# *ТЕХНІЧНІ НАУКИ*

UDC 637.5.03

## DRY AND WET TENDERIZATION OF MEATS: BASIC FEATURES AND TECHNOLOGICAL EQUIPMENT

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**https://doi.org/10.31073/foodresources2022-19-01**

***Subject of research.*** *Tenderization (softening) of meat raw materials by using technological equipment with various working bodies.* ***Purpose.*** *Study of the technological features of raw meat tenderization under mechanical and hydro-mechanical action of tenderizers and multi-needle brine injectors, respectively.* ***Methods.*** *In order to carry out research, we used a systematic approach to factual materials, in particular, scientific and scientific-practical literature, legal acts, regulatory documents, etc., abstract-logical approach to generalize the results of the study and formulate conclusions. The experimental treatment of whole muscle meat raw materials was performed using a pneumatic brine injector brand Ya5-FSh1L with 50 needles.* ***Results.*** *Several methods of softening raw materials have been developed, among which mechanical tenderization takes not the last place. Meat cuts are mechanically tenderized and/or enhanced to add value to lower quality cuts by improving sensory attributes such as palatability and tenderness. The term "mechanically tenderized" is defined as "manipulating meat with deep penetration by processes which may be referred to as "blade tenderizing," "jaccarding," "pinning," "needling," or using blades, pins, needles or any mechanical device". The tenderization process fulfilled without simultaneous injection of pickling brines is dry tenderization. The main methods for the practical implementation of the process of softening meat raw materials are piercing with knives or needles, passing through paired rollers equipped with a notch or wedge-shaped teeth, processing using plates with a notched surface. The wet tenderization is achieved when meats are penetrated by injection needles saturating muscle tissue with pickling brines. The research fulfilled showed that for tenderization of meat of increased hardness, the most effective diameter of needles is 2.5-3.5 mm. The smallest tenderizing effect is observed when raw meat is processed with needles with a diameter of 2 mm. When needles with a diameter of 2 mm are used, the nature of the mechanical action is essentially closer to the separation of muscle and connective fibers without significant incisions. However, combine effect of the mechanical action and hydro-mechanical action upon the treated meats has not yet been properly studied so the corresponding research shall be held in future.* ***Scope of research results.*** *The results of the experiments will be used to improve the technology and specialized equipment for injection of whole muscle meat raw materials to increase the profitability of meat processing, food safety of meat products, and to enhance their quality.*

***Key words:*** *hydro-mechanical treatment, whole muscle meat products, meat raw material injection, brine injectors, multi-needle injectors, penetration, meat raw material tendering*

# СУХА ТА ВОЛОГА ТЕНДЕРИЗАЦІЯ М'ЯСА: ОСНОВНІ ОСОБЛИВОСТІ ТА ТЕХНОЛОГІЧНЕ ОБЛАДАНАННЯ

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**https://doi.org/10.31073/foodresources2022-19-01**

