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Impact of ground size on meat quality and meat products: a review

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ABSTRACT

Minced meat is a crucial and widely accepted ingredient used in the preparation of various foods that are widely consumed worldwide. Because of its versatility and handiness, it is used in various dishes, such as emulsion-based meat products, meatballs, sausages, patties, and hamburgers. The ground size has a significant effect on the meat quality attributes. Based on ground size, minced meat can be categorized into three types, viz., fine, medium, and coarse. The present work critically reviewed the impact of ground size on the various quality attributes of meat and meat products. The different ground sizes obtained as a result from different processing methods (such as by using a mincer, grinder, or knife) had a significant impact on the meat quality attributes, including juiciness, flavor, color, pH, tenderness, and sensory evaluation. However, the changes in the meat quality parameters are not only caused by the intensity of the mincing/grinding or the amount of non-intact cells (ANIC), but also by the breakdown of the muscle fibers, structure loss, connective tissues, myofibrillar proteins, and exposure of the surface area. The results of the study revealed that mincing sizes influence the quality parameters such as textural integrity, WHC, color, juiciness, and pH.

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Introduction

Several factors affect the quality of meat and meat products and are grouped into extrinsic and intrinsic (Cardona *et al.*, 2023; De Lima Jùnior *et al.*, 2016). Intrinsic factors are related to the product's characteristics, such as appearance, color, water holding capacity (WHC), pH, tenderness, fat and protein content, and chemical composition of the meat (Dey *et al.*, 2020; Ferreira *et al.*, 2024). These factors have a greater influence on consumer acceptance of minced meat and its products. Mir *et al.* (2017) reported that flavor and tenderness are the most important factors considered by consumers in acceptance of meat, while other studies reported that the appearance of the meat, which accounts for the quality of fat and visible moisture, has a significant impact on consumer acceptability and influence on purchase (Cardona *et al.*, 2023). Furthermore, factors such as meat processing techniques, storage conditions, and packaging have a great impact on the quality of meat.

Meat processing is a complex process involving a chain of operations aimed at transforming raw muscle tissue into products with enhanced shelf life, safety and consumer appeal. Among these operations, mincing plays an important role in the production of several products.

Meat mincing is one of the most common methods used in the meat processing industry, in which raw meat is cut into smaller particles. Meat mincing is performed to homogenize and standardize the

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meat, which is suitable for a variety of products (Ong *et al*., 2020). Minced meat is an important commercially accepted ingredient used in the preparation of different foods consumed globally because of its versatility and handiness and is used in various dishes such as meatballs, sausages, patties, and hamburgers (Kaur *et al*., 2023). Minced meat has become a popular food component because of its ease of processing and as a good protein source, along with essential amino acids, minerals, and vitamins (Zeng *et al*., 2022).

The choice of meat ground size can vary based on the consumer's preferences and intended use, which has a profound impact on the processing parameters (Luo *et al*., 2021). However, studies have indicated that further processing of minced meat significantly changes consumers' perception of meat quality (Berger *et al*., 2022; 2023). This indicates a good relationship between mincing size and meat quality. Meat quality parameters such as color, texture, juiciness, drip loss, and cooking loss can be affected by minced size (Berger *et al*., 2023).

While review studies have detailed the mechanical aspects of meat grinding and minced size vs texture and juiciness, however, there is a conspicuous absence of comprehensive analyses that correlate the granular size of the minced meat at a molecular level with specific quality parameters such as protein structure, fat distribution, nutritional retention and flavor profile. A deeper investigation into these underexplored areas would enhance meat processing methods, provide opportunities for the meat/food scientists and technologists for the optimization of minced meat products in terms of sensory appeal and consumer preference. Thus, the present study critically examines the impact of ground particle size on the quality of meat and meat products. It synthesizes findings on how different ground sizes affect meat quality parameters such as color stability and texture. Moisture retention, oxidative changes, and sensory characteristics. The study hypothesized that mincing significantly influences the physicochemical and sensory properties of the meat and the final products, with finer minced size improving texture and Water retention Capacity, while larger minced size may preserve better flavor intensity and juiciness.

Methods

A comprehensive search of relevant research articles and review papers was conducted using various scientific databases such as Scopus, Google Scholar, and PubMed. The focus of the study was on papers related to ground, mincing, comminution, and chunking of meat and their effects on meat quality parameters that are published in English. This includes an analysis of the methodologies and key findings.

Grinding techniques

Mechanical grinding of meat is performed by passing the meat through a cylindrical tube equipped with a rotating screw/cross-shaped knife that cuts the incoming meat into smaller particles by rotatory shear cuts (Schnäckel *et al*., 2011). At the end of the rotating shaft, the cutting system is followed by a stationary perforated disc/hole plate having pores size of 1–13 mm. The deboned meat chunks are compressed by the rotating shaft and pushed towards the cutting system followed by cutting by revolving knives and extruding through the holes of the hole plate. The meat grinders could be electrical (operated by electricity) or manual (operated by turning the cranks manually by the operator) and using screws or other mechanisms to chop the meat into finer particles of desired size. Furthermore, in the meat processing industry, the processing line also has mixing and shaping effects in addition to grinding, which is attributed to the different mechanical forces applied to meat (Berger *et al*., 2023).

The flow diagram below (Figure 1) shows the various steps commonly followed by the mincing meat industry.

Various sizes of mincer and grinder blades used in mincing meat are presented in Figure 2.

Meat mincing size on meat quality parameters

Several studies have indicated that the change in meat quality parameters of ground meat is a result of the intensity of the processing of raw meat into a different ground form, which leads to cell destruction and structural alteration of the meat (Bolumar *et al*., 2021; Witte *et al*., 2022; Yu *et al*., 2017). Haq *et al*.

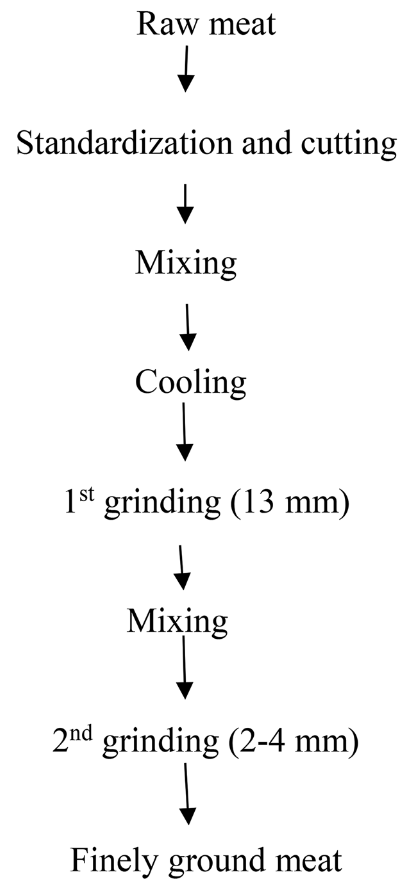

Figure 1. Flowchart of mincing process. Source: Berger *et al*. (2022).

