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Divyanee Patel
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry (COVSc &AH), (NDVSU), Mhow, Indore, Madhya Pradesh, India

NK Nayak
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry (COVSc &AH), (NDVSU), Mhow, Indore, Madhya Pradesh, India

Pranav Chauhan
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry (COVSc &AH), (NDVSU), Mhow, Indore, Madhya Pradesh, India

Corresponding Author:
Divyanee Patel
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry (COVSc &AH), (NDVSU), Mhow, Indore, Madhya Pradesh, India

Recent developments in restructured meat products

Divyanee Patel, NK Nayak and Pranav Chauhan

Abstract
Restructuring meat and meat products has emerged as a promising approach to address several challenges associated with traditional meat production and consumption. Restructuring means reorganizing in same or in a new shape by combining small meat pieces with natural proteins to create a meat product. Meat can be bound in products by forming gels that set thermally "hot-set", with chemical reaction "cold-set" and high pressure processing (HPP). These techniques aim to alter the texture, shape and appearance of meat products in order to enhance their overall sensory attributes and functionality. By reducing the amount of meat required for products, utilizing alternative protein sources, and potentially reducing the environmental impact of livestock farming, the implementation of meat restructuring techniques can contribute significantly towards environmental sustainability. Additionally, these innovations provide an avenue for lowering the consumption of saturated fats and potentially reducing the risk of certain diet-related diseases, contributing to improved public health outcomes.

Keywords: Restructuring, hot-set, cold-set, HPP, meat products

1. Introduction
In the world where dietary preferences and environmental concerns are rapidly evolving, the food industry is continuously seeking innovative approaches to meet the changing needs of consumers. One such groundbreaking development is the concept of restructuring meat- a process that holds immense potential for transforming the future of animal-based protein. A method of restructuring has been developed as a way to transforming lower value cuts into products of higher value. Restructuring refer to the process of causing small pieces of meat and then reforming it into either the same or in a new form. Restructured meat, also referred to as mechanically deboned meat, restructured meat is a way of transforming animal meat into different forms using machines and processes. It involves grinding and separating the meat into smaller pieces, restructuring is when small meat pieces are bound together using natural proteins. This creates a meat product that has the qualities of meat steak, meat ball and meat patties. This process helps improve the texture, taste and overall quality of the meat. It also allows for the removal of unwanted bits like fat and cartilage, resulting in leaner and more consistent meat products. Restructured meat offers versatility and can be customized to meet consumer preferences, while also addressing concerns related to sustainability and animal welfare. Meat and meat products provide us with high-quality protein in our diets. The consumers' meat is fresh, lean, tender, juicy, flavor also be wholesome and healthy. Restructured meat products are called reformed, flaked, chopped or shaped based on size and amount of meat added (Anandh and Villi, 2018) [1]. Meat products are made in various ways in the industry, food service, or at home. They can be made with different processes, ingredients, or cooking methods. The main goal is to create healthy and tasty meat products (De Araujo *et al.*, 2022) [2]. The restructured meat product offers many advantages of economy, low in fat and low in calories. Restructured meat has been modified to include healthy components from plants and other protein sources. Advancements in restructuring techniques: researchers and industry working on enhancing and improving techniques for restructure meat. These advancements aim to make restructured meat products better in texture, taste and nutrition. Researchers are studying methods like high-pressure processing, enzymatic treatment and edible films and coating to improve restructured meat. Health and sustainability considerations: there is increasing emphasis on producing restructured meat products that align with consumer demands for healthier and more sustainable food options. This includes the reduction of saturated fats, sodium and additive in restructured meat products, as well as plant proteins or cultured meat. Currently, the production of restructured meat in the developing countries is just preparatory stage.

But in other parts of the world, especially in the developed countries, manufactured and sell a lot of restructured meat products.

