JMBFS
Journal of Microbiology, Biotechnology and Food Sciences
International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

HORSE MEAT QUALITY: MATURATION ANALYSIS AND EVALUATION IN THE PRODUCTION PROCESS

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https://doi.org/10.55251/jmbfs.13067

ARTICLE INFO

Received 16. 7. 2025
Revised 17. 11. 2025
Accepted 25. 2. 2026
Published 1. 4. 2026

Regular article

OPEN ACCESS

ABSTRACT

Meat maturation is a set of biochemical and biophysical processes that affect the muscle structure, surface color, and taste of a product. The purpose of this study was to compare the qualitative characteristics of horse meat that has undergone dry and wet maturation. The work used *Longissimus Dorsi* muscle samples obtained from a lumbosacral cut with maturation duration of 14 and 21 days. The analysis of losses during stripping, cutting force, chemical composition and microbiological parameters was carried out. It was found that losses during dry maturation are higher, especially at 21 days. However, as the duration increases, the energy value of the product increases. The difference in cutting force between the methods is insignificant, but the overall decrease in effort on day 21 indicates an increase in the tenderness of the meat. The chemical composition varies depending on the method, and the products of dry maturation are characterized by a higher energy value and digestibility of proteins. Microbiological parameters comply with regulatory requirements, which indicates the safety of the finished product.

Keywords: meat, horse, dry maturation, wet maturation, chemical composition

INTRODUCTION

Meat and meat products really play an important role in human nutrition, providing many essential substances that support health. In particular, they are the main sources of complete protein, which consists of all the essential amino acids necessary for the normal functioning of the body. High-quality protein nutrition from meat promotes the growth and repair of tissues, supports the immune system and hormonal regulation (**Leroy *et al.*, 2023)**
Meat maturation is a set of biochemical and biophysical processes that change the structural integrity of muscles, the color of the meat surface and taste qualities. Increasing the maturation time has a positive effect on the tenderness and juiciness of meat; moreover, on the development of various compounds that improve taste and aroma. The use of vacuum packaging for meat maturation increases both the quality and shelf life of meat **(Khazzar *et al.*, 2023)**.
The quality standards of meat products are related to several physical, thermal, mechanical, and sensory properties determined by producers and consumers. Thermal properties consist in determining and understanding the temperature distribution inside meat during heat treatment. Meat undergoes various thermal processes before it reaches the consumer. During cooking, both muscle fibers and connective tissues of meat contract, destroying cell membranes. Moreover, proteins play an important role in changing the characteristics of cooked meat, which affects the tenderness and overall acceptability of cooked meat (**Alfaifi *et al.*, 2023**).
Since the information available in the literature on horse meat of various maturation methods is fragmentary, we conducted studies of the qualitative indicators of horse meat of dry and wet maturation lasting 14 and 21 days. The aim of the study was to compare the qualitative indicators of dry and wet matured horse meat.

MATERIAL AND METHODS

Object of the Study

Four samples (n = 4) of dry and wet matured horsemeat, aged for 14 and 21 days, obtained from the *Longissimus dorsi* of the lumbosacral region of horse carcasses, were used as the object of the study..

Dry Maturation Conditions

The Samaref dry-aging dry maturation cabinet (SAMAREFDE 700 RFPVBK, Samaref, Italy) was used for the dry maturation of horse meat. At a temperature of 1 °C, relative humidity of 60-75% and an air flow of 0.5-2.5 m/s. To absorb excess moisture and sterilize the air, Himalayan salt was placed in the dry maturation cabinet (**Mukhamedov *et al.*, 2024**).

Wet Maturation Conditions

For wet maturation of horse meat, vacuum bags of the polyamide type with polyethylene (PA/PE), 120 microns thick, packed in a Turbovac apparatus (Turbovac ST-320, Turbovac, the Netherlands) were used. Next, wet-matured horse meat in vacuum bags was placed in a Polair refrigerated product chamber (Polair CC214-S, Polair, Russia), maintaining a temperature of 1 °C, relative humidity of no more than 90%, and an air flow of 0.2-7.0 m/s (**Mukhamedov *et al.*, 2024**).