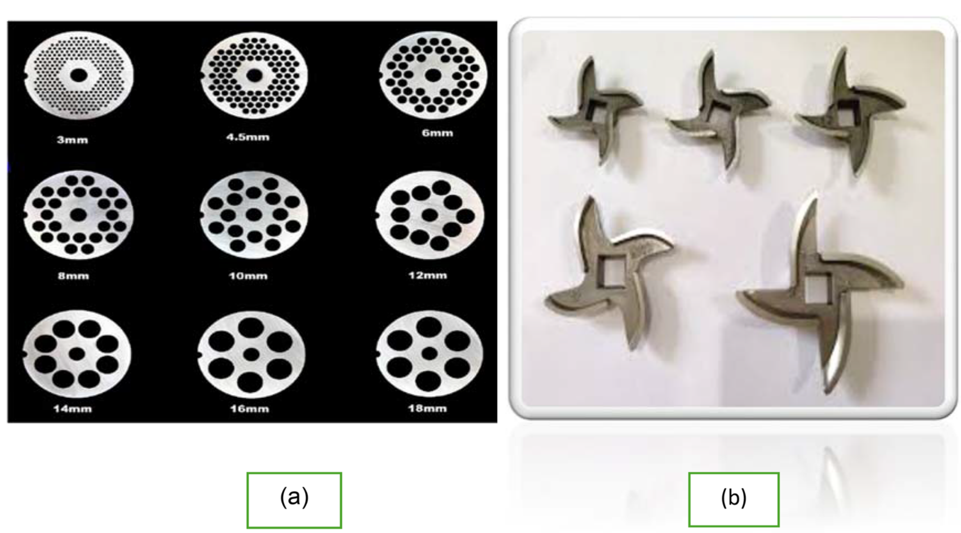

Figure 2. (a) Mincer of different sizes (b) grinder blades of different sizes. source: (a) Made-in-China (2024) (b). Superior Food and Machinery (2024).

(2024) and Akhtar *et al*. (2013) also reported that grinding meat to a finer form reduces muscle fiber and collagen size, thereby increasing the tenderness of the meat, leading to the production of a large surface area, resulting in the release of muscle protein and consumer appearance of the developed products. Research indicates that finer ground meat of < 3 mm size can enhance meat tenderness by breaking down muscle fibers more thoroughly, while carefully controlled processing conditions ensure that juiciness is retained (Warner *et al*., 2021).

The process of grinding meat into coarse, medium, or finer particle sizes not only facilitates the formation of uniformly shaped products when moulded but also enhanced meat tenderness and ensures a uniform flavour distribution (Patel *et al*., 2023; Sen *et al*., 2022). Studies have suggested that these changes are not only affected by the cut size but also by the breed and age of the animal play a significant role (López-Pedrouso *et al*., 2020, Schumacher *et al*., 2022).

The study by Suman and Sharma (2003) examined how different ground sizes of minced Buffalo meat (3, 4, and 6 mm) influenced its physicochemical and sensory properties. In this study, the meat was minced separately through a plate orifice of different sizes. Fat and other additives were added to the minced meat and processed, into a molded raw patty, which was boiled and later cooked for a specific time. The samples of the cooked patties were analyzed for proximate composition, pH, and sensory evaluations. The findings of the study revealed that, in terms of proximate composition, pH, and sensory evaluation, the different minced sizes (3, 4, and 6 mm) did not significantly affect ($p > 0.05$) the quality of the low-fat cooked minced buffalo meat. This indicates that the overall nutritional content, acidity, and sensory appeal remained largely unchanged across the different particle sizes. However, the result of the shear force showed a significant increase as the minced size increased. This could be a result of the presence of a larger particle size owing to the larger ground size, resulting in the production of tougher meat products. The authors concluded that minced meat size affects the quality of buffalo meat patties and recommended the use of the smallest size (3 mm) as an acceptable ground size to improve the tenderness of meat as other indices remained the same regardless of the ground sizes.

Caldas-Cueva *et al*. (2021) study agrees with the findings of Suman and Sharma (2003), which reported an increase in the textural quality of minced chicken meat with an increase in the minced size. This may be due to an increase in particle size leading to reduced protein breakdown, retention of muscle fibers, and improved moisture retention resulting in firmer, more cohesive, and often more desirable texture. However, Afshari *et al*. (2017) conducted a similar study with disagreement in the results, he studied the effects of the degree of comminution on texture and sensory indices of low-fat beef burgers. The study used batches of lean and fat from old heifers, which were frozen for 2 weeks at −23 °C to mimic commercial practices and separately minced into different sizes of 2, 5, and 10 mm with a commercial mincer. The textural properties of the minced product were analyzed using Kramer shear (KS), Warner Brazier (WB), and TPA. The results on cook loss and pH values indicated no significant differences ($p > 0.05$) among the different minced sizes, whereas the results for sensory and texture showed significant differences ($p < 0.05$) between the finely comminuted and the other two plate size orifices (large and medium).

The above results obtained for the sensory assessment are not in agreement with the findings of many studies that increasing ground size due to variability of methods leads to a decrease in texture scores associated with sensory properties of meat products (Ruiz *et al*., 2017). The findings on the effects of different ground-size meat products on texture assessment indicate that no significant difference exists for the TPA method, while KS and WB methods show differences among the minced sizes and further asked about the inability of the TPA method to identify differences among the treatments, rendering this technique useless for the assessment of the product. This could be due to the fact that TPA measures the compressive and elastic characteristics of the meat, which might not be affected by the differences in minced sizes compared to methods that assess the shear strength (KS and WB). The study concluded that beefburgers produced using 5 and 10 mm plate orifices were superior in terms of acceptability.

Fauzi *et al*. (2021) investigated the effects of ground meat size on the quality of burgers made from spent laying duck meat, which were frozen, thawed, deboned, and ground into four different orifice sizes (4.5, 6, 8, and 10 mm) in a meat grinder. Duck meat burgers were prepared using 75% duck meat, 9% ice flakes, 5% Soy protein isolate, and Tapioca flour, 3% condiment powder, 2.5% vegetable shortening, 1.5%, 1% konjac powder, 1.5% salt, and 0.5% sugar. The Minced meat was prepared manually according to the procedure described by Ramadhan *et al*. (2012) and was conducted at a controlled temperature (4 °C). The molded burger prepared was frozen at −18 °C for 3 hours, the Samples were used for the analysis of meat quality parameters (color, TPA, sensory evaluation) and were conducted in triplicate. The findings of the study indicated that the duck burger produced with the larger orifice size has lower fat and protein than the small orifice size. The observed increase in hardness, particularly in the large ground sizes, may be attributed to the higher connective tissue content of spent duck meat, which inherently contributes to increased toughness. The use of a large orifice size resulted in lower fat and protein which would likely reduce the moisture and texture of the duck burger, which can negatively impact on the overall meat quality (juiciness and flavor).

The results for color analysis showed no significant differences ($p > 0.05$) between the different ground sizes; however, the values decreased in the order 6 mm > 8 mm > 10 mm, except for the lower value for lightness (L*). The redness (a*) was higher in the smaller orifice. This might be due to the higher retention of protein components (hemoglobin and heme protein) after grinding, and the lower a* might be due to a greater decrease in heme protein (Fauzi *et al*., 2021). These results disagree with the findings of Zaki and El Faham (2018), who recorded a lower value for chicken burgers; however, the author explained that this could be due to the higher red muscle content in duck meat compared to chicken (Ali *et al*., 2007). The results for yellowness (b*) among the different orifice sizes showed no significant differences ($p > 0.005$).

