor enhancers led to increased chicken aroma, umami taste, and saltiness, with no change in perceived saltiness compared to products with reduced salt levels [85].

In another study on chicken nuggets, a salt mixture comprising potassium chloride, tartaric acid, citric acid, and sucrose replaced 40% sodium chloride. The addition of apple pulp and salt reduction significantly reduced emulsion stability and cooking ability, while increasing moisture content and dietary fiber. However, textural quality was compromised, resulting in products with suboptimal sensory properties [86]. Investigating pastrami production with different salt mixtures revealed variations in quality characteristics. Pastrami made under natural conditions with 100% NaCl was favored for taste, while pastrami produced under controlled conditions with 85% NaCl-15% KCl was preferred for color [87].

A study on fermented sausages substituted 40% of sodium chloride with potassium chloride, 30% with potassium lactate, and 20% with glycine, inhibiting pathogenic microorganisms without compromising food safety [88]. Lysine and succinic acid can replace 75% of NaCl in dry-cured meats, maintaining taste and flavor while water binders like phosphates, gums, and starches preserve water retention capacity lost due to reduced salt content [79, 89].

In research on low-sodium meatballs, phosphate, sodium, and fat contents were varied, with higher meat content reducing perceived saltiness and increased fat content intensifying saltiness. Phosphate decreased cooking losses without affecting salt perception [3]. Another study added potassium lactate to ham with bones during production, improving sensory and physicochemical properties and enhancing microbial stability [90]. Investigating sensory properties of fermented sausages, increased potassium lactate led to sweeter taste, higher pH, doughier texture, and increased disintegration, while high potassium chloride levels yielded similar sensory properties to the control group [91].

3.10. Optimizing the Physical Structure of Salt

One effective approach to reducing salt content in meat and meat products involves altering the physical structure of salt. The size and shape of salt particles significantly influence salt perception. Salt molecules with larger surface areas and smaller sizes dissolve rapidly on food surfaces, intensifying perceived saltiness [92]. Moreover, stratifying salt application across different food layers in varying concentrations can reduce overall salt levels without compromising perceived saltiness.

Granular salt with refined characteristics is typically used in meat and meat products. However, traditional methods, such as those employed in pastrami production, may utilize coarse salt. Altering the shape and crystal structure of salt has been found to enhance water binding in emulsion products, elevate pH levels, increase protein solubility, and improve cooking efficiency [93]. These modifications offer promising avenues for effectively reducing salt content in meat and meat products without compromising sensory attributes.

3.11. Using New Alternative Technologies

Non-thermal food processing technologies such as high pressure (HPP) and ultrasound offer innovative approaches to reducing salt levels in meat products. High pressure treatment, typically ranging from 400 to 600 MPa, is applied to products at relatively low temperatures (<45˚C) [94]. This method serves a dual purpose in meat and meat product processing: firstly, it helps inhibit the growth of pathogenic microorganisms, enhancing product safety, and secondly, it contributes to preserving key characteristics of meat products by reducing salt levels. Pressure application induces changes in the interaction between sodium ions and proteins, facilitating sodium entry into taste receptors on the tongue, thereby enhancing perceived salinity [95].

Ultrasound techniques play a crucial role in ensuring proper salt distribution on meat surfaces during the salting process. Despite reductions in NaCl levels, this method enhances perceived salinity for consumers [96]. Importantly, sodium content in meat products is not solely derived from sodium chloride; various additives such as sodium nitrate, sodium citrate, sodium phosphate, sodium bicarbonate, and monosodium glutamate may also contribute to sodium levels in meat formulations [97].

4. Conclusion

A study examining the effects of high pressure treatment and variations in NaCl and phosphate content at different processing stages on several quality parameters revealed insightful findings. High pressure treatment applied to raw meat adversely affected the structure and water retention capacity of reduced-salt ham. However, it was determined that a 45% reduction in salt content in ham could be achieved by combining high pressure treatment with the use of potassium chloride (KCl). This research highlights the potential of integrating high pressure technology with strategic salt reduction approaches to optimize both product quality and safety in meat processing.

