

Original Research Paper

The Influence of Various Combinations of Aging and Freezing/Defrosting Modes on the Quality Indicators of Saanen Goat Meat

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Abstract: The paper evaluates the effect of various combinations of aging and freezing/defrosting on the water-holding capacity (drip loss, purge loss, and cook loss) and tenderness of four types of goat meat muscles (M. longissimus dorsi, M. laticimus dorsi, M. Semimembranosus, M. gluteobiceps). Samples obtained from 35 goat carcasses after five weeks of storage under different conditions were studied: (1) Aging at minus 1.5°C, 5 weeks (A5-control sample); (2) Aging at minus 1.5°C for 3 weeks, then freezing for 2 weeks at minus 18°C (A3F2); (3) Freezing at minus 18°C for 5 weeks (F5); (4) freezing at minus 18°C for 3 weeks, then aging for 2 weeks at minus 1.5°C (F3A2). In comparison with other experimental groups, the lowest drip loss was obtained under the aging mode followed by freezing-A3F2 (3.29%), and the lowest purge loss was shown by the groups F3A2 (4.92%) and A3F2 (5.54%). The cooking loss significantly increased in all samples compared to the control (A5) and was in the range (28.14-32.92). The minimum values of the shear force of the experimental groups corresponded to the muscle samples M. Semimembranosus (2.84 KgF) and F3A2 temperature regime (2.99 KgF). The analysis of approaches to assessing meat quality indicators allowed us to form the opinion that various combinations of freezing/defrosting and aging, types of goat meat muscles had a significant impact on contraction and purge loss. The study of methods and measures to influence meat quality indicators with further more detailed study of aging and freezing modes will allow us to determine modes with minimal loss of moisture and indicators of meat hardness.

Keywords: Goat Meat, Meat Aging, Meat Freezing, Water-Holding Capacity, Thermodynamic Parameters, Shear Force

Introduction

Meat is an essential part of human nutrition and a source of protein with high biological value, a number of vitamins, zinc, selenium, phosphorus, etc. Accordingly, the meat market is one of the strategic and large segments of the food market. In recent years, there has been a trend of annual growth in production and demand for meat and meat products on a global scale, which is expected to continue to grow (Pal *et al.*, 2022; Jeong *et al.*, 2011; Kim *et al.*, 2015). However, meat is very susceptible to spoilage due to its close-to-neutral pH level, high nutrient content, and a significant proportion of moisture in the composition. All of the above makes storing meat more difficult compared to many other types of food and

requires strict hygiene measures during slaughter and processing (Eastridge and Bowker, 2011; Leygonie *et al.*, 2012). The principle of preserving meat is based on creating unfavorable conditions for spoilage-causing microorganisms (cooling, freezing, freeze-drying, salting, radiation, and pressure treatment) (Kim *et al.*, 2013; Cho *et al.*, 2017; Aaslyng and Meinert, 2017).

From the observations of practitioners, it is known that after the termination of the life of an animal, physico chemical changes occur in the meat, characterized by stiffness, then relaxation (softening) of the muscle fibers. As a result, the meat acquires some flavor and is easier to cook. Its nutritional value is enhanced. These changes in the soft tissues of the carcass are called "ripening" or "fermentation of the meat." The maturation (aging) of meat

is the process during which microbes and enzymes act on the meat to help break down the connective tissue and make the meat more tender. There are two ways to mature:

- Wet aging by placing the beef in a plastic bag under a vacuum; or
- Dry aging by storing beef in a temperature and humidity-controlled room

The main difference is that wet aging results in little or no loss of moisture in the meat, while dry aging can result in up to 50% moisture loss. Product labeling must indicate the aging processes used (Ryu *et al.*, 2020; Dang *et al.*, 2019).

Storage conditions for dry aging of meat (dry aging):

- Temperature: -0.5°C - 1°C (2°C - 3°C can only be used for aging up to 3 weeks)
- Relative humidity: 75-85%
- Airspeed: 0.2-0.5 m/s

During maturation, partial dissociation of actomyosin into actin and myosin and the transition of actomyosin from a contracted to a relaxed state begin. The increase in meat tenderness is due to a change in the structure of myofibrils. There is a close relationship between fragmentation and an increase in meat tenderness, which indicates the great importance of the breakdown of myofibrillar structures during maturation for meat tenderness. A significant reduction in meat stiffness at low positive temperatures is achieved between 48 and 72 h after the slaughter of the animal. With the breakdown of actomyosin, the number of hydrophilic centers of myofibrillar proteins increases, which leads to an increase in the water-binding capacity of muscle tissue. After 6 days of exposure, it reaches 85-87% of the water-binding capacity of fresh meat and does not change in the future (Rant *et al.*, 2019; Coombs *et al.*, 2017).