A. Advantages of restructured meat products are

a. Consumers around the globe are demanding meat products with low fat, minimum synthetic additives and product with a healthier profile. For such consumers, the restructured product could be one of the options.
b. Consumer demand for safe, wholesome and nutritious product with acceptable sensory attributes is ever rising. Restructured meat products have consumer-friendly texture and appearance which can facilitate an increased demand in the market.
c. The ever rising costs of meat production have urged the processors to search efficient processing strategies which will enable utilization of low value cuts and trimmings from the carcasses. During the restructuring process, we can effectively use less valuable cuts of meat and trimmings from the carcass s.
d. The consumers are demanding for quick - and - easy foods. At the same time there is demand for cost-effective, easy-to-handle products requiring little preparation. There is a need for cheap and simple products that required minimum preparation. Consumers and restaurant owner's wants product that are easy to slice, ready to cook, look good and versatile.

2. Basic Procedure

To achieve the desired texture and appearance, different techniques and ingredients are used during the restructuring process. These may include: grinding- the meat is ground into fine particles using specialized equipment. This helps distribute fat more evenly throughout the products, improving succulence and flavor. Binding agents-ingredients like proteins, starches or gelling agents are added to bind the meat particles together. These agents help improve water retention, ensuring the restructured meat retains juiciness during cooking. Forming- once the meat particles are mixed with binders, the mixture is shaped using molds or other forming techniques. This allows manufacturers to create various products shapes like patties, nuggets, fillets. Marinating: before or after forming, restructured meat can be marinated to enhance flavor. Marinating helps infuse the meat with spices, herbs or brine, further improving taste and tenderness. Commonly, while preparing restructured meat products, different methods of size reduction are applied. One method is chunking, where the meat is passed through a coarse grinder plate to decrease in particle size to cubes that are not greater than one and a half inches. This technique enhances the extraction of myosin by increasing surface area. It also improves binding during mixing. High speed dicing or slicing machine is being used for flaking and reforming of restructured meat products. Fine flakes produce more acceptable appearance increase tenderness and decrease shear force value. Sectioned and formed meats are mainly made up of whole muscles or muscle sections that are bound together to create one piece (Reddy *et al*., 2015) [3].

3. Techniques

Recent various techniques have used to restructure meat and meat products. Some of the techniques are: 1. Mechanical restructuring: These methods, such as grinding or mincing, are commonly employed to restructure meat and create new meat products. By mechanically breaking down and rearranging the muscle fibers, the texture and appearance of the final product can be modified. The process of forming gels that set through the application of heat is known as hot-set binding. 2. Meat binding agents: various binding agents, such as transglutaminase, the restructuring of meat products has used to enhance. Transglutaminase is an enzyme. It promotes protein cross-linking, improving meat texture and stability. These mechanism chemically also known as (cold-set) binding. 3. Emerging technologies of meat processing (e.g., HPP high pressure processing, HDP-hydrodynamic pressure processing, Ohmic heating processing), HPP- HPP involves subjecting meat and meat products to high pressure, typically between 100 and 800 mega pascals. This process helps improve the texture and tenderness of the meat with minimizing microbial contamination. 4. Meat extrusion: extrusion technology uses heat, pressure and shear forces to process meat and meat ingredients. This technique enables the creation of novel meat textures, shapes and structures, including meat analogs, effectively restructuring the meat products. 5. Meat marinating: marination involves soaking meat in a liquid solution, typically containing acids (e.g., vinegar, citrus juice), salt, enzymes or tenderizers. This process reduces the size of muscle fibers in meat. It makes meat taste better and improves its texture. The food industry is constantly searching for new ways to create restructured meat and products that meet the demand for texture, flavor and sustainability.