Declarations and Ethical Standards

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author Contributions

Author 1 conceived of the presented idea. Author 2 developed the theory, performed the computations and carried out the experiments. Author 1 supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

References

[1] S. McNeill and M. E. Van Elswyk, "Red meat in global nutrition," Meat Science, vol. 92, pp. 166–173, 2012. Doi: 10.1016/j.meatsci.2012.03.014.

[2] A. Altunboy and C. Sarıçoban, "Muscle stretching techniques used in meat tenderization," Electronic Journal of Food Technologies, vol. 9, no. 2, pp. 63–75, 2014.

[3] M. Ruusunen and E. Puolanne, "Reducing sodium intake from meat products," Meat Science, vol. 70, pp. 531–541, 2015. Doi: 10.1016/j.meatsci.2004.07.016.

[4] M. Alino, R. Grau, A. Fuentes, and J. M. Barat, "Influence of low-sodium mixtures of salts on the post-salting stage of dry-cured crude process," Meat Science, vol. 83, pp. 423–430, 2009. Doi: 10.1016/j.jfoodeng.2010.02.020.

[5] Anonymous, "Türkiye Excessive Salt Consumption Reduction Program 2011-2015," Ministry of Health, General Directorate of Primary Health Care, Department of Nutrition and Physical Activities, Ankara, Turkey, Nov. 2011.

[6] Turkish Hypertension and Kidney Diseases Association, "Salt Consumption Study in Türkiye SALTÜRK2," 2012. [Online]. Available: www.turkhipertansiyon.org/ppt/SALTurk2.ppt.

[7] M. Armenteros, M. C. Aristoy, J. M. Barat, and F. Toldrá, "Biochemical changes in dry-cured loins salted with partial replacements of NaCl by KCl," Food Chemistry, vol. 117, pp. 627–633, 2009. Doi: 10.1016/j.foodchem.2009.04.056.

[8] J. Chandrashekar, M. Hoon, N. Ryba, and C. Zuker, "The receptors and cells for mammalian taste," Nature, vol. 444, no. 7117, pp. 288–294, 2006.

[9] L. Cuenca, "The Bittersweet Truth of Sweet and Bitter Taste Receptors," 2013. [Online]. Available: http://sitn.hms.harvard.edu/flash/2013/the-bittersweet-truth-of-sweet-and-bitter-taste-receptors/. Accessed: Sep. 26, 2020.

[10] Anonymous, "Human Physiology/Senses," 2011. [Online]. Available: https://en.wikibooks.org/wiki/Human_Physiology/Senses. Accessed: Sep. 20, 2020.

[11] C. L. Murphy, A. V. Cardello, and J. G. Brand, "Tastes of fifteen halide salts following water and NaCl: anion and cation effects," Physiology and Behavior, vol. 26, pp. 1083–1095, 1981. Doi: 10.1016/0031-9384(81)90213-4.

[12] Q. Ye, G. L. Heck, and J. A. DeSimone, "The anion paradox in sodium taste reception: resolution by voltage-clamp studies," Science, vol. 254, pp. 726–742, 1991. Doi: 10.1126/science.1948054.

[13] J. F. Delwiche, B. P. Halpern, and J. A. DeSimone, "Anion size of sodium salts and simple taste reaction times," Physiology and Behavior, vol. 66, pp. 27–32, 1999. Doi: 10.1016/S0031-9384(98)00273-X.

[14] K. A. McMahon, "What is the role of salt in taste?" in Tested Studies for Laboratory Teaching, vol. 20, S. J. Karcher, Ed., Proceedings of the 20th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), pp. 387–389, 1999.

[15] D. Kilcast and C. den Ridder, "Sensory issues in reducing salt in food products," in Reducing Salt in Foods, D. Kilcast and F. Angus, Eds., Cambridge, England: Woodhead Publishing, 2007, pp. 201–220.