The results obtained for TPA showed that the smallest ground size recorded a high chewiness, cohesiveness, gumminess, and hardness compared to the other sizes. However, the duck burger made from 6 mm had higher springiness than the other ground-size burgers, and the results showed a decreasing trend from the small to the larger orifice in terms of hardness. The reason for the hardness might be due to the high connective tissue content in spent duck meat, which makes the meat tougher (Kokoszyński *et al*., 2020).

The results of the sensory assessment of a burger made from duck minced meat of different sizes showed no significant differences ($p > 0.005$) among the different orifices for all attributes. However, the 10 mm minced size was the highest for juiciness and overall acceptability. This finding is consistent with the observations of Suman and Sharma (2003), who reported a maximum score for juiciness, texture, and overall acceptability for 3 mm minced ground size of low-fat ground buffalo meat patties prepared with different ground sizes (3, 4, and 6 mm). The study concluded that a duck meat burger with a 10% fat level with smaller orifice (3 mm) produced the best result compared with the other ground sizes and fat levels.

The quantity of the Amount of Non-Intact Cells (ANIC) is used to determine meat quality; ANIC is the proportion of cells that are damaged or lose structural integrity, it usually assesses the level of disruption of muscle cells during post-slaughter handling and processing of meat. Damaged muscle cells can affect meat quality (texture, color and WHC). In some countries the quantity of ANIC is regulated, for instant in Germany over 20% of ANIC in minced meat is officially defined as threshold (Witte *et al*., 2022). However, many researchers have not analyzed ANIC due to technical and conceptual reasons, especially for minced meat (Tomasevic *et al*., 2023). A study conducted by Witte *et al*. (2022) to determine the effects of ANIC on the quality of minced meat and to assess if the mechanical aspect of mincing has a negative effect on its quality, the authors used minced pork shoulder meat mixed with finer-ground pork loin lean, which was used as an intensively processed meat batter, which indicated that the increase in the quality of the meat batter is inversely proportional to the increase in ANIC, and concluded that the increase in meat batter does not show any significant difference in meat quality parameters. Based on this conclusion, it is clear that ANIC does not affect minced meat quality parameters and therefore should not be included in the study.

Effect of heat generated during mincing

Dekkers *et al*. (2018) stated that to have a clear understanding of the effects of minced size on meat parameters, one needs to understand the process of meat mincing. The process involves subjecting raw meat to four different steps: meat cutting, mixing, mincing, and tray (Witte *et al*., 2022). This leads to the generation of heat energy as a result of friction between the moving parts and the meat, resulting in significant effects on meat protein denaturation, loss of water, and shrinkage of the collagen fiber (Alfaifi *et al*., 2023; Puolanne, 2017). The heat generated during mincing may disrupt the cellular structures, including muscle, myofibers, and connective tissues. This disruption can lead to improvements in sensory qualities, tenderness, water binding capacity (WBC), and the solubility of proteins, enhancing overall meat quality (Berger *et al*., 2023; Holloway *et al*., 2019). These changes in meat quality parameters might be caused by the heat produced or the disruption of the number of non-intact cells (ANIC) due to the intensity of the mincing machine. An investigation was made by Tomasevic *et al*. (2023) to determine whether the heat generated during the mincing process has an impact on meat quality parameters. The study used frozen and fresh meat ratios to investigate the heat generated during the mincing process and its effects on the minced quality of pork. The fresh meat temperature was 3 °C, while that of frosted was −12 °C. The fresh and defrosted meat were mixed and homogeneously distributed into six batches (replication) manually, and the percentage of defrosted meat was increased from the control (0%) to 50% maximum increment. The temperature and pH values were checked for unusual differences for each melting step (before and after). The study's findings on temperature revealed that for fresh meat (3 °C), the temperature at the end of the first mincing cycle remained unchanged and when the frozen meat was gradually added to the fresh meat it decreased the temperature. Therefore, the study concluded that the addition of 30% of frozen meat is sufficient, however, he rejected hypothesis that the increase level of frozen meat has significant effect on the sensory quality of minced pig meat.

Effect of mincing process

Krzywdzińska-Bartkowiak *et al*. (2014) investigated the effect of the intensity of the mincing process on minced size and compared the quality of finely ground meat using three different types of knives (smooth knives, knives with riffles, and knives with holes) with identical lengths and cutting edges. Silver skin pork meat was used together with fine fat, emulsion, additives, and water, which were used at different percentages to prepare the batter. The meat was cured by blending for 24 h at 4–6 °C; Later, the meat and the fat were ground with a 3 mm mesh size grinder and then added into a cutter bowl; the process continued until the internal temperature reached 12 °C. The results of the study showed that the types of knives mounted in the cutters affect the quality of the batter produced. A knife with holes on the lateral surfaces was found to be the best knife to produce finely ground meat batter. This could be a result of the holes that facilitate better meat separation, optimize the balance of cutting efficiency, reduce fiction and consistent flow. However, Berger *et al*. (2024) in his studied the effect of cutting set variations on the structural and functional properties of hamburgers, where different cutting set variations (cutting level, middle hole plate and end hole plate) are used for the production. The finding of his study revealed no significant differences in the structural and functional properties of ground beef hamburgers subjected to different cutting set variations. The discrepancies in the results may be due to the differences in the items used for the studies, the former used knives while the latter used knife and plates, differences machine, meat from different species of animal, different time set and products.

In a study by Ismail *et al*. (2021), who compared the processing of buffalo meat patties using a meat mixer, universal mixer, and bowl cutter on microstructural, physicochemical, and sensorial characteristics, the findings indicated significant differences in the meat quality among the three; the bowl cutter recorded the highest value in product color (lightness and yellowness) and lowest in redness. While recording lower values for hardness, chewiness, and gumminess, the author explained that the mechanical action of the bowl cutter produced a smaller pore size particle, leading to the breakdown of muscle fibers and connective tissues oxidation of myoglobin, and reduces the structural integrity of the meat resulting in lighter appearance of the meat, less firm product with lower chewing value (Ismail *et al*., 2021).

In a study conducted by Singh *et al*. (2023) on the effects of particle size, fat content, tumbling time, and their interplay through principal component analysis, the aim was to select the best ground size. The experiment used calf meat (buffalo), which was deboned by separating the fat, lean meat, and connective tissues from the bone, stored at -18 ± 1 °C in a low-density polyethylene bag, frozen, and thawed later. The meat was minced into 3 mm and 6 mm particle sizes with a meat mincer, and the meat batter was prepared with different sizes of minced meat, where the fat levels and tumbling time remained constant (15% and 2 h). The minced meat and the ingredients were used to prepare a total of nine different batter products; batters were filled in a round mold and steam cooked for 40 min until the internal temperature reached 80 °C and transferred to a refrigerator. The samples were used for analysis of pH, cooking yield, TPA, moisture content, and protein content. The results of the study revealed that there was no significant difference ($p > 0.05$) among the products made from different particle sizes for pH and

Table 1. Effect of minced meat sizes on meat quality parameters.