Cold treatment is the simplest and most common method of preserving meat. Of the meat processed at low temperatures, frozen meat is one of the most demanded in terms of thermal condition. However, as studies confirm, frozen meat is inferior in a number of ways to non-frozen (chilled): It has lower indicators of meat tenderness, greater loss of meat juice and weight (Kim *et al.*, 2013; Choe *et al.*, 2016). This, in turn, is partly due to the fact that when meat is frozen, ice crystals form in the intercellular spaces and, accordingly, moisture loss is observed during defrosting (Šopik *et al.*, 2022; Pinheiro *et al.*, 2019). There is also evidence that organoleptic parameters may decrease during the thawing of frozen meat due to the oxidation of fat and protein resulting from the release of pro-oxidant enzymes and the destruction of muscle cells (Holman *et al.*, 2017; Leygonie *et al.*, 2012). However, freezing meat is the most affordable method and is practically

indispensable for long-distance transportation and long-term storage (up to 18 months) compared to chilled meat (up to 16 days) (Grayson *et al.*, 2014; Farouk *et al.*, 2012; Vieira *et al.*, 2009). Both methods require careful observance of storage regimes, any deviation of which can cause defects and defects of the finished product.

The aim of the study is to evaluate the effect of various combinations of aging and freezing/defrosting on the tenderness and water-holding capacity (drip loss, purge loss, and cook loss) of four types of goat meat muscles (*M. longissimus dorsi*, *M. latisimus dorsi*, *M. Semimembranosus*, *M. gluteobiceps*). To achieve the goal, samples obtained from 35 goat carcasses (age-8 months, Saanen breed, weight of a pair carcass 11.58 ± 1.24 kg) after five weeks of storage under different conditions were examined. They were kept for 24 h at $18 \pm 2^{\circ}\text{C}$, then the muscles of *M. longissimus dorsi*, *M. latisimus dorsi*, *M. semimembranosus*, and *M. Gluteobiceps* were separated. The muscles were vacuum-packed and divided into 4 experimental groups with different storage regimes. The physicochemical parameters of goat meat muscles were studied under various modes of ripening and freezing/thawing, as well as under different temperature conditions. Further, the influence of different types of goat meat muscles on the shear force indicators and the effect of different temperature regimes of ripening and freezing/thawing on the shear force of goat meat were studied.

Materials and Methods

Standard Methods and Raw Materials Used for Research

This study was preceded by a number of works by authors on similar issues. The main part of the sources analyzed by us was based on the data obtained as a result of the study.

Raw materials and sampling methods: In the conditions of the slaughterhouse of IE "Aigerim" (Republic of Kazakhstan, South Kazakhstan region) 35 goat carcasses were slaughtered (age-8 months, Saanen breed, weight of a hot carcass 11.58 ± 1.24 kg). The carcasses were aged for 24 h at $18 \pm 2^{\circ}\text{C}$, then the muscles of *M. longissimus dorsi*, *M. latisimus dorsi*, *M. semimembranosus*, *M. Gluteobiceps* were separated (Fig. 1).

The muscles were vacuum-packed and distributed into 4 experimental groups with different storage modes:

- Aging at minus 1.5°C , 5 weeks-control method (A5)
- Aging at minus 1.5°C for 3 weeks, then freezing for 2 weeks at minus 18°C (A3F2)
- Freezing at minus 18°C for 5 weeks (F5)
- Freezing at minus 18°C for 3 weeks, then aging for 2 weeks at minus 1.5°C (F3A2)



(a)



(b)

Fig. 1: Packed goat carcass muscle samples: (a) Before storage
 (b) After freezing and defrosting

All frozen samples were thawed at 2°C for 24 h before the study.