[16] E. Desmond, "Reducing salt: A challenge for the meat industry," Meat Science, vol. 74, pp. 188–196, 2006. Doi: 10.1016/j.meatsci.2006.04.014.

[17] J. G. Silva, H. A. Morais, and M. P. C. Silvestre, "Comparative study of the functional properties of bovine globin isolates and sodium caseinate," Food Research International, vol. 36, pp. 73–80, 2003. Doi: 10.1016/S0963-9969(02)00110-2.

[18] E. Luck and M. Pager, Conservación Química de los Alimentos: Characterísticas, Usos, Efectos, Zaragoza, Spain: Acribia, 2000, pp. 46–98.

[19] E. Durack, M. Alonso-Gomez, and M. G. Wilkinson, "Salt: A review of its role in food science and public health," Current Nutrition & Food Science, vol. 4, no. 4, pp. 290–297, 2008. Doi: 10.2174/157340108786263702.

[20] G. Betts, L. Everis, and R. Betts, "Microbial issues in reducing salt in food products," in Reducing Salt in Foods, D. Kilcast and F. Angus, Eds., Cambridge, England: Woodhead Publishing, 2007, pp. 174–200.

[21] Intersalt Cooperative Research Group, "Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion," BMJ, vol. 297, pp. 319–328, 1988.

[22] N. R. Cook, J. A. Cutler, E. Obarzanek, et al., "Long term effects of dietary sodium reduction on cardiovascular disease outcomes: observational follow-up of the trials of hypertension prevention (TOHP)," BMJ, vol. 334, p. 885, 2007.

[23] B. Cianciaruso, V. Bellizzi, R. Minutolo, et al., "Salt intake and renal outcome in patients with progressive renal disease," Mineral and Electrolyte Metabolism, vol. 24, pp. 296–301, 1998. Doi: 10.1159/000057385.

[24] Y. Erdem, M. Arici, B. Altun, C. Turgan, S. Sindel, B. Erbay, et al., "The relationship between hypertension and salt intake in Turkish population: SALTURK study," Blood Pressure, vol. 19, no. 5, pp. 313–318, 2010..

[25] S. B. Eaton, S. B. Eaton 3rd, M. J. Konner, and M. Shostak, "An evolutionary perspective enhances understanding of human nutritional requirements," Journal of Nutrition, vol. 126, no. 6, pp. 1732–1740, 1996. Doi: 10.1093/jn/126.6.1732.

[26] T. W. Kurtz, H. A. Al-Bander, and R. C. Morris Jr., "‘Salt-sensitive’ essential hypertension in men. Is the sodium ion alone important?" New England Journal of Medicine, vol. 317, p. 1043, 1987. Doi: 10.1056/NEJM198710223171702.

[27] N. J. Aburto, A. Ziolkovska, L. Hooper, et al., "Effect of low sodium intake on health: systematic review and meta-analyses," BMJ, vol. 346, p. 1326, 2013. Doi: 10.1136/bmj.f1326.

[28] A. Mente, M. O'Donnell, S. Rangarajan, et al., "Associations of urinary sodium excretion with cardiovascular events in individuals with and without hypertension: a pooled analysis of data from four studies," The Lancet, vol. 388, pp. 465–475, 2016. Doi: 10.1016/S0140-6736(16)30467-6.

[29] M. Cirillo, M. Laurenzi, W. Panarelli, and J. Stamler, "Urinary sodium to potassium ratio and urinary stone disease," Kidney International, vol. 46, pp. 1133–1139, 1994. Doi: 10.1038/ki.1994.376.

[30] A. Goulding and D. R. Campbell, "Effects of oral loads of sodium chloride on bone composition in growing rats consuming ample dietary calcium," Mineral and Electrolyte Metabolism, vol. 10, pp. 58–62, 1984.

[31] A. T. Whaley-Connell, J. R. Sowers, and L. A. Stevens, "CKD in the United States: Kidney Early Evaluation Program (KEEP) and National Health and Nutrition Examination Survey (NHANES) 1999–2004," [Online]. Available: [NHANES Dataset Reference].