Ground size	Purpose	Results	References
2, 5 and 10 mm	Effects of degree of comminution on texture and sensory of low-fat beef burgers	• Size of 2 mm was less acceptable • Finer mincing is not recommended for low-fat beefburgers	Dreeling *et al.* (2000)
2–3 and 4–5 cm	Effects of chunk size on quality of restructured pork blocks	• Higher product yield and sensory attributes with minced particle size of 2–3 mm • Products with the minced particle size of 2–3 mm had low shear force and optimum for making restructured pork block	Gurikar *et al.* (2014)
5, 8, 12 and 20 mm	Effects of particle size on quality attributes of mutton streaks	• Shear force is greater in 5 and 12 mm • No significant difference was recorded for the protein and moisture content of mutton steak	Sen and Karim (2003)
2.4, 3.4, 4.8, 6.8, and 9.6 mm	Effect of meat ground sizes on sensory and physical properties of meat patties	• Hardness values increase in the order of increase in mincing size, the same goes for the elasticity of the product • Juiciness of the product tends to decrease as the ground size increased • Cohesiveness values significantly increase with an increase in ground size • WHC increases with increases in mincing size	Imai *et al.* (1994)

protein content, but there were significant differences ($p < 0.05$) in cooking yield, water holding capacity, and textural profile analysis. The non-significant difference ($p > 0.05$) in pH and protein content of the product could be that they are not directly influenced by the particle size, or the particle size variations is not large enough to impact on the parameters.

The results indicated a strong correlation between Water Holding Capacity (WHC) and particle size, as products prepared from 3 mm particles recorded a higher cooking yield. In addition, the product produced with 3 mm had a higher moisture content, which is contrary to the findings of Sen and Karim (2003), who reported no significant differences in moisture content and particle size. This could be due to the prolonged tumbling time, which may lead to a reduction in the moisture content. The TPA results indicated that the hardness of the products did not show a significant difference among the different sizes, whereas products prepared with 3 mm showed an increase in springiness, cohesiveness, gumminess, and chewiness. The enhanced softness and rapid breakdown during chewing, attributed to smaller particle sizes, likely result in a greater percentage of smaller, more easily chewed pieces, potentially improving the sensory experiences of the meat product. The authors concluded that the small particle size (3 mm) coupled with a 10% fat level and 1 h tumbling time improved the meat quality of batter prepared from buffalo meat. Table 1. Presents summarizes the findings of the effects of minced meat size on various quality parameters.

A study conducted by Fernández–López *et al.* (2000) to assess the degree of mincing of pork meat on color characteristics, using three different pork minced meat sizes of 10 mm and 20 mm in diameter, and finer particle minced size used as a control; the samples were placed into a glass cylindrical container of 9×6 mm to give it a shape, which was used for the determination of the color. The findings of the study indicated that L* (lightning) increases with the degree of mincing size; finer particles recorded the highest value, and a similar pattern was also recorded in the mincing of chicken and beef lean mean (Perez Alvarez *et al.*, 1998), however, the author explained how fatty meat and offal act in the opposite direction with the decrease in L* with the mincing degree and finalized that mincing reduces lightning in pork meat.

In trying to explain the causes of the increase in lightning in minced meat, studies have indicated a direct link between water holding capacity (WHC) and mincing (increase in WHC with a decrease in lightning), which might be due to modification of the meat structure, resulting in greater availability of moisture on the surface of the meat, which would mix with bubble air trapped in the meat, which could be responsible for the increase in lightning (Shao *et al.*, 2016). The result on the redness (a*) and yellowness (b*) shows no significant differences ($p > 0.05$) exist between the three mincing (10 mm, 20 mm, and finer particle) sizes. However, there were significant differences ($p < 0.05$) between the control and different minced meat sizes, the author concluded mincing reduces a* values and increases b* values regardless of the mincing size. The decrease in a* value is attributed to an increase in metmyoglobin (Krasulya *et al.*, 2021). Hoa *et al.* (2021) reported that this is due to the conversion of myoglobin (the pigment responsible for the redness of meat) to metmyoglobin (brown-colored pigment) upon the oxidation of

Table 2. Various changes in the quality attributes of meat due to mincing.

Parameter	Effect	References
Color	• Causes oxidation of pigment leading to a darker appearance. • More surface area is exposed • Increase reaction between myoglobin and oxygen.	Quevedo *et al.* (2013), Suman *et al.* (2014), Suman *et al.* (2016), Faustman *et al.* (2023)
Textural profile analysis	• Reduces fibrous • Disruption of muscle structure. • Leading to the softer and tender meat.	Saengsuk *et al.* (2021), Warner *et al.* (2021), Younis *et al.* (2023)
Protein denaturation	• Occur in mechanical mincing process leading to modification of protein's structure.	Sukmanov *et al.* (2019), Kumar *et al.* (2022)
WHC	• More surface area. • Enhance the interaction between proteins. • Leads to a decrease in moisture retention.	Balestra *et al.* (2019), Sukmanov *et al.* (2019)
Binding properties	• Disrupting the muscle structure. • Denaturation of protein.	Sukmanov *et al.* (2019)
pH	• Increase production of lactic acid. • Breakdown of glycogen in the muscle. • Leading to slightly more acidic. • Resulting in low pH of the meat	Andrés-Bello *et al.* (2013)
Microorganisms	• By Increasing the surface area, the microbes in the meat are distributed through the minced	

Figure 3. Minced meat of different ground sizes.

myoglobin. The author further explained that oxidation and myoglobin oxygenation of myoglobin in the mincing process trigger the disintegration of the muscle structure, leading to the release of liquid from the interior of the muscle cell, the presence of this liquid might be the reason for the reduction in the a* of pig meat. According to Shimizu and Iwamoto (2022), mincing breaks the muscle structure, freeing sarcoplasmic protein in myoglobin, thereby catalyzing the formation of oxymyoglobin by incorporating it with air, which increases the yellowness values. Table 2. Below present the research conducted by different authors on the effects of mincing on meat quality parameters.

Effects of mince size on texture

- According to Sukmanov *et al.* (2019), the degree of mincing significantly influences the textural and structural properties of many products. Köse *et al.* (2009) also reported that mincing meat helps to improve the texture, juiciness, and WBC of meat. Smaoui *et al.* (2014) reported an improvement in textural profile analysis (TPA) of chicken minced meat with an increase in ground size. In addition, Nayak and Pathak (2016) discovered an improvement in the TPA of low-fat ground beef patties according to their mincing size of 2 mm > 3 mm > 5 mm. While Barbut (2011) reported a contrary result, he observed an improvement in tenderness and overall palatability of low-fat minced beef patties in a mincing size of 0.48 cm compared to a 0.32 cm plate. Figure 3, below, shows the images of minced meat of different ground sizes.

Influence of mince size on nutrient retention.

According to Cheng and Sun (2008) mincing process affects the structural integrity of meat, which influences the ability to retain or lose nutrients. This was explained by Sharma *et al.* (2022) could be as a result of an increase or decrease in surface area and fat content, which affects nutrient stability and retention, particularly for fats and water-soluble vitamins. Fat content of minced meat is influenced by

Table 3. Impact of mince sizes on physicochemical characteristics of meat.