***Предмет дослідження.*** *Тендерізація (м'якшення) м'ясної сировини шляхом застосування технологічного обладнання з різними робочими органами.* ***Мета.*** *Вивчення технологічних особливостей тендерізації м'ясної сировини за механічного та гідромеханічного впливу тендеризаторів та багатоголкових ін'єкторів розсолу відповідно.* ***Методи.*** *З метою виконання досліджень використовували системний підхід до фактологічних матеріалів, зокрема наукової та науково-практичної літератури, нормативно-правових актів та ін., абстрактно-логічний підхід до узагальнення результатів дослідження та формулювання висновків. Експериментальну обробку цільном'язової м'ясної сировини проводили за допомогою пневматичного ін'єктора розсолу марки Я5-ФШ1Л з 50 голками.* ***Результати.*** *Розроблено кілька способів пом'якшення сировини, серед яких не останнє місце посідає механічна тендеризація. М'ясні відруби механічно пом'якшують та/або додатково оброблюють, щоб підвищити цінність відрубів нижчої якості за рахунок поліпшення органолептичних властивостей – смаку, ніжності та ін. Терміном «механічно тендеризований» визначають «оброблення м'яса з глибоким проникненням за допомогою процесів, які можуть називатися «розм'якшення лезами», «жаккардування», «проколювання піками», «проколювання голками» або використання лез, пік, голок або будь-яких механічних пристроїв». Процес тендеризації, що здійснюється без одночасного введення розсолів, це суха тендеризація. Основними способами практичної реалізації процесу пом'якшення м'ясної сировини є проколювання ножами або голками, пропускання через парні вальці, з насічкою або клиноподібними зубами, обробка за допомогою пластин з рифленою поверхнею. Волога тендеризація досягається при проколюванні м'яса ін'єкційними голками, що насичують м'язову тканину розсолами. Проведені дослідження показали, що для тендеризації м'яса підвищеної жорсткості найефективнішим діаметром голок є 25-35 мм. Найменший пом'якшувальний ефект дає оброблення м'ясної сировини голками діаметром 2 мм. У разі використання голок діаметром 2 мм характер механічної дії суттєво ближче до відокремлення м'язових та сполучнотканинних волокон без значних розрізів. Однак сукупний вплив механічного та гідромеханічного впливу на оброблюване м'ясо ще недостатньо вивчено.* ***Сфера застосування результатів.*** *Виконані дослідження сприятимуть вдосконаленню процесів сухої та вологої тендеризації м'ясної сировини, повнішому розумінню їхніх технологічних особливостей, створенню сучасного технологічного обладнання, призначеного для реалізації зазначених процесів.*

***Ключові слова:*** *м'ясна сировина, тендерізація, механічна обробка, гідромеханічна обробка, суха тендеризація, волога тендеризація, ін'єктування м'ясної сировини, багатоголкові ін'єктори розсолу*

**Formulation of the problem**. In countries with a market economy, Ukraine being among them, the full satisfaction of the needs and wishes of consumers becomes a weighty argument in the competition and a constant incentive for technical and technological progress. A good example of the determining influence of consumer demands on the technology of meat products is whole muscle meat products. On the one hand, not everyone consumes softer pork – according to religious canons or based on their own views on healthy eating. On the other hand, differing types of slaughter meat common throughout the world – beef and lamb – are much tougher and require long processing before consumption. Thus, the meat industry received a kind of project task for the development of a technology for tenderizing (softening) usually tough types of meat – primarily beef.

When time is not a limiting factor, natural tenderization will do: meat is kept fresh and the proteolytic enzymes remain working throughout the entire shelf life, resulting in a significant improvement in product tenderness. At the temperatures at which the meat is kept, the calpains have an adequate action that ensures the dissolution of the proteins of the meat and, consequently, the softness increases progressively. The longer the storage time, the greater the softening of lean tissue is [1, 2]. In practice, time defines the very profitability an industrial process and is rather to be minimized using all the methods available.

The specialists successfully coped with the task and developed several methods for softening raw materials, among which mechanical tenderization occupies not the last place. Meat cuts are mechanically tenderized and/or enhanced to add value to lower quality cuts by improving sensory attributes such as palatability and tenderness [3, 4]. The term “mechanically tenderized” is defined as “manipulating meat with deep penetration by processes which may be referred to as “blade tenderizing,” “jaccarding,” “pinning,” “needling,” or using blades, pins, needles or any mechanical device” This definition does not include processes by which solutions are injected into meat, commonly referred to as enhancement [5, 4]. The authors of [6] consider that postmortem processing strategies can help improve the tenderness and subsequent eating quality of mature beef muscles. Such processing strategies as blade tenderization, pretumbling and moisture enhancement are used, alone and in combination, so the processing yield and eating quality-related parameters of muscles shall be studied.