[32] L. D'Elia, G. Rossi, R. Ippolito, et al., "Habitual salt intake and gastric cancer risk: a meta-analysis of prospective studies," Clinical Nutrition, vol. 31, pp. 489–498, 2012. Doi: 10.1016/j.clnu.2012.01.003.

[33] J. M. Fernandez-Gines, J. Fernandez-Lopez, E. Sayas-Barbera, and J. A. Pérez-Alvarez, "Meat products as functional foods: A review," J. Food Sci., vol. 70, pp. 37–43, 2005. Doi: 0.1111/j.1365-2621.2005.tb07110.x.

[34] S. T. Joo, G. D. Kim, Y. H. Hwang, and Y. C. Ryu, "Control of fresh meat quality through manipulation of muscle fiber characteristics," Meat Sci., vol. 95, no. 4, pp. 828–836, 2013. Doi: 10.1016/j.meatsci.2013.04.044.

[35] X. Hou, R. Liang, Y. Mao, Y. Zhang, L. Niu, R. Wang, C. Liu, Y. Liu, and X. Luo, "Effect of suspension method and aging time on meat quality of Chinese fattened cattle M. Longissimus dorsi," Meat Sci., vol. 96, no. 1, pp. 640–645, 2014. Doi: 10.1016/j.meatsci.2013.08.026.

[36] P. Lewicki, J. A. Arboix, P. G. Botó, J. C. Beringues, and I. M. Moreno, "Drying," in M. Dikeman and C. Devine, Eds., Encyclopedia of Meat Science (Second Edition), London, UK: Elsevier Ltd., 2014, pp. 471–479.

[37] M. G. Martins, D. E. G. Martins, and R. D. S. Pena, "Drying kinetics and hygroscopic behavior of pirarucu (Arapaima gigas) fillet with different salt contents," LWT-Food Sci. Technol., vol. 62, pp. 144–151, 2015. Doi: 10.1016/j.lwt.2015.01.010.

[38] M. Bampi, N. N. Domschke, F. C. Schmidt, and J. B. Laurindo, "Influence of vacuum application, acid addition and partial replacement of NaCl by KCl on the mass transfer during salting of beef cuts," LWT-Food Sci. Technol., vol. 74, pp. 26–33, 2016. Doi: 10.1016/j.lwt.2016.07.009.

[39] G. Barbieri, M. Bergamaschi, M. Francheschini, and E. Berizi, "Reduction of NaCl in cooked raw by modification of the cooking process and addition of seaweed extract (Palmaria palmata)," LWT-Food Sci. Technol., vol. 73, pp. 700–706, 2016. Doi: 10.1016/j.lwt.2016.06.057.

[40] Z. Wang, W. Xu, N. Kang, Q. Shen, and D. Zhang, "Microstructural, protein denaturation and water holding properties of lamb under pulse vacuum brining," Meat Sci., vol. 113, pp. 132–138, 2016. Doi: 10.1016/j.meatsci.2015.11.015.

[41] G. Feiner, *Meat Products Handbook: Practical Science and Technology*, Boca Raton, FL, USA: CRC Press, Elsevier Ltd., 2016, pp. 648.

[42] F. C. Schmidt, B. A. M. Carciofi, and J. B. Laurindo, "Salting operational diagrams for chicken breast cuts: Hydration-dehydration," J. Food Eng., vol. 88, pp. 36–44, 2008. Doi: 10.1016/j.jfoodeng.2007.12.005.

[43] H. Wu, W. Yan, H. Zhuang, M. Huang, J. Zhao, and J. Zhang, "Oxidative stability and antioxidant enzyme activities of dry-cured bacon as affected by the partial substitution of NaCl with KCl," Food Chem., vol. 201, pp. 237–242, 2016. Doi: 10.1016/j.foodchem.2016.01.025.