Mince size	Fat level	Effect on texture/ binding	Effect on cooking loss	Effect on sensory	Effect on juiciness and tenderness	References
Fine	High fat	Soft/greasy If overprocessing led to fat exudation	High Fat leach out	Depends on the product	Highly tender	Zhang *et al.*, 2025
Fine (< 3 mm)	Low fat	Excellent binding	Higher cooking yield. Better water retention	Higher sensory scores	Juicy due to matrix tightness	Marchetti *et al.*, 2025
3–5 mm	Low fat	Good binding Visible integrity	Moderate yield Retained fat better than coarse	Moderate-high sensory acceptability	Good tenderness and juiciness	Ciobanu *et al.*, 2025
coarse	High fat	Poor structural cohesion	Moderate-high cooking loss	Mixed acceptability	Juicy but greasy mouthfeel possible	Zhang *et al.*, 2025
Coarse (> 6 mm)	Low fat	Dry texture Weak binding	Higher cooking loss Poor fat/protein emulsion	Overall acceptability has a Low score	Low juiciness	Bhaskar Reddy *et al.*, 2025

the mincing process, as the distribution of fat becomes uniform across the smaller particle sizes. This is because more fats are visible and exposed to oxidation (Meng *et al.*, 2022). Fat oxidation occurs because of exposure to oxygen due to the finer particle sizes, which not only affects the flavour but also the nutritional quality, especially the levels of omega-3 fatty acids and fat-soluble vitamins (Brown, 2016). Conversely, coarser minced size results in less fat being exposed to air and may help in the retention of these nutrients. Similarly (Hrubša *et al.*, 2022) reported that the finer the particle size, the higher the tendency of water-soluble vitamins (Riboflavin and B12) to leach out due to their sensitivity to heat and oxygen. Whereas larger minced sizes allow these nutrients to remain intact within the muscle. The impact of different ground sizes on the physicochemical properties of meat is presented in Table 3.

Overview

The size of ground meat particles affects the capability of the meat to retain moisture and color; the finer the meat size, the greater the surface area, which can result in a significant amount of moisture loss during cooking, leading to a drier texture and reduced meat quality. It also changes the exposure to oxygen and light, which affects the color of the minced meat; therefore, the smaller the minced size, the greater the chance of exposure to oxygen and accelerated oxidation of pigments such as myoglobin, resulting in the production of darker colored meat. However, larger ground sizes could retain sufficient moisture, resulting in more moisture and tender meat production. Larger minced meat sizes are less exposed to oxygen, thereby producing lighter meat.

The mincing process can cause protein denaturation depending on the ground size, which is the description and rearrangement of protein molecules in meat that influences the textural properties of the meat. Smaller ground sizes lead to more protein denaturation and a firmer meat texture.

The size of meat particles can also affect the distribution of fat in minced meat. Typically, finer minced meat has a more even distribution of fat throughout the meat, which results in improved flavor and juiciness, whereas larger minced sizes lead to lopsided fat distribution, leading to undesirable meat texture.

The mincing size plays an important role in the binding properties of minced meat, and once the minced size is smaller, it results in more binding forces that hold the particle very tightly, leading to a more cohesive and firmer texture, while larger meat particles have loose binding properties, resulting in softer and more tender meat. There is a strong correlation between tenderness, juiciness, and water-holding capacity, a smaller minced size will result in an increase in the aforementioned quality due to an increased disintegration of the connective tissues, thereby improving the water-holding capacity of the minced meat. However, the finest mincing may lead to a paste-like texture, which might negatively affect sensory assessment and lead to a reduction in juiciness with a chewier texture.

The pH of meat is also influenced by the ground of the meat, the finer the meat particles result in the release of many endogenous enzymes and a higher rate of glycolysis, leading to the accumulation of lactic acid leading to decrease in meat pH while higher pH is recorded in larger minced sizes due to a slower rate of glycolysis.

Prospects

There is an increasing trend in the production of minced meat on an industrial scale. The mincing of meat also affects the mixing and shape of the meat. The degree of disintegration of meat during grinding correlates with the specific mechanical force applied. The mincing should be done at a lower temperature, so to maintain the quality of the ground meat and meat products. Thus, there is an increasing trend of using meat mincer equipped with the provision of refrigeration. Furthermore, to improve the quality of minced meat, various novel meat processing technologies could be used such as high-pressure processing, pulse electric field, ultrasonication, and cold plasma. In addition to improving the quality of minced meat, the application of these technologies could improve meat safety.

The impact of ground size on meat quality parameters depends on many factors such as meat type, cooking methods, processing methods, and individual preferences. However, the changes are not only caused by the intensity of the mincing/grinding or the ANIC, but also by the breaking down of the muscle fibers, structure, connective tissues, myofibrillar proteins, and exposure of the surface area. The application of ground meat varies and is used for making a wide range of meat products. This warrants the production of good-quality minced meat with desired particle size, so as to be used in the desired applications. There is a need for further in-depth studies on the impact of various particle sizes, specific mechanical energy, and applied pressure during the mincing of meat, and their effects on meat quality attributes at the molecular level through the application of various omics approaches.

Further research should be conducted on the impacts of mincing size on microbial growth, oxidation stability and shelf life of meat and meat products because the differences in mincing sizes lead to an increase or decrease in surface area of the meat, which could accelerate the spoilage of the product. The grind size of minced meat has a significant impact on both its processing and storage. Finer minced sizes are easier to process and absorb flavor well however, they can lose moisture and spoil faster. The coarse grind sizes are better for products that require texture and moisture retention, but they require longer cooking duration.

Conclusion

The ground size of the minced meat had a significant impact on the various meat quality attributes. The fine particle size leads to an improvement in tenderness, juiciness, and sensory attributes compared to medium and coarse ground sizes of minced meat and its products. However, an excessively fine ground size tends to increase cooking loss, which leads to a decrease in moisture content, dry and less tender meat, and less juice. Understanding these implications could be very useful for the optimization of product quality, ensuring consistency in production, and enhancing consumer satisfaction by using the desired ground size of the minced meat.

Author contributions

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Data availability statement

No new data has been generated and updated in the Manuscript accordingly.

References

Afshari, R., Hosseini, H., Khaneghah, A. M., & Khaksar, R. (2017). Physio-chemical properties of functional low-fat beef burgers: Fatty acid profile modification. *LWT*, *78*, 325–331. https://doi.org/10.1016/j.lwt.2016.12.054

Akhtar, S., Khan, M. I., & Faiz, F. (2013). Effect of thawing on frozen meat quality: A comprehensive review. *Pakistan Journal of Food Sciences*, *23*(4), 198–211.

Alfaifi, B. M., Al-Ghamdi, S., Othman, M. B., Hobani, A. I., & Suliman, G. M. (2023). Advanced red meat cooking technologies and their effect on engineering and quality properties: A review. *Foods (Basel, Switzerland)*, *12*(13), 2564. https://doi.org/10.3390/foods12132564

Ali, M. S., Kang, G. H., Yang, H. S., Jeong, J. Y., Hwang, Y. H., Park, G. B., & Joo, S. T. (2007). A comparison of meat characteristics between duck and chicken breast. *Asian-Australasian Journal of Animal Sciences*, *20*(6), 1002–1006. https://doi.org/10.5713/ajas.2007.1002

Andrés-Bello, A., Barreto-Palacios, V. I. V. I. A. N., García-Segovia, P., Mir-Bel, J., & Martínez-Monzó, J. (2013). Effect of pH on color and texture of food products. *Food Engineering Reviews*, *5*(3), 158–170. https://doi.org/10.1007/s12393-013-9067-2

Balestra, F., Bianchi, M., & Petracci, M. (2019). Applications in meat products. In *Dietary Fiber: Properties, recovery, and applications* (pp. 313–344). Academic Press.