Heat Treatment Procedure

In the study of dry and wet matured horse meat brought to culinary readiness, a method of heat treatment, such as frying, was used. The heat treatment is carried out as follows:
- heat a grill pan or a frying pan with a thick bottom to a temperature of 280 °C. For better roasting, the horse meat must be soaked with paper kitchen towels, then oiled on both sides and lightly grated with coarse sea salt. Place in a hot frying pan and fry for 1-1.5 minutes on one side, then flip to the other side so that the crust retains the juices inside. After 1-1.5 minutes, turn the horse meat over again to get the characteristic stripes from the grill, then turn down the heat to a minimum to avoid burning, and fry for another 3 minutes. Turning the horse meat over, fry for another 3 minutes and remove from the pan, put it on the dishes, let it rest for about a minute. During the laying of horse meat, salt was added. The degree of roasting of Medium horse meat is determined by the Kitfort thermometer (KT-2066, Kitfort, Russia).

Analytical Methods

The following methods were used in the study:

- mass loss - was determined by the direct method: weighing samples and calculating the amount of loss relative to the initial mass, %;
- the mass fraction of protein was determined according to GOST 33319-2015;
- the mass fraction of moisture was determined according to GOST 25011-2017;
- the mass fraction of fat was determined according to GOST 23042-2015;
The energy value was determined by the calculation method;
- the conformity of horse meat products intended for direct consumption was determined according to GOST 34159 – 2017;
- the digestibility of proteins by digestive enzymes in in vitro experiments. The method consists in the sequential action of a proteinase system consisting of pepsin and trypsin on the protein substances of the test object, while continuously removing hydrolysis products from the reaction zone by dialysis. The amount of low molecular weight hydrolysis products was determined by tyrosine;

Microbiological indicators:

- microbiological parameters were determined by the number of aerobic and facultative anaerobic microorganisms (TAMC) according to GOST 10444.15-94, pathogenic microorganisms of the genus Salmonella according to GOST 31659-2012 and L. Monocytogenes according to GOST 32031-2022, bacteria of the *E. Coli* group (*Escherichia Coli*) according to GOST 31747-2012;

Hygiene and safety criteria:

- hygienic indicators of horse meat products were established in accordance with the Technical Regulations of the Customs Union TR CU 021/2013 "On food safety", TR CU 034/2013 "On the safety of meat and meat products".

Statistical Processing

Mathematical processing of the results of studies performed with 3-5-fold repetition, as well as the calculation of correlation dependencies, was carried out using the generally accepted parametric method Student's t-criterion using the program "*Statistica 10.0*" (Stat Soft Inc., 2010).

RESULTS AND DISCUSSION

The duration of maturation is associated with weight losses that occur: during the maturation process, during stripping of the surface hardened layer (or "crust"), during the release of meat juice in vacuum packaging and during the heat treatment of horse meat. The data is presented in tables 1-3.

Table 1 Weight loss of horse meat during maturation

The maturation method	Duration of maturation, day							
	14				21			
	Quantity				Quantity			
	g		%		g		%	
Dry	994	943	50.7	5.1	994	911.5	82.5	8.3
Wet	994	980	14	1.4	994	923.4	70.6	7.1

Table 1 shows that the value of horse meat weight loss during dry maturation averaged 6.7%. Losses of wet-matured horse meat averaged 4.25%, which were formed due to the release of meat juice in a vacuum package (**Zhang *et al*. 2022**, **Di Paolo M *et al.* 2023**).

Table 2 Weight loss of horse meat maturation during stripping

The maturation method	Duration of maturation, day							
	14				21			
	Quantity				Quantity			
	g			%	g			%
Dry	943	821.4	121.6	12.9	911.5	748.3	163.2	17.9
Wet	980	-	-	-	923.4	-	-	-

According to the data obtained in Table 2, the value of horse meat weight loss during stripping lasting 14 and 21 days of dry maturation averaged 15.4%. According to the results of a number of studies, it follows that with prolonged maturation of dry-matured meat, weight loss increases during stripping of the surface crust **(Dragoev *et al*., 2018, Kim S *et al.,* 2022)**. In wet-matured horse meat, there is no loss of mass during stripping.