[44] J. Żochowska-Kujawska, "Effects of fiber type and structure of longissimus lumborum (Ll), biceps femoris (Bf) and semimembranosus (Sm) deer muscles salting with different NaCl addition on proteolysis index and texture of dry-cured meats," Meat Sci., vol. 12, pp. 390–396, 2016. Doi: 10.1016/j.meatsci.2016.07.001.

[45] M. Kaya and G. Kaban, "Quality control of meat and meat products," in Quality Control Handbook, M. Kıvanç, Ed., Eskişehir, Turkey: Anadolu University Web-Ofset, 2010, pp. 24–42.

[46] M. Aksu and M. Kaya, "Pastrami production using different curing methods and starter culture," Turk J. Vet. Anim. Sci., vol. 26, pp. 909–916, 2002.

[47] G. Kaban, "Changes in the composition of volatile compounds and in microbiological and physicochemical parameters during bacon processing," Meat Science, vol. 82, pp. 17–23, 2009. Doi: 10.1016/j.meatsci.2008.11.017.

[48] G. Kaban, "Sucuk and pastrami: Microbiological changes and formation of volatile compounds," Meat Science, vol. 95, pp. 912–918, 2013.

[49] O. C. Tekinşen and Y. Doğruer, Pastrami in All Aspects, Konya, Turkey: Selçuk University Press, 2000, pp. 123.

[50] Ministry of Agriculture and Forestry, "Meat, Prepared Meat Mixtures and Meat Products Communiqué," 2018.

[51] S. S. Lim, T. Vos, A. D. Flaxman, G. Danaei, K. Shibuya, H. Adair-Rohani, and Z. A. Memish, "A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the global burden of disease study," Lancet, vol. 380, no. 9859, pp. 2224–2260, 2010. Doi: 10.1016/s0140-6736(12)61766-8.

[52] TÜRKSOM Database, [Online]. Available: http://www.turkom.gov.tr/database.

[53] M. Ruusunen, M. S. Tirkkonen, and E. Puolanne, "Saltiness of coarsely ground cooked ham with reduced salt content," Agricultural and Food Science in Finland, vol. 10, pp. 27–32, 2001.

[54] B. C. Breidenstein, "Understanding and calculating the sodium content of your products," Meat Processing, vol. 21, no. 5, p. 62, 1982.

[55] M. Karakaya, "Emulsion Type Meat Products," Selçuk University, Institute of Science and Technology, Food Engineering Department Lecture Notes, Konya, Turkey, 2008.

[56] H. Y. Gökalp, M. Kaya, and Ö. Zorba, Meat Products Processing Engineering, Erzurum, Turkey: Atatürk University Faculty of Agriculture, Department of Food Engineering, 2004.

[57] R. N. Terrell, "Reducing the sodium content of processed meats," Food Technology, vol. 37, no. 7, pp. 66–71, 1983. Doi: 10.1016/j.meatsci.2004.07.016.

[58] R. Hamm, "Functional properties of the myofibrillar system," in P. J. Bechtel, Ed., Muscle as Food, New York, NY, USA: Academic Press, 1986, pp. 135–200.

[59] G. Offer and K. Night, "The structural basis of water-holding in meat," in R. A. Lawrie, Ed., Developments in Meat Science, vol. 4, London, UK: Elsevier Applied Science, 1988, pp. 173–243.

[60] H. Y. Gökalp, M. Kaya, and Ö. Zorba, Meat Products Processing Engineering, Erzurum, Turkey: Atatürk University Faculty of Agriculture Offset Facility, Publication 786, 1994.

[61] A. Öztan, Meat Science and Technology, Ankara, Turkey: Hacettepe University Faculty of Engineering Publications, Publication No: 19, 1995.

[62] H. Y. Gökalp, M. Kaya, and Ö. Zorba, Meat Product Processing Engineering, Erzurum, Turkey: Atatürk University Faculty of Agriculture Offset Facility, Publication No: 786, Textbook Series No: 70, 2002.