Mechanically tenderized beef (MTB) products are not heat-treated beef products that have been tenderized using blades, needles, or other mechanical tools to improve consumer palatability [7]. Beef products that have been mechanically tenderized or enhanced may carry greater foodborne illness risks than intact beef because of introduction of pathogens into the meat [4]. MTBs have been associated with outbreaks of Shiga toxin-producing *Escherichia coli* [7]. The resulting risk requires various risk management steps, such as stricter time/temperature cooking combinations for pathogen destruction [4]. According to [8], mechanical tenderization has been widely discontinued due to the numerous reports of bacterial contamination caused by contaminated tenderization blades forcing bacteria deep into meat products during processing.

Indeed, for consumers of non-heat-treated meat products intended for home cooking, the issue of proper food safety of these products is vital. Over the years, influential consumer advocacy organizations in the US and Canada have urged the competent authorities to introduce special labeling of mechanically tenderized meat, indicating precautions for its preparation and consumption [9]. The most popular meat product in North America, tenderized steaks and other processed meats from beef, carry the potential danger that the blades or needles of tenderizers can facilitate the transfer of *E. coli* bacteria from the surface of the steak deep into the muscle tissue, where they are much harder to be neutralized. Thin needles or blades do not leave noticeable marks, so looking at a meat cut, it is difficult to determine whether it has been mechanically tenderized. And the previous labeling rules did not at all require informing consumers about this, as well as drawing their attention to the fact that such meat requires more thorough heat treatment [9].

Mechanically tenderized meat was responsible for at least five *E. coli* outbreaks between 2003 and 2009, according to the US National Centers for Disease Control and Prevention. Then 174 people suffered from this infection, four of whom died [10]. In August 2014, Canada became the first country to make the labeling of mechanically tendered beef mandatory. In May 2013, Health Canada conducted a risk assessment, which found that eating tenderized steaks was five times more likely to get sick than eating steaks that had not undergone such a treatment [11]. According to the Canadian norms in force [12], MTB refers to uncooked, solid cut beef that has been prepared by mechanical tenderization, for example, a process where the integrity of the beef surface has been compromised by being pierced by blades, needles or other similar instruments, or the beef has been injected with a marinade or other tenderizing solution. This includes all cuts of MTB regardless of thickness, which includes veal and cubed steaks (for example, fast fry/minute steaks) in either fresh or frozen form. This does not include other species of meat besides beef (for example, pork and poultry) and ground beef or any uncooked beef that has been subject to a comminution process such as grinding, chopping, flaking, mincing, fine texturing and/or mechanical separation. The prepackaged or non-prepackaged MTB that is offered or exposed for sale must be identified as mechanically tenderized. The label must include the identification of the food as "mechanically tenderized", safe cooking instructions stating "Cook to a minimum internal temperature of 63°C". In the case of steak, an additional safe cooking instruction to help achieve a consistent temperature throughout stating "Turn steak over at least twice during cooking". In the USA MTB labeling was mandated in May 2016 [7].

**The subject of research.** Processes and machines necessary to tenderize meats in order to achieve their palatability and necessary microbiological safety.

**The purpose of the study.** The assessment of the processes and equipment used for the tenderization of meats aiming at the further progresses of meat processing industry.

**Materials and methods.** In order to carry out research, we used a systematic approach to factual materials, in particular, scientific and scientific-practical literature, legal acts, regulatory documents, etc., abstract-logical approach to generalize the results of the study and formulate conclusions. The experimental treatment of whole muscle meat raw materials was performed using a pneumatic brine injector brand Ya5-FSh1L with 50 needles produced by the State Experimental Enterprise of IPR of NAAS. The shear stress of the sample $Q_{ss}$ and the specific cutting work $A_{cw}$ were used as criteria for evaluating the efficiency of the modes of the process under study. The rheological properties of meat products were studied with the use of the universal testing machine CMT2503 (Shenzhen SANS Testing Machine Co., PRC) and its Kramer Shear Press, which is a fixed rectangular chamber with ten slots b = 3 mm wide and a movable knife with ten blades. The speed of the knife $V_n$ was equal to 50 mm / min [13, 14].