For a comparative assessment of the ripening losses of horse meat during heat treatment, samples weighing from 205 g to 207 g were isolated, isolated after stripping for 14 and 21 days, and subjected to frying. The results of the determination are shown in Table 3.

Table 3 Weight loss of maturation of horse meat subjected to heat treatment by frying

The maturation method	Duration of maturation, day	Weight, g		% losses
		Before heat treatment	After heat treatment	
Dry	14	207	171.60	17.09
Wet		207	166.7	19.47
Dry	21	205	173.84	15.20
Wet		205	169.86	17.14

Table 3 shows the results of determining losses, according to which, when dry–matured horse meat is fried for 14 and 21 days, losses average 16.15%, while wet-matured horse meat with a similar duration is 18.31%. The difference between the duration and the method of maturation during frying averages 2.38% and 1.95%.
The obtained data on the maturation of horse meat are consistent with studies on the determination of total moisture and water-binding capacity and confirm that as a result of evaporation of free moisture and an increase in the bond strength of the remaining moisture, heat treatment losses are significantly reduced **(Juárez *et al.,* 2011, Chaosap *et al.,* 2025)**. According to the wet maturation of horse meat, the data are consistent with the study **(Beldarrain *et al.* 2021)**. It follows from Table 3 that the weight loss during heat treatment of ripe horse meat ranges from 15.09% to 19.47%. The results obtained are consistent with the studies **(Berger *et al.,* 2018, Kim J *et al.,* 2018, Setyabrata *et al.,* 2021, Sujiwo *et al.*, 2024, Forte et *al.*, 2024)** and depend on the degree of roasting (internal temperature) of the meat.

The value of losses from stripping dry-matured horse meat intended for processing and sale turns out to be large, compared with losses during maturation. Horse meat is characterized by the greatest weight loss during heat treatment, which exceeds this indicator in beef by almost 8.6%. Overall, losses can reach almost 65%. These losses are typical for dry-aged meat, mainly because it is an unpackaged product, which leads to evaporation of water in the aging chamber **(Dashdorj *et al.,* 2016, Cavani *et al.,* 2024)**. In addition, differences in temperature, humidity, and air velocity, as well as the type of cut and the characteristics of the meat, have a significant impact on losses **(Rezende-de-Souza *et al.,* 2021, Stanisławczyk *et al.,* 2023).**
To establish the dynamics of softening of roast horse meat during maturation, the cutting force was investigated. The data is presented in table 4.

Table 4 Changes in the strength properties of finished horsemeat products during maturation

Indicator	Duration of maturation, day			
	14		21	
	The maturation method			
	Dry	Wet	Dry	Wet
Cutting force n/m^2	4.1±0.01	4±0.02	3.5±0.03	3.4±0.05

The data obtained in Table 4 showed that after heat treatment - frying, the value of the cutting force of dry and wet matured horsemeat lasting 14 and 21 days' decreases. The greatest hardness of horse meat occurs on the 14th day of maturation and less hardness of horse meat on the 21st day of maturation during frying. The difference between the methods and the duration of horse meat maturation was 0.1 N/m^2 and 0.6 N/m^2 **(Lee *et al.,* 2023, Stanisławczyk *et al.,* 2025)**.

There was no significant difference between the method and the duration of maturation in the complex value of the horsemeat cutting force.
The chemical composition and energy value of the finished dry-matured horsemeat products after heat treatment are shown in Table 5.