3.1 Hot-set binding system

Conventional restructured meat products rely on heat-induced binding of meat proteins. These proteins are extracted using salt, phosphate and mechanical action. The product must be sold precooked or frozen with this technology. The raw product binding is low, but high yields are possible it may 25% above meat weight.

a. Mechanism of hot set binding

In this, we use two techniques: tumbling and massaging. Tumbling uses impact energy, and massaging uses frictional energy. Both techniques aim to extract salt soluble proteins for enhanced tenderness, juiciness and slicing characteristics (Gurikar *et al.,* 2014) [4].

i. Tumbling

Recently the method of tumbling or fall massage is used. It improves the quality of tough meats like pork and beef. This technology is also used to produce re-formed and restructured meat. Tenderness and color are two important characteristics that affect consumer satisfaction. Binding characteristics of muscle and water holding capacity both affects the sensory characteristics. The myofibrillar proteins are responsible for these characteristics. They are extracted and solubilized to form exudates. The method can benefit consumers and manufacturers. It reduces processing time and improves product quality and also saves the costs. A vacuum extracts air from the tumbler, preventing foam formation. Foam is undesirable because it reduces binding strength in the product. Tumbling is often done in a vacuum to prevent the oxidation of protein and lipid (Nino *et al*., 2022) [5].

ii. Massaging

Massaging is a common method in the processing meat industry. It loosens and damages the structure of meat. The

final effects of massaging depend on two main factors. These factors include massaging time and paddler speed. The more time spent massaging, the better the appearance, texture, binding and the palatability (Gurikar *et al*., 2014) [4].

3.2 Cold-set binding systems

Cold-set binding systems allow offering consumers uniform compact meat products can be raw or refrigerated and have consistent shape, color and texture. Cold-set binders like calcium alginate, transglutaminase, and fibrinogen/thrombin can restructure and enhance lower valued muscles, trimmings, and smaller lean muscle pieces. Typically, these are used for minced or ground meat. The products functionality and acceptability depend on the binder and raw materials.

a. Alginate: Is a type of hydrocolloid derived from brown algae. It comes from the class *Phaeophyceae* (Joye and McClements, 2014) [6]. The alginate system consists of three main components. These include sodium alginate, a calcium source and an acidifier. The acidifier helps to the release of calcium. The components of this system are added to a meat product. They slowly form gel in the product during mixing. Alginate gels form without heating. The gels do not melt when heated, so the product stays intact when cooked.

b. Transglutaminase: Scientists have found transglutaminase in animals, plants and microorganisms. The enzyme can be obtained by *Streptomyces mobaraensis*. Microbial transglutaminase (MTG) is a protein in restructuring enzyme used in food technology. It is commonly used to modify protein foods like meat, dairy and fish products, and introduces covalent bonds. These bonds improve foods functional properties such as viscosity, solubility, elasticity, and more (Rodriguez *et al*., 2017) [7].

c. Fibrinogen/thrombin: Blood clotting is a complex process, which ends with thrombin converting fibrinogen to fibrin. Once released, the fibrin aggregates. The system inherently activates transglutaminase particularly thrombin also activates transglutaminase. Transglutaminase converts the fibrin adds to an insoluble gel. It forms covalent cross-links between the fibrin aggregate molecules and is the preferred reaction between fibrin molecules. Cross-links form between fibrin and fibronectin; and fibrin and collagen, these cross-links bind meat particles together. The fibrinogen and thrombin in restructured meat come from beef, similar systems have been developed in recent years from pig sources. This is due to concerns about bovine spongiform encephalopathy (BSE). Additionally, young animals blood (under 30 months of age) is used to manufacture the binder. The United States has not approved Fibrimex as meat binder. The EU Directive revoked approval for blood based binders in 2010.