[63] Anonymous, "Bacon Standard," Turkish Standards Institute, TS No: 1071, Feb. 2002.

[64] A. M. Pearson and T. Gillett, Processed Meat, New York, NY, USA: Chapman and Hall, 1996, p. 448.

[65] J. P. Girard, Technology of Meat and Meat Products, England: Ellis Horwood, 1992, p. 272.

[66] A. Öztan, Meat Science and Technology, 4th ed., Ankara, Turkey: TMMOB Chamber of Food Engineers Publications, Books Series Publication No: 1, 2003.

[67] H. Vural and A. Öztan, "Our traditional meat product is roasting," Meat and Fish Association Industry Magazine, vol. 58, no. 9, pp. 22–28, 1989.

[68] M. Kaya and H. Y. Gökalp, "The Behavior of Listeria monocytogenes in Sucuks Produced with Different Lactic Starter Cultures," Turkish Journal of Veterinary & Animal Science, vol. 28, no. 6, pp. 1113–1120, 2004.

[69] M. Kaya and H. Y. Gökalp, "The Effects of Starter Cultures and Different Nitrite Doses on the Growth of Listeria monocytogenes in Sausage Production," Turkish Journal of Veterinary & Animal Science, vol. 28, no. 6, pp. 1121–1127, 2004.

[70] B. A. D. Dos Santos, P. C. B. Campagnol, A. G. Cruz, M. A. Morgano, R. Wagner, and M. A. R. Pollonio, "Is there a potential consumer market for low-sodium fermented sausages," Journal of Food Science, vol. 80, no. 5, pp. 1093–1099, 2015. Doi: 10.1111/1750-3841.12847.

[71] G. S. Nielsen, B. R. Petersen, and A. J. Møller, "Impact of salt, phosphate and temperature on the effect of a transglutaminase (FXIIIa) on the tissue of restructured meat," Meat Science, vol. 41, pp. 293–299, 1995. Doi: 10.1016/0309-1740(94)00002-o.

[72] W. C. Schwartz and R. W. Mandigo, "Effect of salt, sodium tripolyphosphate and storage on restructured pork," Journal of Food Science, vol. 41, pp. 1266–1269, 1976. Doi: 10.1111/j.1365-2621.1976.tb01148.x.

[73] T. Israr, A. Rakha, M. Sohail, S. Rashid, and A. Shedzad, "Salt reduction in baked products: strategies and constraints," Trends in Food Science & Technology, vol. 51, pp. 98–105, 2016. Doi: 10.1016/j.tifs.2016.03.002.

[74] M. Ekmekçi, "Effects of the Use of Potassium Chloride and Calcium Chloride on Some Quality Characteristics in the Production of Reduced Salt Pastrami," Master's Thesis, Ankara University, Institute of Science and Technology, Ankara, Turkey, 2012, p. 77.

[75] E. S. Inguglia, Z. Zhang, B. K. Tiwari, J. P. Kerry, and C. M. Burgess, "Salt reduction strategies in processed meat products - A review," Trends in Food Science & Technology, vol. 59, pp. 70–78, 2017.

[76] M. E. Doyle, "Sodium reduction and its effects on food safety, food quality, and human health," FRI Briefings, pp. 1–12, 2008.

[77] Anonymous, "Salt and health: review of the scientific evidence and recommendations for public policy in Ireland," Food Safety Authority of Ireland, 2005.

[78] O. Ketenoğlu and K. Candoğan, "Effect of low-sodium salt utilization on some characteristics of ground beef patties," Food, vol. 36, no. 2, pp. 63–69, 2011.

[79] J. F. Price, "Low-fat/only cured meat products," in A. M. Pearson and T. R. Dutson, Eds., Advances in Meat Research: Production and Processing of Healthy Meat, vol. 11, London, UK: Blackie Academic & Professional, 1997, pp. 242–256.