Physical and Chemical Properties

Water-holding capacity. Drip loss was determined according to the method described by Honikel (1998). According to this method, muscle samples were attached inside an inflated plastic bag, so that the walls of the bag did not come into contact with meat. After 24 h and a storage temperature of 4°C, the samples were removed from the bags, and excess meat juice was removed from the surface and weighed. Drip loss was determined by the following formula:

$$\text{Drip loss (\%)} = \frac{\text{initial mass of the sample (g)} - \text{mass of the sample after 24h (g)}}{\text{initial mass of the sample}} * 100\% \quad (\text{a})$$

Purge loss/loss of weight during defrosting. The purge loss /decrease in weight during defrosting was determined by weighing before freezing and after thawing, having previously removed the released juice from the surface with a napkin. The weight loss value during defrosting was calculated by the formula:

$$\text{Contraction during defrost. (\%)} = \frac{[\text{sample's mass before freezing (g)} - \text{samples's mass after defrost. (g)}] * 100\%}{\text{sample's mass before freezing (g)}} \quad (\text{b})$$

Cook loss: Cook loss was determined by the method described by Kim and Kim (2017). Muscle samples were cooked in a frying pan with a surface temperature of 135°C until the temperature in the center of the muscles reached 71°C. The temperature was determined by a food thermometer with a tip (Testo 105, Germany). The loss of weight values during heat treatment was determined by the formula:

$$\text{Cook loss (\%)} = \frac{\text{The initial weight of the sample (g)} - \text{The final cooking weight (g)}}{\text{The final cooking weight (g)}} * 100\% \quad (\text{c})$$

Moisture content: The moisture content in the meat was determined on the MX-50 weight moisture meter (LTD A and D Co, Japan). All samples for determining the moisture content were weighed by 5 g. and evenly distributed inside the cup of the device.

Determination of the shear force by Warner Bratzler. To determine the Warner-Bratzler shear force, the samples were pre-cut into a tube-shaped shape with a diameter of 1.27 mm. The measurement was carried out on a Brookfield texture analyzer.

Results

Water-holding capacity was investigated by three indicators based on the loss of mass of samples due to a decrease in moisture (Table 1).

a-c Values with different letters inside the graph mean a significant difference between different types of muscles ($p < 0.05$).

Indicators of physico-chemical indicators water holding capacity expressed in the form of drip loss, purge loss, and cook loss during heat treatment of muscles of all groups are presented in Table 2.

The results of physico-chemical parameters of all types of muscles at different temperature conditions are presented in Table 3.

a-c Values with different letters inside the graph mean a significant difference between different temperature conditions ($p < 0.05$).

Table 1: Physico-chemical parameters of 4 goat meat muscles under different aging and freezing/thawing modes

Types of muscles	Water-holding capacity, %		
	Drip loss	Purge loss	Cook loss
A5			
M. longissimus dorsi	3,10 ^a	3,01 ^a	27,7 ^c
M. latissimus dorsi	3,98 ^a	3,17 ^b	28,2 ^c
M. semimembranosus	4,07 ^a	4,05 ^a	30,02 ^b
M. gluteobiceps	3,14 ^a	3,10 ^a	27,94 ^b
A3F2			
M. longissimus dorsi	3,17 ^a	3,50 ^b	32,10 ^c
M. latissimus dorsi	3,34 ^a	6,94 ^b	34,87 ^c
M. semimembranosus	3,40 ^a	7,05 ^b	37,52 ^c
M. gluteobiceps	3,22 ^a	4,65 ^b	35,71 ^c
F5			
M. longissimus dorsi	4,74 ^a	4,01 ^b	26,6 ^c
M. latissimus dorsi	5,25 ^a	5,22 ^a	28,5 ^b
M. semimembranosus	6,04 ^a	5,78 ^b	29,47 ^c
M. gluteobiceps	5,12 ^a	4,71 ^b	27,98 ^c
F3A2			
M. longissimus dorsi	6,19 ^a	5,74 ^b	29,80 ^c
M. latissimus dorsi	7,91 ^a	8,05 ^b	32,57 ^c
M. semimembranosus	9,64 ^a	9,78 ^b	35,85 ^c
M. gluteobiceps	8,58 ^a	7,25 ^b	33,46 ^c

Note:

- 1) Purge loss includes mass loss during defrosting of frozen samples (F3A2, A3F2, F5)
- 2) Temperature conditions: A5 (control, without freezing), aging at minus 1.5°C, A3F2, aging at minus 1.5°C for 3 weeks, then freezing for 2 weeks at minus 18°C; F5 (frozen and thawed) freezing at minus 18°C for 5 weeks; F3A2, freezing at minus 18°C for 3 weeks, then aging for 2 weeks at minus 1.5°C