3.3 High pressure processing (HPP)

This innovative approach utilizes high-pressure treatments to modify the structural and textural properties of meat, resulting in improved quality, functionality and preservation. HPP can produce numerous changes in the meat structure, including protein denaturation, enzymatic activity modulation and microbial inactivation. These changes results in meat products with desirable texture and safety. The alteration also improves the shelf life of the products. High-pressure processing is gaining more attention in the meat industry. This technique can extend the shelf life of meat products and deactivate micro-organisms and enzymes at room temperature. By using high-pressure processing, muscle based products can be decontaminated while preserving nutritional and sensory qualities (Akhtar and Abrha, 2022) [8]. The application of high pressure provides interesting opportunities in the processing as can impact meat texture and gel-forming properties and more. It can tenderize, enhance color and other properties. The effects processing on muscle products rely on pressure, time and temperature. These factors impact the thermodynamic and transport properties of meat systems. However, some meat protein systems, like myosin or myoglobin, are pressure sensitive. This limits their use to mostly prefermented and cooked meat products.

3.3.1 Effect of high pressure on the texture of myofibrillar proteins

The texture of myofibrillar proteins gel is affected by protein solubility. This is because the functional properties of the myofibrillar proteins require solubilization. High pressure is an important parameter in thermodynamics and greatly affects molecular systems. The treatment of high pressure can cause de-polymerisation of myofibrillar proteins and increasing solubility. The elasticity of chicken myofibrillar gels increased by 2- 3 times. This increased was observed at 200 MPa for 10–20 minutes. The gels were then heated to 70 °C (Iwasaki *et al*., 2006) [9]. Cando *et al*. (2015) [10] study indicated the surimi gel was stronger with 150 MPa treatments, however, the breaking force decreases with 300 MPa treatments. It is well known for impacting molecular systems whereas proteins denaturation occurs at pressure over 400 MPa. At 200 MPa, only quaternary structures affected, causing the separation of oligomeric proteins. Zhang *et al*. (2017) [11] found that the hardness of the gel made from myofibrillar proteins initially increased from 20.25 (0.1 MPa) to 46.6 g (200 MPa), then decreased gradually to 33.3 g (500 MPa). This change in hardness was mainly due to the high pressure treatment, which affected the interactions between molecules (hydrogen bonds, hydrophobic interactions and electrostatic bonds) and the conformation of the protein. As a results the protein lead to denaturation, dissociation, aggregation, and leading to alterations in their functional properties. Ma, *et al*. (2011) [12] found that myosin light chains and actin thin filaments in beef muscle were responsive to pressure. They observed the sensitivity when the myofibrils were exposed to 100 MPa and released. The network structure of rabbit myosin gel looked small and even when observed under scanning electron microscopy after treatment at 200 MPa. Above 200 MPa, the gel holes became larger (Cao *et al*., 2012) [13]. The myofibrillar proteins were found to be partially unfolded at 100 MPa; this causes the gels to contain many filaments and irregular cavities. At 200 MPa, the smallest particle size of myofibrillar proteins was formed with denser gels and homogeneous network and resulted in the highest hardness value. However, at 300 MPa and above, the myofibrillar proteins denatured excessively. This caused the interior hydrophobic and sulfhydryl groups exposed; led to larger and heterogeneous gel cavities. As a result, the hardness was decreased (Zhang *et al*., 2017) [11]. Gels with higher hardness have smaller, denser and homogeneous microstructure. Gels with lower hardness have larger cavities and coarse microstructure. The high pressure treatment significantly affects the gel properties and protein conformation. The high pressure treatment has the potential to

modify the structural properties of myofibrillar proteins. This can lead to denaturation, solubilization, aggregation, or gellation and create innovative functional properties. A moderate pressure (<200 MPa) can enhance water holding capacity and texture. HPP affects both the internal structure and the external appearance of the food.