Barbut, S. (2011). *Saturated fat reduction in processed meat products in reducing saturated fats in foods* (pp. 210–233). Woodhead Publishing.

Berger, L. M., Adam, F., Gibis, M., Witte, F., Terjung, N., & Weiss, J. (2024). Effect of cutting set variations on structural and functional properties of hamburgers. *European Food Research and Technology*, *250*(3), 701–713. https://doi.org/10.1007/s00217-023-04414-7

Berger, L. M., Witte, F., Tomasevic, I., Heinz, V., Weiss, J., Gibis, M., & Terjung, N. (2023). A review on the relation between the grinding process and the quality of ground meat. *Meat Science*, *205*, 109320. https://doi.org/10.1016/j.meatsci.2023.109320

Berger, L., Bockle, C., Gibis, M., Herrmann, K., Terjung, N., & Weiss, J. (2023). Effect of manufacturing and frozen meat temperatures on structural and functional properties of hamburgers. *Journal of Food Engineering*, *111526* https://doi.org/10.1016/j.jfoodeng.2023.111526

Berger, L., Gibis, M., Witte, F., Terjung, N., & Weiss, J. (2022). Influence of meat batter addition in ground beef on structural properties and quality parameters. *European Food Research and Technology*, *248*(10), 2509–2520. https://doi.org/10.1007/s00217-022-04065-0

Bhaskar Reddy, G. V., Amaravathi, P., Sen, A. R., & Vijay Kumar Reddy, S. (2025). Effect of egg white powder on quality and structural properties of restructured buffalo meat slices. *International Food Research Journal*, *32*(2).

Bolumar, T., Orlien, V., Sikes, A., Aganovic, K., Bak, K. H., Guyon, C., Stübler, A.-S., de Lamballerie, M., Hertel, C., & Brüggemann, D. A. (2021). High-pressure processing of meat: Molecular impacts and industrial applications. *Comprehensive Reviews in Food Science and Food Safety*, *20*(1), 332–368. https://doi.org/10.1111/1541-4337.12670

Brown, R. A. (2016). Bioactive oxidised products of omega-6 and omega-3, excess oxidative stress, oxidised dietary intake and antioxidant nutrient deficiencies, in the context of a modern diet. *Omega-3 Fatty Acids: Keys to Nutritional Health*, 349–383. https://doi.org/10.1007/978-3-319-40458-

Caldas-Cueva, J. P., Mauromoustakos, A., & Owens, C. M. (2021). Instrumental texture analysis of chicken patties prepared with broiler breast fillets exhibiting woody breast characteristics. *Poultry Science*, *100*(2), 1239–1247. https://doi.org/10.1016/j.psj.2020.09.093

Cardona, M., Izquierdo, D., Barat, J. M., & Fernández-Segovia, I. (2023). Intrinsic and extrinsic attributes that influence the choice of meat and meat products: Techniques used in their identification. *European Food Research and Technology*, *249*(10), 2485–2514. https://doi.org/10.1007/s00217-023-04301-1

Cheng, Q., & Sun, D. W. (2008). Factors affecting the water holding capacity of red meat products: A review of recent research advances. *Critical Reviews in Food Science and Nutrition*, *48*(2), 137–159. https://doi.org/10.1080/10408390601177647

Ciobanu, M. M., Manoliu, D. R., Ciobotaru, M. C., Flocea, E. I., & Boişteanu, P. C. (2025). Dietary fibres in processed meat: A review on nutritional enhancement, technological effects, sensory implications and consumer perception. *Foods (Basel, Switzerland)*, *14*(9), 1459. https://doi.org/10.3390/foods14091459

De Lima Jùnior, D. M., de Carvalho, F. F., Da Silva, F. J., do N Rangel, A. H., Novaes, L. P., & Difante, G. (2016). Intrinsic factors affecting sheep meat quality: A review. *Revista Colombiana de Ciencias Pecuarias*, *29*(1), 03–15. https://doi.org/10.17533/udea.rccp.v29n1a01

Dekkers, B. L., Boom, R. M., & van der Goot, A. J. (2018). Structuring processes for meat analogues. *Trends in Food Science & Technology*, *81*, 25–36. https://doi.org/10.1016/j.tifs.2018.08.011

Dey, J. C., Jahan, I., Ghosh, S., Halder, B. C., Ahmad, M. H., & Hossain, M. A. (2020). Assessment of broiler chicken meat quality collected from different markets of Chittagong. *Bangladesh Journal of Animal Science*, *49*(1), 29–36. https://doi.org/10.3329/bjas.v49i1.49375

Dreeling, N., Allen, P., & Butler, F. (2000). Effect of the degree of comminution on sensory and texture attributes of low-fat beefburgers. *LWT - Food Science and Technology*, *33*(4), 290–294. https://doi.org/10.1006/fstl.2000.0658

Faustman, C., Suman, S. P., & Ramanathan, R. (2023). The eating quality of meat: I Color. In *Lawrie's Meat Science* (pp. 363–392). Woodhead Publishing.

Fauzi, N. M., Huda, N., & Adzitey, F. (2021). November). Effect of orifice size on quality characteristics of burger made from spent laying duck meat. In *IOP Conference Series: Earth and Environmental Science*. (Vol. 888, No. 1, p.012046). IOP Publishing. https://doi.org/10.1088/1755-1315/888/1/012046

Fernández–López, J., Pérez–Alvarez, J. A., & Aranda–Catalá, V. (2000). Effect of mincing degree on colour properties in pork meat. *Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur*, *25*(5), 376–380.

Ferreira, S. M., Matos, L. C., & Santos, L. (2024). Harnessing the potential of chestnut shell extract to enhance fresh cheese: A sustainable approach for nutritional enrichment and shelf-life extension. *Journal of Food Measurement and Characterization*, *18*(2), 1559–1573. https://doi.org/10.1007/s11694-023-02260-5

Gurikar, A. M., Lakshmanan, V., Gadekar, Y. P., Sharma, B. D., & Anjaneyulu, A. S. R. (2014). Effect of meat chunk size, massaging time and cooking time on quality of restructured pork blocks. *Journal of Food Science and Technology*, *51*(7), 1363–1369. https://doi.org/10.1007/s13197-012-0644-9

Haq, I. U., Asghar, B., Manzoor, A., Ali, S., Nauman, K., Ahmad, S., Hopkins, D. L., & Nasir, J. (2024). Investigating the impact of sous vide cooking on the eating quality of spent buffalo (BUBALUS BUBALIS) meat. *Meat Science*, *209*, 109417. https://doi.org/10.1016/j.meatsci.2023.109417