The main methods for the practical implementation of the process of softening meat raw materials are piercing with knives or needles (Fig. 1 [15]), passing through paired rollers equipped with a notch or wedge-shaped prongs, processing using plates with a notched surface. If there is a need to soften pork, which has a fatty layer and skin, devices equipped with two rollers are advisable. One of these rollers is cutting, and the other is with a smooth peripheral surface. The said methods of mechanical softening of meat raw materials have their own advantages and disadvantages: when tenderizing with the help of roller devices, only the surface layer of the piece is subjected to intensive softening, and with knife/needle tenderization, the positive effect can be limited by the volume of the cut near the inserted part of the needle or blade [16].

Tenderization, along with tumbling, is also practiced to process whole-muscle meats and restructured products such as hams. In [17], it is reported that it is expedient to combine treatment on a needle tenderizer (puncture grid density: 15 punctures per 1 $cm^2$, pressure: from $3 \cdot 10^5$ Pa to $4 \cdot 10^5$ Pa, needle diameter: 2 mm, needle height: 2 cm) with treatment on a massager (tumbler) with the addition of 15% brine to the mass of meat raw materials. There is information [16] that before tumbling beef, it should be mechanically softened, which makes it possible to reduce the duration of its processing from 6.5-7.0 hours to 3.5-4.0 hours, that is, by 3 hours. In [18], the design of a meat tenderizer with knife drums is described, which allows changing the distance between them depending on the size of the raw meat being processed, as well as adjusting the depth of penetration of the knives. The authors of [18] note that partial destruction of the cellular structures of muscle fibers leads to the release of exudate on the surface of the meat, which contributes to its intensive loosening, alignment of the pieces and bonding of individual layers due to the intermolecular interaction of muscle proteins. The cuts formed due to the action of the knives increase the contact surfaces, proteins bind water more actively, which helps to reduce shrinkage during heat treatment. At the same time, the yield of finished products increases by 3-5%, and the required time for massaging and heat treatment of meat is noticeably reduced: pork – by 1 hour, beef – by 1.5 hours.

**Fig. 1. Beef being mechanically tenderized by blades [15]**

According to [19], the use of tenderizers makes it possible to give the meat the necessary porosity, due to which, during massaging, curing substances are distributed more actively and more evenly in the thickness of the raw material. During the tenderization process, the connective tissue is cut, which prevents its contraction while heated to 60°C. This contributes to less loss of meat juice and an increase in the yield of the finished product. Intensive release of exudate promotes better adhesion of meat pieces in the product due to thermal coagulation of proteins, which confirms the feasibility of using tenderization in the production of molded ham products. In order to ensure an acceptable appearance of softened meat, whole-piece smoked and boiled-smoked products are best processed using puncture tenderizers with full-length (Fig. 2a) or shortened (Fig. 2b) working bodies. The latter allow tendering in a softer mode. It shall be admitted that pieces of meat processed using drum knife tenderizers have a very unpresentable appearance. That is why in [19] it is recommended to use drum tenderizers for restructured products, and to process whole-piece smoked and boiled-smoked products using puncture tenderizers, preferably equipped with small knives (Fig. 2b).

a b

**Fig. 2. Working bodies of blade tenderizers manufactured by Lutetia (France): a – with full length blades; b – with short blades [19]**

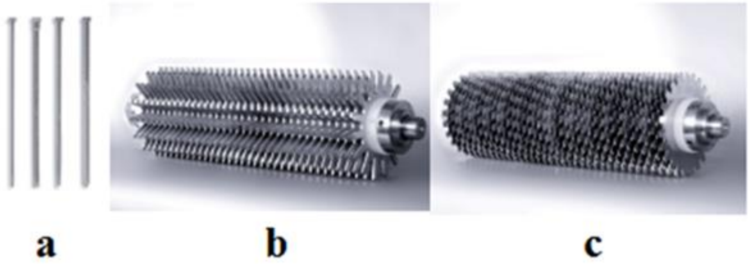



**Fig. 3. Working bodies of tenderizers manufactured by Metalquimia (Spain):** blades of 5 mm; b) roller prongs; c) roller knives – adopted from [20]