3.3.2 Hydrodynamic pressure processing

Hydrodynamic pressure processing is an advancing innovation that has gained significant attention in the food sector, especially in the production of restructured meat products. Hydrodynamic pressure processing (HDP) uses rapid changes in pressure to treat meat products. This technology involves exposing the meat to sudden pressure changes for a short duration, resulting in the disruption of muscles fibers and the creation of a restructured meat product. The pressure changes cause the protein structure to break down, leading to a reorientation and binding of meat protein, thus creating a meat-like texture. Meat processing can be enhanced using hydrodynamic shockwave and high pressure processing. High pressure is utilized in two ways: static treatment in a vessel and dynamic treatment in a fluid flow. Another method is hydrodynamic pressure processing or shockwave treatment, which create instantaneous pressure waves up to 1 GPa in milliseconds. Detonating explosives or electrical discharge generate a pressure front under water. A pressure wave or shockwave results from both methods, and the waves intensity and speed characterize it over time. A shockwave travels faster than sound in liquid. As meat is composed of 75% of water, when a wave travels through meat, it breaks apart the proteins in the muscle. This gives what can be called "the rupture effect" and as a simultaneously enhances favors and tenderization of meat. The important quality parameter of meat is tenderness, which facilitates the total perception and acceptability of a product and influences its cost (Gorbunova, 2022) [14].

3.4 Meat Extrusion

Extrusion is a popular method for manufacturing protein based food and used to create different textured convenience foods. During extrusion protein sources are cooked continuously with heat, pressure and mechanical force. This process transforms the raw material into a new, restructured form. Macromolecules in proteinaceous ingredients lose their natural structure and create a continuous, visco-elastic mass; while passing through the extruder barrel and die, the molecules align in the flow direction. This realignment exposes bonding sites for cross-linking and forms a restructure structure (Plattner, 2020) [15]. Some of the additional important functions of extrusion technique includes as:

- **Denaturing protein:** Proteins are denatured during moist and thermal extrusion process. Denaturation lowers solubility, make it digestible and destroying the biological activity. Enzymes and toxic proteins are affected by denaturation.
- **Deactivating residual heat-labile growth inhibitors:** Growth inhibitors are in some vegetable proteins, causing harm to humans or animals. Deactivating these growth inhibitors reduced or eliminates the harmful effects.
- **Controlling raw or bitter flavors:** Many undesirable flavors are removed by extrusion and decompression of protein. Preconditioning and venting devices help eliminate off-flavors in extrusion system.
- **Providing a homogeneous, irreversible, bonded dispersion of all micro-ingredients throughout a protein matrix:** Dispersion helps make sure all ingredients are evenly distributed. It also allows minor ingredients to interact with reaction sites. This promotes cross-linking or other desirable changes in the product.
- **Shaping and sizing of the final extruded product:** Final products are shaped and sized to create textured vegetable protein. These products are convenient and come in transportable portions. They can be packaged in retail or institutional market places.

Advantages of restructured meat extrusion: texture and acceptability, enhanced nutritional profile, economical and sustainable, versatility in product development caters to a growing consumer demand for diverse protein options.

3.5 Meat marinating

We will delve into the fascinating world of marination techniques specifically tailored to enhance the flavors of restructured meat, allowed to create mouthwatering dishes that leave a lasting impression on taste buds. Marination is mainly used to enhance the sensory and textural properties of meat (Goli *et al*., 2014) [16]. Marinating restructured meat: 1. Time and temperature- longer marination times are generally recommended for restructured meat due to its denser and compact structure. Ensure the marination takes place in the refrigerator to maintain food safety. 2. Acidic marinades- such as those containing citrus juices or vinegar, help tenderize the restructured meat, Enzymatic marinades, like those containing pineapple or papaya, aid in breaking down the meat fibers but should be used judiciously. 3. Flavors and ingredients- various flavor and ingredients like soy sauce, honey and spices to bring depth and complexity to marination concoctions. In Marinate, salts, organic acids, fruits, vegetables, drinks (soda, wine, etc.), enzymes, vinegar and combinations are used. Studies show that with marination water-holding capacity increases and cooking loss reduces. It also improves textural properties; develops color, taste and aroma, reduces flavor loss, antimicrobial which limits microbial growth and extend shelf life (Serdaroglu *et al*., 2007; Sharedeh *et al*., 2015) [17, 18]. Vinegar is a common marinade for acidic marination and is made from grains and fruits through fermentation. High sugar fruits are necessary for making vinegar such as grapes, apples, figs, pomegranates, and other fruits are used for fruit vinegar. Vinegar contains bioactive compounds and is useful in food industry. Vinegar has antimicrobial, antioxidant, antidiabetic, anticarcinogenic and anti-infection properties. Fencioglu *et al*. (2022) [19] examined the effects of marination with different vinegar types and showed that vinegar marination affected heterocyclic aromatic amine (HAA) formation in beef steaks. Among the vinegar types only pomegranate vinegar caused an increase in HAA content. The daily intake of HAAs per person is reported to be 0-15 g/day (Skog, 2002) [20]. In this study, the intake level (0.222 g) remains below the established limit, even when consuming 100 g of pomegranate vinegar-marinated steaks with the highest HAA content.