[80] J. E. Collins, "Reducing salt (sodium) levels in processing meat, poultry and fish products," in A. M. Pearson and T. R. Dutson, Eds., Advances in Meat Research: Production and Processing of Healthy Meat, Poultry and Fish Products, vol. 11, London, UK: Blackie Academic & Professional, 1997, pp. 283–297.

[81] A. Costa-Corredor, X. Serra, J. Arnau, and P. Gou, "Reduction of NaCl content in restructured dry-cured hams: Post-resting temperature and drying level effects on physicochemical and sensory parameters," Meat Science, vol. 83, pp. 390–397, 2009. Doi: 10.1016/j.meatsci.2009.06.011.

[82] M. Ruusunen, M. Niemistö, and E. Puolanne, "Sodium reduction in cooked meat products," Agricultural and Food Science in Finland, vol. 11, pp. 199–207, 2002.

[83] M. Ruusunen, J. Vainionpää, M. Lyly, L. Lähteenmäki, M. Niemistö, R. Ahvenainen, and E. Puolanne, "Reducing the sodium content in meat products: The effect of formulation in low-sodium ground meat patties," Meat Science, vol. 69, pp. 53–60, 2005. Doi: 10.1016/j.meatsci.2004.06.005.

[84] M. Ruusunen, M. Simolin, and E. Puolanne, "The effect of fat content and flavor enhancers on the perceived saltiness of cooked bologna-type sausages," Journal of Muscle Foods, vol. 12, pp. 107–120, 2001. Doi: 10.1111/j.1745-4573.2001.tb00303.x.

[85] J. Leong, C. Kasamatsu, E. Ong, J. T. Hoi, and M. N. Loong, "A study on sensory properties of sodium reduction and replacement in Asian food using difference-from-control test," Food Science & Nutrition, vol. 4, no. 3, pp. 469–478, 2015. Doi: 10.1002/fsn3.308.

[86] K. V. Arun, B. D. Sharma, and R. Banarjee, "Effect of sodium chloride replacement and apple pulp inclusion on the physico-chemical, textural and sensory properties of low-fat chicken nuggets," LWT - Food Science and Technology, vol. 43, pp. 715–719, 2010.

[87] E. Hastaoğlu, "Effects of Potassium Chloride Use on Some Quality Characteristics of Pastrami," Master's Thesis, Hacettepe University, Institute of Science, Department of Food Engineering, Ankara, Turkey, 2011.

[88] J. Gelabert, P. Gou, L. Guerrero, and J. Arnau, "Effect of sodium chloride replacement on some characteristics of fermented sausages," Meat Science, vol. 65, pp. 833–839, 2003. Doi: 10.1016/S0309-1740(02)00288-7.

[89] P. Gou, L. Guerrero, J. Gelabert, and J. Arnau, "Potassium chloride, potassium lactate and glycine as sodium chloride substitutes in fermented sausages and in dry-cured pork loin," Meat Science, vol. 42, no. 1, pp. 37–48, 1996. Doi: 10.1016/0309-1740(95)00017-8.

[90] E. Fulladosa, X. Serra, P. Gou, and J. Arnau, "Effects of potassium lactate and high pressure on transglutaminase restructured dry-cured hams with reduced salt content," Meat Science, vol. 82, no. 2, pp. 213–218, 2019. Doi: 10.1016/j.meatsci.2009.01.013.

[91] M. D. Guardia, L. Guerrero, J. Gelabert, P. Gou, and J. Arnau, "Sensory characterization and consumer acceptability of small caliber fermented sausages with 50% substitution of NaCl by mixtures of KCl and potassium lactate," Meat Science, vol. 80, pp. 1125–1230, 2008. Doi: 10.1016/j.meatsci.2008.05.031.

[92] Cargill Salt, "Wow-alberger brand salt," Product Brochure, 2001.

[93] M. Noort, J. Bult, and M. Stieger, "Saltiness enhancement by taste contrast in bread prepared with encapsulated salt," Journal of Cereal Science, vol. 55, pp. 218–225, 2012. Doi: 10.1016/j.jcs.2011.11.012.