Hoa, V.-B., Cho, S.-H., Seong, P.-N., Kang, S.-M., Kim, Y.-S., Moon, S.-S., Choi, Y.-M., Kim, J.-H., & Seol, K.-H. (2021). The significant influences of pH, temperature, and fatty acids on meat myoglobin oxidation: A model study. *Journal of Food Science and Technology*, *58*(10), 3972–3980. https://doi.org/10.1007/s13197-020-04860-1

Holloway, J. W., Wu, J., Holloway, J. W., & Wu, J. (2019). Tenderness intrinsic character. In Red Meat Science and Production: Volume 2. Intrinsic Meat Character, 39–141. Springer

Hrubša, M., Siatka, T., Nejmanová, I., Vopršalová, M., Kujovská Krčmová, L., Matoušová, K., Javorská, L., Macáková, K., Mercolini, L., Remião, F., & Máťuš, M. (2022). Biological properties of vitamins of the B-complex, part 1: Vitamins B1, B2, B3, and B5. *Nutrients*, *14*(3), 484. https://doi.org/10.3390/nu14030484

Imai, E., Hayakawa, F., Hatae, K., Shimada, A., & Aiuchi, M. (1994). Effect of the granular size of ground meat on the sensory distinction and physical properties of meat patties. *Journal of Home Economics of Japan*, *45*(8), 697–708.

Ismail, M. A., Chong, G. H., & Ismail-Fitry, M. R. (2021). Comparison of the microstructural, physicochemical, and sensorial properties of buffalo meat patties produced using bowl cutter, universal mixer, and meat mixer. *Journal of Food Science and Technology*, *58*(12), 4703–4710. https://doi.org/10.1007/s13197-020-04960-y

Kaur, R., Gupta, T. B., Bronlund, J., & Kaur, L. (2023). The potential of rosemary as a functional ingredient for meat products. A review. *Food Reviews International*, *39*(4), 2212–2232. https://doi.org/10.1080/87559129.2021.1950173

Kokoszyński, D., Arpášová, H., Hrnčar, C., Żochowska-Kujawska, J., Kotowicz, M., & Sobczak, M. (2020). Carcass characteristics, chemical composition, physicochemical properties, texture, and microstructure of meat from spent Pekin ducks. *Poultry Science*, *99*(2), 1232–1240. https://doi.org/10.1016/j.psj.2019.09.003

Köse, S., Balaban, Boran, M., & Boran, G. (2009). The effect of mincing methodon the quality of refrigerated whiting burgers. *International Journalof Food Science and Technology*, 44(8), 1649-1660. https://doi.org/10.1111/j.1365-2621.2009.01984.x

Krasulya, O., Smirnova, A., Bogush, V., Shlenskaya, N., Vostrikova, N., & Mettu, S. (2021). Estimation of the stability of skeletal muscle myoglobin of chilled pork treated with brine activated by low-frequency high-intensity ultrasound. *Ultrasonics Sonochemistry*, *71*, 105363. https://doi.org/10.1016/j.ultsonch.2020.105363

Krzywdzińska-Bartkowiak, M., Piątek, M., & Dolata, W. (2014). A comparative quality appraisal of finely comminuted batters produced using three types of knives. *Meat Science*, *96*(1), 429–435. https://doi.org/10.1016/j.meatsci.2013.08.011

Kumar, P., Sharma, N., Ahmed, M. A., Verma, A. K., Umaraw, P., Mehta, N., Abubakar, A. A., Hayat, M. N., Kaka, U., Lee, S.-J., & Sazili, A. Q. (2022). Technological interventions in improving the functionality of proteins during processing of meat analogs. *Frontiers in Nutrition*, *9*, 1044024. https://doi.org/10.3389/fnut.2022.1044024

López-Pedrouso, M., Rodríguez-Vázquez, R., Purriños, L., Oliván, M., García-Torres, S., Sentandreu, M. Á., Lorenzo, J. M., Zapata, C., & Franco, D. (2020). Sensory and physicochemical analysis of meat from bovine breeds in different livestock production systems, pre-slaughter handling conditions, and ageing time. *Foods (Basel, Switzerland)*, *9*(2), 176. https://doi.org/10.3390/foods9020176

Luo, M., Shan, K., Zhang, M., Ke, W., Zhao, D., Nian, Y., Wu, J., & Li, C. (2021). Application of ultrasound treatment for improving the quality of infant meat puree. *Ultrasonics Sonochemistry*, *80*, 105831. https://doi.org/10.1016/j.ultsonch.2021.105831

Made-in-China. (2024). https://bolexknife.en.made-in-china.com/product/vZwfrDFBiMWS/China-No-12-Stainless-Steel-Food-Grade-Mincer-Plate-Disc-Meat-Grinder-Flash-Plate.html accessed on 8/7/2024.

Marchetti, M. D., Perez, C. J., Czerner, M., & Loredo, A. B. G. (2025). Multi-Method Evaluation of Surimi Quality from a Bycatch Species (Trachurus lathami): Physicochemical, Textural, Sensory, and Thermal Responses to Washing Conditions. *Food and Bioproducts Processing*, *153*, 400–409. https://doi.org/10.1016/j.fbp.2025.07.005

Meng, X., Wu, D., Zhang, Z., Wang, H., Wu, P., Xu, Z., Gao, Z., Mintah, B. K., & Dabbour, M. (2022). An overview of factors affecting the quality of beef meatballs: Processing and preservation. *Food Science & Nutrition*, *10*(6), 1961–1974. https://doi.org/10.1002/fsn3.2812

Mir, N. A., Rafiq, A., Kumar, F., Singh, V., & Shukla, V. (2017). Determinants of broiler chicken meat quality and factors affecting them: A review. *Journal of Food Science and Technology*, *54*(10), 2997–3009. https://doi.org/10.1007/s13197-017-2789-z

Nayak, N. K., & Pathak, V. (2016). Development and quality assessment of carrageenan incorporated low fat chevon patties. *Journal of Food Science and Technology*, *53*(9), 3477–3484. https://doi.org/10.1007/s13197-016-2322-9

Ong, S., Choudhury, D., & Naing, M. W. (2020). Cell-based meat: Current ambiguities with nomenclature. *Trends in Food Science & Technology*, *102*, 223–231. https://doi.org/10.1016/j.tifs.2020.02.010

Patel, D., Nayak, N. K., & Chauhan, P. (2023). Recent developments in restructured meat products. *Pharma Innovation Journal*, *12*, 1124–1129.

Perez Alvarez, J. A., Fernandez Lopez, J., Sayas Barbera, M. E., & Cartagena Garcia, R. (1998). Description of colour parameters of the different raw materials used in the meat industry. *Eurocarne (Espana)*, 63,115–122.

Puolanne, E. (2017). Developments in our understanding of water-holding capacity in meat. In *New Aspects of Meat Quality*. (pp. 167–190). Woodhead Publishing.

Quevedo, R., Valencia, E., Cuevas, G., Ronceros, B., Pedreschi, F., & Bastías, J. M. (2013). Color changes in the surface of fresh cut meat: A fractal kinetic application. *Food Research International*, *54*(2), 1430–1436. https://doi.org/10.1016/j.foodres.2013.10.006

Ramadhan, K., Huda, N., & Ahmad, R. (2012). Physicochemical and sensory characteristics of burger made from duck surimi-like material. *Poultry Science*, *91*(9), 2316–2323. https://doi.org/10.3382/ps.2011-01747

Ruiz, J., Pagan, M. J., Garcia-Segovia, P., & Martinez-Monzo, J. (2017). Spanish Dry-cured Hams and Fermented Sausages. In *Mediterranean Foods* (pp. 141ra–14170). CRC Press.