4. Benefits of restructured meat products

4.1 Cooking yield: Cooking yield and cooking loss are important for the meat products processing industry. They predict how products behave during cooking considering binder, non-meat ingredients or other factors. Losses

decreases as particle size decreases in restructured meat products. Intact and restructured beef steaks produced with salt/phosphate and algin/calcium had lower cooking loss than the restructured steaks made with crude myosin, whey protein, wheat gluten, soy protein isolate and surimi.

4.2 Batter stability: The salt, polyphosphates and mechanical agitation extract salt soluble proteins. This creates a fine protein matrix in homogenous batter. The protein matrix binds meat chunks, stabilizing the batters during processing and cooking of restructured meat products.

4.3 Water holding capacity: The ability of food to hold water during application of forces is called water holding capacity (WHC). Functional differences in water holding were more pronounced in meat treatment, when yield was calculated as a percentage of meat weight. Small particle size formulations had higher WHC than big particle size formulations in restructured mutton product. The reason for lower WHC values in low value cuts added formulations is likely to be more connective tissue fibers.

4.4 pH: The product had a higher pH, when the meat chunk size was smaller, this could be because the protein denatured during cooking. Generally, changes in pH in protein-rich food are caused by protein denaturing due to heat. The pH of frozen restructured beef steaks has been reported to slightly increase. The products increased significantly with longer storage (Shin *et al*., 2014) [21].

4.5 Shrinkage in diameter: The type of binder used influenced the dimensional changes in steakettes. The method of size reduction or size opening had no effect. Overall, mutton steak had more distortion, when small particle size was used. The restructured mutton product with big particle size and low value cuts had the highest diameter shrinkage, the type of binder used affected the size of steakettes. The method of size reduction didn't change the dimensions of the meat. Restructured mutton steaks had more distortion when made with small particles. The largest shrinkage occurred in mutton with big particles and low-value cuts manufactured with small particle size. The highest diameter shrinkage was found in restructured mutton product with big particle size and low value cuts.

4.6 Protein extractability: Restructured meat products succeed by mixing meat with salts and phosphates. They extract salt-soluble proteins that bind meat chunk together; it creates a desirable steak-like texture. Restructured mutton product formulated with small size particles had the highest protein extractability and other formulations had lower extractability. Adding low value cuts reduced protein extractability due to more connective tissue.

Table 1: Recent research on restructured meat products

Restructured product	Features of reforming	Reference
Restructured pork blocks	Optimized processing conditions	(Gurikar *et al*., 2014) [4]
Restructured spent hen meat nuggets	Processed with salt, sodium tripolyphosphate, sodium nitrite to enhance quality and acceptability	(Anandh and Villi 2018) [1]
Restructured pork chops	Optimized processing conditions (pressure-transform tumbling)	(Zhu *et al*., 2019) [22]
Restructured meat products	Recombinant transglutaminase gene (*Pichia pastoris*)	(Yang and Zhang, 2019) [23]
Restructure tilapia (*Oreochromis mossambicus*)	Citric acid (0.2%) improve physicochemical properties of products	(Gu *et al*., 2021) [24]
Restructured beef steak	Application of extrusion-based 3D food printing	(Park *et al*., 2023) [25]
Restructured buffalo meat fillets	Low in sodium, high fiber and enriched with antioxidant	(Ahmad *et al*., 2021) [26]
Restructured fresh meat	shockwave (SW) technique- for meat tenderization	Gorbunova *et al*., 2022 [14]
Restructured pork steak	alginate/calcium, κ-carrageenan	(Saengsuk *et al*., 2022) [27]
Low fat restructured jerky products	Jerky seasoning with raisin paste(natural preservative)	(Lemma *et al*., 2022) [28]
Restructured spent hen meat slices	Use of soy protein for enhancing texture of slices	(Gupta and Sharma, 2023) [29]