Table 2: Physico-chemical parameters of 4 goat muscles

Water-holding capacity, %	Types of muscles			
	M. longissimus dorsi	M. latissimus dorsi	M. semimembranosus	M. gluteobiceps
Drip loss	3,10 ^a	5,12 ^a	5,79 ^a	5,02 ^a
Purge loss	3,00 ^a	5,84 ^a	6,67 ^a	4,93 ^a
Cook loss	27,80 ^a	31,05 ^a	33,21 ^a	31,27 ^a

Note:

- 1) Purge loss includes loss in mass during defrosting of frozen samples (F3A2, A3F2, F5)
- 2) a-c Values with different letters inside the graph mean a significant difference between different types of muscles (p<0.05)

Table 3: Physico-chemical parameters at different temperature conditions

Water-holding capacity, %	Temperature regime			
	A5 (control)	A3F2	F5	F3A2
Drip loss	3,10 ^a	3,29 ^a	8,08 ^b	5,29 ^b
Purge loss	4,70 ^a	5,54 ^b	7,70 ^c	4,93 ^b
Cook loss	27,80 ^{ac}	31,05 ^b	28,14 ^b	32,92 ^b

Note:

- 1) Purge loss includes weight loss during defrosting of frozen samples (F3A2, A3F2, F5)
- 2) Temperature conditions: A5 (control, without freezing), aging at minus 1.5°C, A3F2, aging at minus 1.5°C for 3 weeks, then freezing for 2 weeks at minus 18°C; F5 (frozen and defrosted) freezing at minus 18°C for 5 weeks; F3A2, freezing at minus 18°C for 3 weeks, then aging for 2 weeks at minus 1.5°C

Drip loss: The drip loss showed significant differences (p<0.05) depending on the storage conditions (Table 1). Contraction rates with the inclusion of all storage groups for 4 types of muscles did not have significant differences (p<0.05) (Table 2). It is noteworthy that in comparison with other experimental

groups involving freezing (F5, F3A2), the lowest decrease was obtained during the aging mode followed by freezing-A3F2. The A3F2 group had no significant differences from the control group. However, the F3A2 group with pre-freezing showed a significant mass loss compared to the other groups (p>0.05) (Table 3).

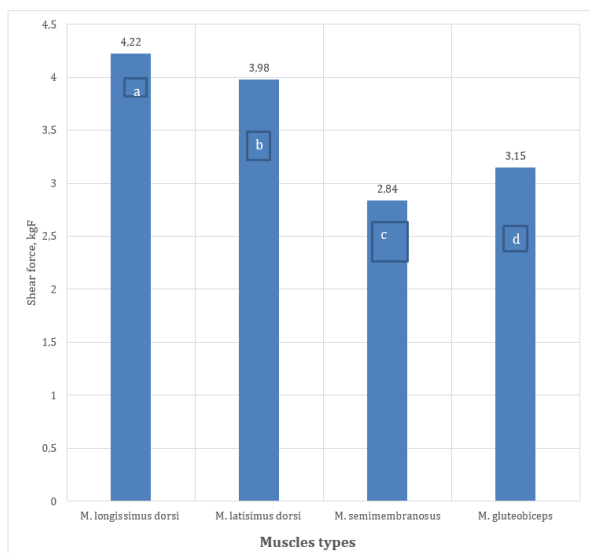


Fig. 2: The effect of different types of goat meat muscles on the performance of the shear force. SED = 0, 12

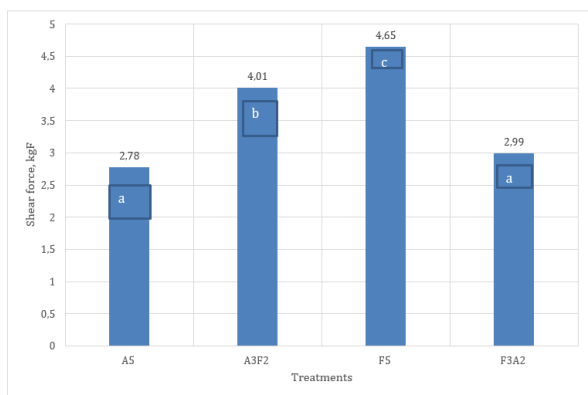


Fig. 3: The effect of different temperature regimes of aging and freezing/thawing on the shear force of goat meat muscles, SED = 0.12

Purge loss: Depending on the type of muscle, the values of purge loss did not have significant differences ($p < 0.05$) (Tables 1-2). F3A2 and A3F2 groups showed the lowest moisture loss among the experimental groups.