Saengsuk, N., Laohakunjit, N., Sanporkha, P., Kaisangsri, N., Selamassakul, O., Ratanakhanokchai, K., & Uthairatanakij, A. (2021). Physicochemical characteristics and textural parameters of restructured pork steaks hydrolysed with bromelain. *Food Chemistry*, *361*, 130079. https://doi.org/10.1016/j.foodchem.2021.130079

Schnäckel, W., Krickmeier, J., Schnäckel, D., & Micklisch, I. (2011). Untersuchungen zur Optimierung des Wolfprozesses Teil 1: Modellierung der Bedingungen beim Schneiden in einer Wolfmaschine. *Fleischwirtschaft (Frankfurt)*, *91*(7), 83–87.

Schumacher, M., DelCurto-Wyffels, H., Thomson, J., & Boles, J. (2022). Fat deposition and fat effects on meat quality—A review. *Animals*, *12*(12), 1550. https://doi.org/10.3390/ani12121550

Sen, A. R., & Karim, S. A. (2003). Effect of meat particle size on quality attributes of restructured mutton steaks. *Journal of Food Science and Technology*, 40:423–425. [Google Scholar]

Sen, A. R., Naveena, B. M., Banerjee, R., & Muthukumar, M. (2022). Value addition in meat and fish products for human health and nutrition. In *Agriculture, Livestock Production and Aquaculture: Advances for Smallholder Farming Systems Volume. 1* (pp. 287–303). Springer International Publishing.

Shao, J. H., Deng, Y. M., Jia, N., Li, R. R., Cao, J. X., Liu, D. Y., & Li, J. R. (2016). Low-field NMR determination of water distribution in meat batters with NaCl and polyphosphate addition. *Food Chemistry*, *200*, 308–314. https://doi.org/10.1016/j.foodchem.2016.01.013

Sharma, S. K., Barthwal, R., Saini, D., & Rawat, N. (2022). Chemistry of food fats, oils, and other lipids. In *Advances in Food Chemistry: Food Components, Processing and Preservation* (pp. 209–254). Springer Nature Singapore.

Shimizu, H., & Iwamoto, S. (2022). Problems of lipid oxidation in minced meat products for a ready-made meal during cooking, processing, and storage. *Reviews in Agricultural Science*, *10*(0), 24–35. https://doi.org/10.7831/ras.10.0_24

Singh, P. K., Jairath, G., Yadav, S., Pathera, A. K., Ahlawat, S. S., & Sharma, D. P. (2023). Fine-tuning Buffalo-Veal meat slices: The impact of particle size, fat content, and tumbling time and their interplay through principal component analysis.

Smaoui, S., Elleuch, L., Ben Salah, R., Najah, S., Chakchouk-Mtibaa, A., Sellem, I., Besbes, S., & Mellouli, L. (2014). Efficient role of BacTN635 on the safety properties, sensory attributes, and texture profile of raw minced meat beef and chicken breast. *Food Additives & Contaminants. Part A, Chemistry, Analysis, Control, Exposure & Risk Assessment*, *31*(2), 218–225. https://doi.org/10.1080/19440049.2013.873144

Sukmanov, V., Hanjun, M., & Li, Y. P. (2019). Effect of high-pressure processing on meat and meat products. A review. *Ukrainian Food Journal*, *8*(3), 448–469. https://doi.org/10.24263/2304-974X-2019-8-3-4

Suman, S. P., & Sharma, B. D. (2003). Effect of grind size and fat levels on the physico-chemical and sensory characteristics of low-fat ground buffalo meat patties. *Meat Science*, *65*(3), 973–976. https://doi.org/10.1016/S0309-1740(02)00313-3

Suman, S. P., Hunt, M. C., Nair, M. N., & Rentfrow, G. (2014). Improving beef color stability: Practical strategies and underlying mechanisms. *Meat Science*, *98*(3), 490–504. https://doi.org/10.1016/j.meatsci.2014.06.032

Suman, S. P., Nair, M. N., Joseph, P., & Hunt, M. C. (2016). Factors influencing internal color of cooked meats. *Meat Science*, *120*, 133–144. https://doi.org/10.1016/j.meatsci.2016.04.006

Superior Food and Machinery. (2024). https://www.superiorfoodmachinery.com/spare-parts-c5/mincer-blades-knives-c108/no-32-mincer-knife-to-fit-100mm-diameter-plate-p177, accessed on 7/7/24

Tomasevic, I., Witte, F., Kühling, R., Berger, L., Gibis, M., Weiss, J., Röser, A., Upmann, M., Joeres, E., Juadjur, A., Bindrich, U., Heinz, V., & Terjung, N. (2023). Effect of frozen to fresh meat ratio in minced pork on its quality. *Applied Sciences*, *13*(4), 2323. https://doi.org/10.3390/app13042323

Warner, R. D., Miller, R. K., Ha, M., Wheeler, T. L., Dunshea, F., Li, X. W., … Purslow, P. (2021). Meat tenderness: underlying mechanisms, instrumental measurement, and sensory assessment. Meat and Muscle Biology, 4(2). https://doi.org/10.22175/mmb.10489

Witte, F., Sawas, E., Berger, L., Gibis, M., Weiss, J., Röser, A., Upmann, M., Joeres, E., Juadjur, A., Bindrich, U., Heinz, V., & Terjung, N. (2022). Influence of finely chopped meat addition on quality parameters of minced meat. *Applied Sciences*, *12*(20), 10590. https://doi.org/10.3390/app122010590

Younis, K., Ashfaq, A., Ahmad, A., Anjum, Z., & Yousuf, O. (2023). A critical review focusing on the effect of ingredients on the textural properties of plant-based meat products. *Journal of Texture Studies*, *54*(3), 365–382. https://doi.org/10.1111/jtxs.12704

Yu, T. Y., Morton, J. D., Clerens, S., & Dyer, J. M. (2017). Cooking-induced protein modifications in meat. *Comprehensive Reviews in Food Science and Food Safety*, *16*(1), 141–159. https://doi.org/10.1111/1541-4337.12243

Zaki, E. F., & El Faham, A. I. (2018). Quality characteristics of chicken burger processed from broiler chicken fed on different types of vegetable oils and feed additives. *International Journal of Health, Animal Science and Food Safety*, 5, 1–11.

Zeng, Y., Chen, E., Zhang, X., Li, D., Wang, Q., & Sun, Y. (2022). Nutritional value and physicochemical characteristics of alternative protein for meat and dairy—a review. *Foods (Basel, Switzerland)*, *11*(21), 3326. https://doi.org/10.3390/foods11213326

Zhang, R., Farouk, M. M., Realini, C. E., & Thum, C. (2025). Hybridization in meat-based dual protein foods: Mechanisms, challenges, and consumer insights. *Comprehensive Reviews in Food Science and Food Safety*, *24*(4), e70216. https://doi.org/10.1111/1541-4337.70216