In the course of practical research carried out by scientists and specialists of Metalquimia, meat raw materials were tenderized using a head consisting of 336 heads shown in Fig. 3a knife blades 5 mm thick [20]. The working organs of this design are able to penetrate deep into meats however tenderization is not accompanied by ruptures of muscle tissue or separation of muscles from each other. Tenderizers of this design are most often used for processing whole-muscle meat products, since cutting is carried out only on one side of the muscle. For comparison, at the same time, tenderization was carried out using two-roller working bodies, which are a set of pin or knife plates. The action of the work rollers with pin plates (Fig. 3b), similar to the action of vertical blades, guarantees deep penetration into the thickness of the raw material with minimal muscle damage, but processing takes place on both sides of the cut. Devices of this design should be used for the production of valuable products with a low degree of injection of curing brines. Rollers with knife plates (Fig. 3c) perform numerous cuts in raw meat, contributing to the intensive extraction of proteins without causing, at the same time, significant damage to its appearance. In the course of research, 20% brine was injected into pork ham meat by weight of raw materials, which was then subjected to massaging, filling and cooking. Sample T1 was tenderized using vertical blades (Fig. 3a), samples T2a and T2b were processed on pin rolls, the distance between which was 0 and 10 mm, samples T3a and T3b were processed on knife rolls, the distance between which was also 0 and 10 mm respectively. The appearance of the samples after tendering is illustrated in Fig. 4 [20].

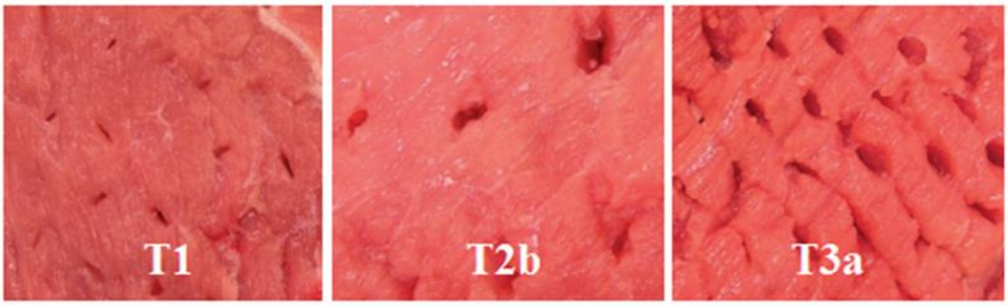
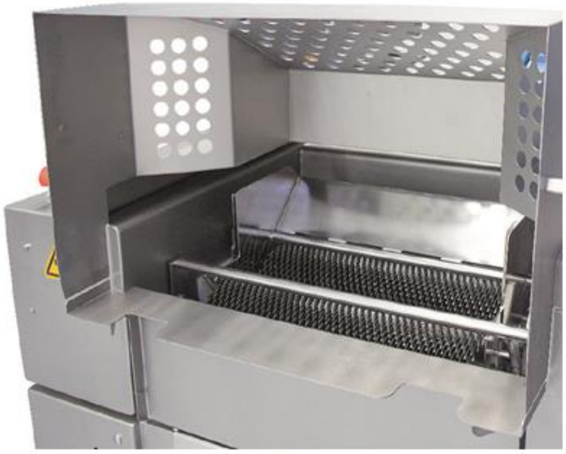