5. Conclusion

Meat restructuring technology offers a potential benefit of utilization of meat trimmings and lower value cuts into value-added products, thereby improving the palatability and consumer acceptance. To further improve the quality and consistency of restructured meat products, detailed studies are still needed on particle size, blending conditions, meat tenderizing processes, color and flavor stability. Besides the economy, the restructuring process also provides healthier meat products, as restructured products are leaner and health conscious consumers are demanding healthier products having low fat, low salt, and high fibre and minimum synthetic ingredients. Numbers of restructured products using a variety of ingredients have been developed, but acceptance of these products by the consumer is still challenging. At the same time, proper marketing and educating the consumers about the importance of restructured products is essentially required.

6. References

1. Anandh MA, Villi RA. Quality and Acceptability of Restructured Spent Hen Meat Nuggets Prepared from Spent Hen Meat Emulsion and Ground Spent Hen Meat Batter. International Journal of Current Microbiology and Applied Sciences. 2018;7(2):220-225.
2. Araujo DPD, Araujo WMC, Patarata L, Fraqueza MJ. Understanding the main factors that influence consumer quality perception and attitude towards meat and processed meat products. Meat Science. 2022;193:108952.
3. Reddy B, Sen GV, Sudhakara AR, Reddy K, Reddy K, Rao TM, *et al*. Quality characteristics of restructured mutton slices developed by cold-set binding system. Indian Journal of Small Ruminants 2015;21(2):300-305.
4. Gurikar AM, Lakshmanan V, Gadekar YP, Sharma BD, Anjaneyulu AS. Effect of meat chunk size, massaging time and cooking time on quality of restructured pork blocks. Journal Food Science Technology. 2014;51(7):1363-1369.
5. Nino T, Sasidharan A, Sabu S, Sunooj KV, Pradhan C, Xavier KM. Effect of vacuum tumbling assisted