Cook loss: The type of muscles in the experimental groups did not significantly affect the values of cook loss (Table 2). However, on the contrary, the type of temperature regime caused significant differences in weight loss during heat treatment ($p > 0.05$).

The Warner-Bratzler shear force: All types of experimental muscle samples showed significant differences among themselves in terms of shear force (Fig. 2). M. longissimus dorsi had the highest index and M. Semimembranosus had the lowest index of shear force (Fig. 3).

All types of experimental muscle samples showed significant differences among themselves in terms of shear force (Fig. 2). M. longissimus dorsi had the highest index and M. Semimembranosus had the lowest index of the shear force.

According to the results of the study of the influence of temperature regimes of aging and freezing/thawing on the shear force of goat meat muscles-the highest tenderness was shown by group F5, then A3F2, F3A2, and A5 (Fig. 3).

Discussion

Water-holding capacity. According to the samples of the experimental groups F5, A3F2, and F3A2, which included freezing and thawing, an increase in moisture loss was observed compared to the control group F5. (Tables 1 and 3). There were no significant differences in the indicators of water-holding capacity by type of muscle (Table 2).

Drip loss: As the research results showed, among the experimental groups, the lowest drip loss was obtained during the aging mode followed by freezing-A3F2. Moreover, the experimental group A3F2 and F5 had no significant differences in drip loss (Table 3). This is confirmed by the results of Wiklund *et al.* (2009) in the absence of significant differences between samples of Mm. longissimus dorsi subjected to aging without freezing (-1.5°C , 4 weeks) and frozen samples (-18°C 5 weeks) with pre-aging at minus 1.5°C 4 weeks ($p > 0.05$). Also, these results are confirmed by studies by Farouk *et al.* (2012), where during aging and subsequent freezing of meat, moisture is blocked inside muscle tissues and, as a result, its loss during storage is less pronounced.

Purge loss: Minimal purge loss results were obtained for samples of experimental groups F3A2 and A3F2 (Table 3). These experimental results partially coincide with Kim and Kim (2017) data on a lower loss of moisture in bovine muscle samples Mm. gluteus medius and biceps femoris when frozen with subsequent aging when stored in similar temperature conditions compared to frozen samples.

Cook loss: The type of temperature regime had a significant effect on cook loss ($p > 0.05$) (Table 3). Our results differ from the results of Rahman *et al.* (2014) (cattle meat, freezing at -20°C for 80 days and subsequent storage at 40°C , 20°C , 15°C). Perhaps these differences are related to the difference in the type of raw materials under study, the type of animal, and in temperature conditions.

The shear force of the Warner-Bratzler. The experimental group F3A2 had no significant differences from the control group without freezing (A5) and had minimal tenderness among the experimental groups (Fig. 3). Kim and Kim (2017) explain such differences in the indicators of the shear force during aging with pre-

freezing by more significant destruction in the muscle tissues of meat compared with the reverse sequence of aging and freezing.

Conclusion

An analysis of the results of the study showed that various combinations of freeze/thaw and maturation had a significant effect on shrinkage and natural wastage, while muscle type did not cause significant changes in water-holding capacity. In particular, samples stored under freeze-and-age conditions (F3A2) showed high water holding capacity (natural shrinkage/defrost shrinkage) and low shear forces. However, the lowest values of weight loss during shrinkage were obtained for the A3F2 group. Notably, samples stored without maturation (F5) showed significantly higher rates of moisture loss during natural/thaw loss, weight loss on shrinkage, and high stiffness at the end of storage compared to control and samples combined with maturation and freeze/thaw.

In future studies, experimental studies in this direction are important to determine the optimal storage conditions for frozen meat without loss in quality.

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Author's Contributions

Urishbay Chomanov: Developed the idea, looked for suitable literature, and compiled the first version.

Gulmira Kenenbay and Alibek Tursynov: Wrote the manuscript and studied the relevant literature.

Torgyn Zhumalieva and Nurzhan Tultabayev:
Edited and reviewed the article.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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