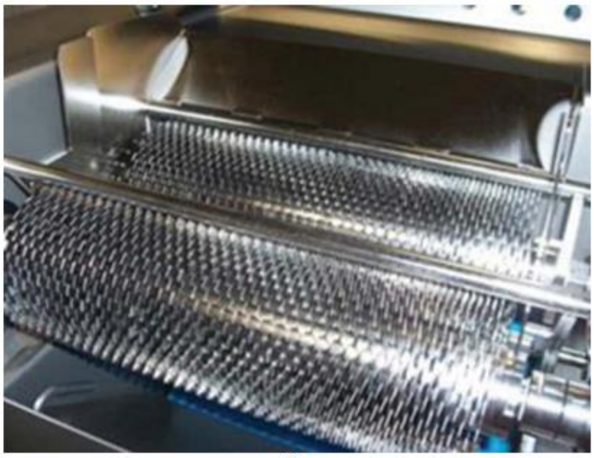

**Fig. 4. Tenderizing meat with the use of Metalquimia machines:**
T1 – Blades; T2b – Prongs at 10 mm; T3a – knives at 0 mm – adopted from [20]

Mechanical meat tenderizers are in high demand on the equipment market, so they are offered by many machine-building enterprises and firms. Metalquimia produces four sizes of Filogrind roller tenderizers with the working bodies of both (customer's choice) designs described above. These are 3-Option Mod.360 and 3-Option Mod.5500 with one pair of working bodies, as well as 360 Twin and 5500 Twin with two pairs of working bodies [21]. Alco-Food-Machines (Germany) offer mobile ASC tenderizers with knife shafts (Fig. 1) [22]. These machines are available in four sizes: with conveyor belt widths of 400, 600, 700 and 900 mm. Model 403 tenderizers (Fig. 2) are manufactured by Hobart (USA) [23]. The information materials of the company say that the use of knife plates with the number of knives reduced to 11 units allows the processing of raw materials with less damage to the surfaces of the cuts. Small KT-PK tenderizers similar to Hobart equipment are offered by the Finnish company Koneteollisuus Oy, which is widely represented on our market [24]. The French company

Provisur Technologies produces Lutetia tenderizers with vertical blades, as well as combined devices for tenderization and needle injection [25]. Schröder Maschinenbau (Germany), a well-known manufacturer of equipment for salting and softening meat raw materials, produces T-MAX 620 tenderizers with vertical working bodies, PSM 650 machines with working rollers, as well as a Mac MAX 500 roller tenderizer equipped with pointed spikes [26]. Manual, semi-automatic and automatic (Fig. 4) tenderizers are offered by another well-known manufacturer of equipment of the specified profile – Suhner (Switzerland) [27]. It is clear that the above brands and sizes of equipment for raw meat tenderization are only a part of what machine builders offer on the world market.