marination on textural and sensory properties of deep-fried Indian white shrimp. Indian Journal Fish. 2022;69(3):100-107.
6. Joye IJ, McClements DJ. Biopolymer-based nanoparticles and microparticles: Fabrication, characterization and application. Current opinion in colloid & interface science. 2014;19(5):417-427.
7. Rodriguez CG, Ramirez LJ, Bustos VG, Ruiz CO. Properties of fish and beef restructured by MTG derived from *Streptomyces mobaraensis* grown in media based on enzymatic hydrolysates of sorghum. Czech Journal of Food Science. 2017;35(6):517-521.
8. Akhtar J, Abrha MG. Pressurization technique: principles and impact on quality of meat and meat products. Food and Agricultural Immunology. 2022;33(1):264-285.
9. Iwasaki T, Noshiroya K, Saitoh N, Okano K, Yamamoto K. Studies of the effect of hydrostatic pressure pretreatment on thermal gelation of chicken myofibrils and pork meat patty. Food Chemistry. 2006;95:474-483.
10. Cando D, Herranz B, Borderias AJ, Moreno HM. Effect of high pressure on reduced sodium chloride surimi gels. Food Hydrocolloids. 2015;51:176-187.
11. Zhang Z, Yang Y, Zhou P, Zhang X, Wang J. Effects of high pressure modification on conformation and gelation properties of myofibrillar protein. Food Chemistry. 2017, 678-686.
12. Ma H, Zhou G, Ledward DA, Yu X, Pan R. Effect of combined high pressure and thermal treatment on myofibrillar proteins solubilization of beef muscle. International Journal of Molecular Sciences. 2011;12(5):3034-3041.
13. Cao Y, Xia T, Zhou G, Xu X. The mechanism of high pressure–induced gels of rabbit myosin. Innovative Food Science and Emerging Technologies. 2012;16:41-46.
14. Gorbunova NA. Shockwave effects in the technology of meat raw material processing. Theory and Practice of Meat Processing. 2022;7(1):22-29.
15. Plattner B. Extrusion techniques for meat analogues. Cereal foods world, 2020, 65(4).
16. Goli T, Ricci J, Bohuon P, Marchesseau S, Collignan A. Influence of sodium chloride and pH during acidic marination on water retention and mechanical properties of turkey breast meat. Meat Science. 2014;96:1133-1141.
17. Serdaroglu M, Abdraimov K, Oenenc A. The effects of marinating with citric acid solutions and grapefruit juice on cooking and eating quality of turkey breast. Journal Muscle Foods. 2007;18:162-172.
18. Sharedeh D, Gatellier P, Astruc T, Daudin JD. Effects of pH and NaCl levels in a beef marinade on physicochemical states of lipids and proteins and on tissue microstructure. Meat Science. 2015;110:24-31.
19. Fencioglu H, Oz E, Turhan S, Proestos C, Oz F. The effects of the marination process with different vinegar varieties on various quality criteria and heterocyclic aromatic amine formation in beef steak. Foods. 2022;11(20):3251.
20. Skog K. Problems associated with the determination of heterocyclic amines in cooked foods and human exposure. Food Chememical Toxicology. 2002;40:1197-1203.
21. Shin HB, Kim HY, Chun JY. Quality characteristics of emulsion-type chicken sausages added different level of buckwheat powder. Korean Journal of Poultry Science. 2014;44:135-141.
22. Zhu C, Yin F, Tian W, Zhu Y, Zhao L, Zhao G. Application of a pressure-transform tumbling assisted curing technique for improving the tenderness of restructured pork chops. Food Science Technology. 2019;111:125-132.
23. Yang Y, Zhang Y. expression of recombinant transglutaminase gene in Pichia pastoris and its uses in restructured meat products. Food Chemistry. 2019;291:245-252.
24. Gu Z, Liu S, Duan Z, Kang R, Zhao M, Xia G, *et al*. Effect of citric acid on physicochemical properties and protein structure of low salt restructure tilapia (*Oreochromis mossambicus*) meat products. Journal of the Science of Food and Agriculture. 2021;101(4):1636-1645.
25. Park JW, Lee SH, Kim HW, Park HJ. Application of extrusion-based 3D food printing to regulate marbling patterns of restructured beef steak. Meat Science. 2023;202:109203.
26. Ahmad SR, Sharma BD, Irshad A, Kumar RR, Malav OP, Talukder S. Effect of aerobic storage conditions on the quality of functional restructured buffalo meat fillets enriched with natural sources of dietary fibers and antioxidant components. Journal of Food Processing and Preservation. 2021;45(1):15072-15080.
27. Saengsuk N, Laohakunjit N, Sanporkha P, Kaisangsri N, Selamassakul O, Ratanakhanokchai K, *et al*. Comparative physicochemical characteristics and in vitro protein digestibility of alginate/calcium salt restructured pork steak hydrolyzed with bromelain and addition of various hydrocolloids. Food Chemistry. 2022;393:133315.
28. Lemma BB, Lee JH, Kannan G, Kouakou B. Natural preservative properties of raisins in restructured goat meat (chevon) jerky. International Journal of Food Properties. 2022;25(1):1736-1752.
29. Gupta S, Sharma BD. Effect of texturized soy protein on quality of restructured meat slices from spent hen. Agricultural Research. 2023;12:319-324.