[94] A. G. Cruz, J. A. F. Faria, S. M. I. Saad, H. M. A. Bolini, A. S. Sant'Ana, and M. Cristianini, "High pressure processing and pulsed electric fields: potential use in probiotic dairy foods processing," Trends in Food Science and Technology, vol. 21, no. 10, pp. 483–493, 2010.

[95] M. Clariana, L. Guerrero, C. Sárraga, I. Díaz, A. Valero, and J. A. García-Regueiro, "Influence of high pressure application on the nutritional, sensory and microbiological characteristics of sliced skin vacuum packed

dry-cured ham: Effects along the storage period," Innovative Food Science & Emerging Technologies, vol. 12, no. 4, pp. 456–465, 2011. Doi: 10.1016/j.ifset.2010.12.008.

[96] A. D. Alarcon-Rojo, H. Janacua, J. C. Rodriguez, L. Paniwnyk, and T. J. Mason, "Power ultrasound in meat processing," Meat Science, vol. 107, pp. 86–93, 2015. Doi: 10.1016/j.meatsci.2015.04.015.

[97] A. Tamm, T. Bolumar, B. Bajovic, and S. Toepfl, "Salt (NaCl) reduction in cooked crude by a combined approach of high pressure treatment and the salt replacer KCl," Innovative Food Science and Emerging Technologies, vol. 36, pp. 294–302, 2016. Doi: 10.1016/j.ifset.2016.07.010.

About the Authors

 Hüdayi Ercoşkun	Hüdayi Ercoşkun is an Associate Professor at the Department of Food Engineering, Faculty of Engineering, Çankırı Karatekin University. He completed his undergraduate education at Atatürk University, his master's degree at Pamukkale University, and his Ph.D. at the Institute of Natural and Applied Sciences, Ankara University. His research areas include meat technology, food technologies, and food science, with a particular focus on the relationship between salt and food. Ercoşkun has enriched his academic career with international experiences. He has studied at institutions such as the Technical University of Denmark (Denmark), Wageningen University (Netherlands), Tokyo University (Japan), and Nanyang Technological University (Singapore). Additionally, he has served as a short-term lecturer at several universities, including the Catholic University of Portugal (Portugal), West Pomeranian University of Technology (Poland), Daffodil International University (Bangladesh), Khartoum University (Sudan), Sudan University of Science and Technology (Sudan), Al Zaiem Al Azhari University (Sudan), and Makerere University (Uganda). He has also pursued studies in Instrument Pre Accession Assistance Rural Development at the Ministry of Agriculture and Forestry in Turkey and has conducted technical visits for rural development purposes to Belgium, the Netherlands, Spain, Hungary, and Croatia. Ercoşkun has contributed to various national and international journals with articles covering topics such as the quality of fermented meat products, salt reduction strategies, and biochemical reactions in meat products. He has edited scientific books including "Salt and Food" and "Salt in All Aspect," addressing topics such as salt consumption, its effects on health, and its role in food technologies. He is also the author of the "Sucuk Technology" chapter in the book "Industrial Food Production Technologies." His work in the intersection of salt, food science, and rural development has established him as a respected figure in the field of food engineering.
 Fatma Bayrakçeken Nişancı	Fatma Bayrakçeken Nişancı is an assistant professor at the Department of Chemistry, Faculty of Science, Atatürk University. She began her academic career in 2006 as a research assistant in the Department of Chemistry at the Faculty of Science, Atatürk University. In 2016, she worked as an assistant professor in the Department of Food Processing at Narman Vocational School. Since 2020, she has been continuing her role as an assistant professor at the Department of Chemistry, Faculty of Science, Atatürk University. She is also notable for her scientific publications and book chapters. Among these, she has written a chapter in the scientific book titled "Salt and Food" and has contributed to numerous textbook chapters on occupational health and safety. Her scientific research focuses on nanotechnology, materials science, and electrochemical synthesis. She has published numerous peer-reviewed articles in both national and international journals.