a



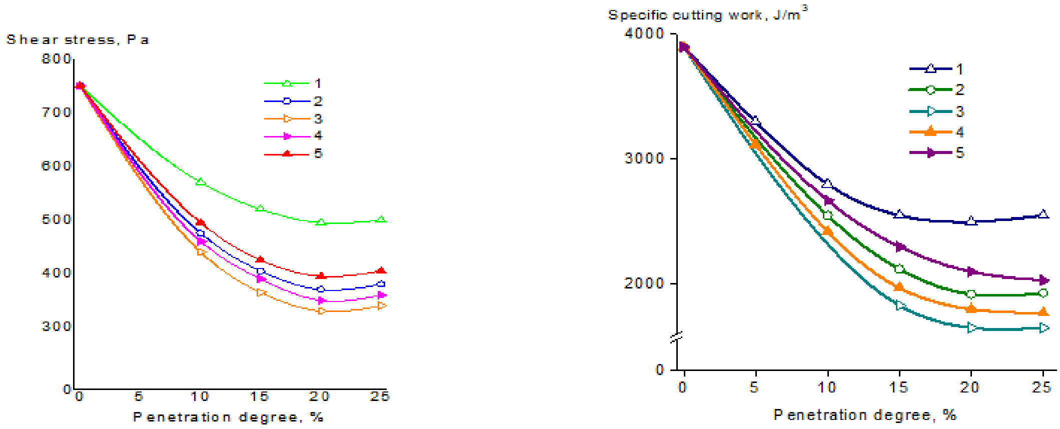
b

**Fig. 5. Tenderizing machines manufactured by Suhner (Switzerland):**
a) working area; b) working bodies

Speaking of brine injectors, the implementation of intensive salting of meat raw materials with the help of these devices is usually recalled, which ensures the formation of the necessary taste and aroma characteristics, tenderness, juiciness in the raw material, helps to reduce the duration of the process and prevents microbiological spoilage. Brine injectors allow intensifying the distribution of brine and maturation of meats, increases their tenderness and moisture-binding ability, while increasing the yield of products and reducing its cost [28]. The principle of their operation is that the raw materials are pierced (manually or mechanically) with needles (from one to several dozen), and the salting brine is injected through their central channels to holes of small diameter in the tip and / or in the periphery of the needle. The high rate of diffusion of salting substances to meat raw materials, characteristic of needle injection, ensures the proper intensification of the curing process. In modern injectors, brine is usually injected under a pressure of 2 to 4 kg/cm$^2$ through needles directly inserted into the thickness of the meat, on the side surface of which there are holes with a diameter of 1 mm, due to which the brine evenly fills the space between the muscle fibers and brings salts to all internal zones of the processed cut [29].

At the same time, industrial brine injectors are equipped with dozens of injection needles that rupture the integrity of the muscle tissue of the meat. Therefore, it is advisable to evaluate the macerating effect that injection needles have on meat raw materials in a complex way – that is, taking into account both the hydro-mechanical (injection) and mechanical (tenderization) components. In [14] our experiments are described where such parameters as the rational diameter of the needles and the degree of penetration into a round of beef in the cooled state as well as the dependence of the shear stress and cutting work on the degree of penetration are determined (Fig. 6).

The results obtained confirm the information of [30, 31] that multi-needle marinating + tenderizing improve the tenderness, taste, and value of meat. In particular, for the tenderization of meat with increased hardness, the most effective needle diameter is 2.5- 3.5 mm. The obtained value of hardness is reduced by 208% compared to the control batch, and the shear stress reaches 350-380 Pa. Needles of the diameter 2 mm appear to show the smallest tenderizing effect. Tenderizing with 2 mm needles is the mechanical action much closer to the traditional process – the separation of muscle and connective fibers without significant incisions that is why the curve 1 is of flatter character, and the shear stress decreases only to 500 Pa. So the experimental batches are saturated with brine with almost no changes in the structure of tissues, and the reduction in the tenderizing effect of penetration is evident. The hardness of raw meats of the same degree of penetration when processed with needles with a diameter of 2 mm is 50% higher than when processed with needles with a diameter of 3 mm. The study of the hardness in terms of shear stress and the specific cutting work proves that using needles of 4 mm causes the reduction of tenderizing effect by an average of 10% compared to processing with needles with a diameter of 2.5- 3.5 mm. So it is advisable to tenderize meat of high rigidity with 2.5- 3.5 mm needles. Analyzing the graphs above we can see the rigidity of the treated meats is decreasing most intensively at the initial stages of tenderization and reaches a maximum at a penetration degree of 20 %, and then stabilizes. The sensory evaluation of the samples correlated with the data of rheological characteristics. The dependence is directly proportional: the lower the shear stress and cutting work, the greater the degree of penetration of samples, the higher the juiciness and tenderness of the product [14].




a b

**Fig. 6. Dependence of penetration degree on the shear stress (a) and the specific cutting work (b) for the needles with diameter (mm):** 1 – 2.0; 2 – 2.5; 3 – 3.0; 4 – 3.5; 5 – 4.0 [14]

A sensorial evaluation of samples with different degrees of penetration was carried out according to the most important indicators – tenderness and juiciness. Studies have shown that the sensory evaluation of the samples correlates with the data of structural and mechanical characteristics. Moreover, the dependence is directly proportional: the lower the shear stress and cutting work, the greater the degree of penetration of samples, the higher the juiciness and tenderness of the product.