Table 5 Nutritional value of finished horse meat products during maturation, %

Indicator	Duration of maturation, day			
	14		21	
	The maturation method			
	Dry	Wet	Dry	Wet
Mass fraction of moisture	61.85	63.14	59.97	61.79
Mass fraction of protein	27.03	21.11	27.96	21.39
Mass fraction of fat	1.97	2.02	1.67	2.17
Energy value, kcal/100 g	125.85	102.62	126.87	105.09

After heat treatment of frying, the mass fraction of moisture in the finished product of dry-matured horse meat lasting 14 and 21 days decreased by 2.3%, wet-matured horse meat by 1.35%, respectively. The mass fraction of protein in the finished horsemeat product lasting 14 and 21 days increased on average: with dry maturation 0.93%, with wet maturation 0.28%. The mass fraction of fat in the finished horsemeat product in similar heat treatment methods and duration was: 0.3% with dry maturation, 0.15% with wet maturation. The energy value of the finished product from dry-matured horsemeat for 14 and 21 days is higher than that of wet-matured horsemeat, respectively (Table 5) **(Pereira *et al.*, 2021, Stanisławczyk *et al.*, 2023).**

These data indicate that with increasing duration, maturation increases the energy value of the finished horsemeat product.

One of the indicators of the quality of finished products is the in vitro digestibility of proteins (Table 6).

Table 6 Protein digestibility of finished horse meat products during maturation

The maturation method	Duration of maturation, day	Digestibility, mg tyrosine/g protein		
		pepsin	trypsin	in total
Dry	14	6.1	6.4	12.5
Wet		5.9	6.2	12.1
Dry	21	8.1	8.7	16.8
Wet		8.0	8.5	16.5

According to the data obtained in Table 6, the digestibility of dry-matured horse meat lasting 14 and 21 days is higher by 0.4 mg tyrosine/g protein and 0.3 mg tyrosine/g protein than wet-matured horse meat, respectively **(Rahman *et al.*, 2017)**.

To determine the qualitative indicators, the dynamics of the composition of the microflora of finished horsemeat products during maturation lasting 14 and 21 days was studied, according to the number of mesophilic aerobic and facultative anaerobic microorganisms (TAMC) (Table 7).

Table 7 Changes in the microflora of finished horse meat products during maturation

Indicator	Standard	Duration of maturation, day			
		14		21	
		The maturation method			
		Dry	Wet	Dry	Wet
***TAMC*, CFU/g, no more than**	1×10^3	1×10^2	3×10^2	2×10^2	4×10^2
***Salmonella*, in 25 g**	n/a	n/d	n/d	n/d	n/d
***Listeria monocytogenes*, in 25 g**	n/a	n/d	n/d	n/d	n/d
***BGKP* (*coliforms*), in 1 g**	n/a	n/d	n/d	n/d	n/d

Notes: KMAFAnM — total mesophilic aerobic and facultative anaerobic microorganisms; **BGKP (coliforms)** — bacteria of the coliform group; **n/d** — not detected; **n/o** — not observed / not determined.

According to the data obtained in Table 7, the microbiological indicators correspond to the regulatory ones, which indicates the safety of finished horse meat products during maturation **(Gonzalez-Fandos *et al.*, 2024)**.

CONCLUSION

As a result of the obtained data on the application of the method of dry and wet maturation of horse meat at a duration of 14 and 21 days, the following conclusions can be drawn. The total loss of dry-matured horsemeat is greater with an increase in duration up to 21 days than wet-matured horsemeat of a similar duration. The cutting force of finished horse meat products of dry and wet maturation decreases with an increase in duration up to 21 days, thereby becoming more tender. The chemical composition varies depending on the method and duration of maturation, and the energy value of finished products from dry-matured horsemeat is higher than that of wet-matured horsemeat. The digestibility of proteins of finished products from dry-matured horsemeat is greater than that of wet-matured horsemeat. The microbiological parameters of the finished horse meat products during maturation comply with the regulatory requirements, which indicates the safety of the products. Based on the conducted experiment, it has been established that the method and duration of meat maturation significantly affect the quality of horse meat. Despite higher mass losses during dry-aging, this method ensures greater energy value and better protein digestibility. The obtained data confirm the microbiological safety of the product. To optimize the production process, it is recommended to consider the balance between mass loss and the nutritional value of the final product. A promising direction for further research is the study of combined maturation methods and the evaluation of organoleptic properties to enhance consumer appeal of the finished product.

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