The complex treatment process that meat raw materials undergo in multi-needle brine injectors combines the curing brine soaking of meat and its tenderization as a result of the mechanical action of numerous needles. These two components of the complex process, to a certain extent, contradict each other, since a significant destruction of the structure of the muscle tissue prevents the curing brine from being retained in its deep. The goal of minimizing damage to the meat structure is set by both developers of low-pressure injectors and designers who prefer designs based on the spray-injection effect, which requires the use of high brine pressure. In the first case brines are fed into the meat through 2-4 holes with a diameter of 1 mm or more. These machines operate freely at various pressures in the brine circuit, usually not exceeding 4 kg/cm².

The authors of such design solutions believe that higher pressure causes damage to the structure of the meat, since the brine settles down inside the meat in an unbound form, which causes poor separation and brine retention. Subsequently, these injection defects turn into salting anomalies, which take the form of colored spots and adversely affect the appearance of the product [14]. The manufacturers of the so-called spray injectors have other arguments in favor of their designs – the injectors where the brine is injected using hollow needles, which, depending on the thickness of the pieces of meat, have up to 22 holes of small diameter (0.6 mm) located at different heights. Due to the small size of the holes and the use of higher pressures, the brine injection, according to the developers of such installations, sprays the jet into drops. Their size and high speed allows them to penetrate deeply between tissues without damaging the structure of the meat. The brine introduced in this way has minimal loss due to leakage, since the main reason for it is the free brine remaining in the channels formed by the needles after they exit the meat [13, 14, 32].

Brine injectors, including multi-needle ones, are produced by many engineering companies. For example, the machines manufactured by the Danish company Fomaco and the Polish company Metalbud NOWICKI can be mentioned. Fig. 7 [33] shows the M3 brine injector manufactured by Fomaco, Fig. 8 [34] – a needle block of SAS injector manufactured by Metalbud NOWICKI. The designs of brine injectors are well developed in the world practice of specialized engineering. In the European Union, safety and hygiene requirements for multi-needle saline injectors are standardized [35].

**Fig. 7. Multi-needle brine injector M3 manufactured by Fomaco (Denmark)**

**Fig. 8. Needle block of SAS injector manufactured by Metalbud nowicki (Poland)**

So it is reasonable to define the tenderization process fulfilled without simultaneous injection of pickling brines as dry tenderization. Correspondingly, wet tenderization is achieved when meats are penetrated by injection needles saturating muscle tissue with pickling brines. Pressurized liquid also causes certain destruction of tissues and the effects of low-pressure processing and so called “spray injection” differ significantly. The combine influence of the mechanical action and hydro-mechanical action upon the treated meats shall become a subject of theoretical and practical studies in future.

**Conclusion.** Several methods have been developed for softening raw materials, among which mechanical tenderization is not the last. Meat cuts are mechanically tenderized and/or enhanced to add value to lower quality cuts by improving sensory attributes such as palatability and tenderness. The term “mechanically tenderized” is defined as “manipulating meat with deep penetration by processes which may be referred to as “blade tenderizing,” “jaccarding,” “pinning,” “needling,” or using blades, pins, needles or any mechanical device”. The tenderization process fulfilled without simultaneous injection of pickling brines as dry tenderization. The main methods for the practical implementation of the process of softening meat raw materials are piercing with knives or needles, passing through paired rollers equipped with a notch or wedge-shaped teeth, processing using plates with a notched surface.

The wet tenderization is achieved when meats are penetrated by injection needles saturating muscle tissue with pickling brines. The research fulfilled showed that for tenderization of meat of increased hardness, the most effective diameter of needles is 2.5 – 3.5 mm. The smallest tenderizing effect is observed when raw meat is processed with needles with a diameter of 2 mm. When needles with a diameter of 2 mm are used, the nature of the mechanical action is essentially closer to the separation of muscle and connective fibers without significant incisions. However, combine influence of the mechanical action and hydro-mechanical action upon the treated meats has not yet been properly studied so the corresponding research shall be held in future.

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