Factors affecting meat quality in farm animals

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Abstract. Meat has been one of the most basic nutrients since the first day of humanity. As food, meat is expressed as the muscle and fat found between the bones and skin of animals. It has an important place in human nutrition due to the protein (amino acids), fatty acids, minerals (iron and zinc) and vitamins (especially B12) it contains. Thanks to these nutrients, vital activities such as growth and development of individuals, regeneration of cells, repair and growth of tissues, formation of vital fluid blood, functioning of body systems, development of immunity and reproduction are ensured. As with other animal products, there are factors such as species, breed, feeding, environmental temperature, stress or processing that affect meat yield and quality in farm animals. In the current study, similar biotic and abiotic factors affecting the meat quality of farm animals are discussed.

1 Introduction

Meat, which contains nutrients in high quantity and quality, has an important place in people's nutrition. It is generally named according to the type of animal it is obtained from (beef, lamb, goat meat, etc.). Depending on the species, the protein (amino acids), vitamins, minerals and fatty acids it contains vary. These nutrients are essential for the development and growth of tissues and organs, the functioning of vital systems, reproductive activities, and the development of immunity. In addition, it is a good dietary product as it spends more time in the digestive system due to its high protein content and provides satiety for a long time. For a healthy life, it is recommended to consume approximately 1 g/day of protein per 1 kg of body weight [1] and half of this amount should be obtained from animal proteins [2].

Insufficient meat consumption causes a decline in muscle and skeletal development, especially in children, due to protein and mineral deficiency. In cases where meat consumption, which is also a good source of iron, is insufficient, anemia occurs, as zinc intake decreases, reproductive and immune problems and problems in cognitive development occur. On the other hand, it is stated that when consumed in excess, it causes cardiovascular diseases, metabolic problems and some types of cancer [3]. Similar to the increase in human population, meat production (Table 1) and consumption (Table 2) values in the world also change.

Table 1. Meat production values in the world (million tonnes) [4].

Country	2000	2005	2010	2015	2020	2021
China	62.0	71.2	80.9	88.7	80.2	92.6
USA	37.6	39.7	41.9	43.3	48.7	48.9
Brasil	15.4	19.7	23.6	26.6	28.9	29.5
Russia	4.5	4.9	7.2	9.6	11.2	11.4
Germany	6.2	6.8	8.2	8.3	7.8	7.6
India	4.9	6.3	8.2	10.3	11.2	10.9
Mexico	4.4	5.3	5.8	6.3	7.5	7.7
World	233	261	296	329	343	357

Table 2. Meat consumption values in the world in 2022 (kg/per capita) [5].

Countries	2002	2009	2017	2020
China	52.40	58.20	61.70	60.60
USA	124.80	120.20	121.00	124.11
Brasil	82.40	85.30	99.36	77.32
Russia	51.00	69.20	85.95	87.81
Germany	82.10	88.10	80.50	87.79
India	5.20	4.40	3.97	3.78
Mexico	58.60	63.80	67.54	64.88

There is a linear relationship between the level of development and meat consumption worldwide. However, even though high amounts of meat are produced in countries such as China and India, per capita meat consumption remains behind the world average due to the overcrowding of the population.

1.1 Meat quality

The quality of meat, which has an important place in people's healthy nutrition, is as important as its production. Although sensory, nutritional and hygienic

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properties are the basic elements used to determine the quality of meat, they may vary from person to person or from society to society. In terms of nutritional properties, amino acids and vitamins such as B12, which are not found in other foods or are present at lower levels, play a leading role in the quality of meat. From this perspective, red meat stands one step ahead of other meats. On the other hand, the nutritional values of meat; It varies depending on species, age, gender, genetics, feeding and other environmental factors. The table below shows the nutritional compositions of meat from different species (Table 4).

Table 3. Meat Nutritional Composition of Some Species [6]

	Chicken	Beef	Pork	Turkey (skinless)	Duck (skinless)
Energy (kcal)	113	123	353	136	130
Protein (g)	22.8	21	18.1	19.9	19.4
Fat (g)	1.9	4.5	31.7	7.1	6.6
Saturated Fat (g)	0.6	1.9	10.8	1.8	1.8
Vit. B12 (mcg)	0.7	1.9	1	1.9	2.8
Na (mg)	78	59	60	42	90
Zn (mg)	1.4	1.7	1.8	1.5	1.8
P (mg)	202	167	190	209	201
Fe (mg)	0.7	1.3	1.4	2.1	2.5

The parameters examined in meat quality can be examined under 3 main headings: physical or structural, chemical and sensory. Texture is one of the primary physical properties of meat. Textural components can be listed as hardness, chewability, elasticity, stickiness, gumminess and resilience. In meat, cut resistance and cooking loss are other quality parameters that consumers pay attention to. Chemical quality parameters consist mostly of nutritional elements. These include pH, moisture or dry matter, protein (amino acid), fats (fatty acids), vitamins and minerals. These parameters determine the flavor of the meat as well as its nutritional value, especially depending on its fatty acid composition. The most taken into consideration quality parameters in meat are sensory properties. Elements such as color, smell and taste, perceived by the eyes, nose and tongue, can be easily detected by consumers and help them to have an idea about meat.

1.2 Factors effecting meat quality

Some factors play a role in obtaining meat of a quality that meets the consumer's wishes. These; It can be examined under two main headings: before slaughter (ante-mortem) and after slaughter (post-mortem). Ante-mortem factors may be animal dependent or independent of the animal. Species and breed, gender, age, feeding, season, location of the muscle, pre-slaughter conditions and stress experienced by the animal are among the ante-mortem factors. On the other hand, meat processing and preservation conditions, storage time, cooking time and applied temperature are some of the factors that affect post-mortem meat quality.

1.2.1 Ante-mortem factors

Species and breed: Genetic factors that vary depending on species and breed are among the factors affecting meat quality. Fat synthesis and storage in the body and synthesis of muscle fibers can change the taste, appearance, smell and texture of meat. The type of fat stored in the body (phospholipids, cholesterol, triglycerides) and the fat-muscle ratio affect the sensory and physical properties of meat. While fat deposits in poultry are concentrated around the abdomen or wings, in sheep, it occurs around the tail or under the skin, depending on the breed. In Wagyu cattle, the fatty deposits progress into the muscle and become marbled, whereas in the Angus breed, it occurs mostly in the form of bark fat under the skin.

Gender: The hormonal mechanism of different genders also differs. Testosterone hormone secreted from the testicles in men improves protein synthesis, insulin sensitivity and lipid profile in muscles [7]. On the other hand, it is stated that estrogen, the female hormone, has a negative effect on muscle building and stimulates more fat gain [8; 9]. Due to the influence of hormones, the meat of male animals, which have a more muscular structure, is considered more texturally acceptable than that of females. It has also been stated by previous researchers that meat quality and fatty acid composition vary depending on gender [10; 11th].

Age: It is known that the nutrients in meat affect its quality. Essentially, moisture, protein, fat and other components can change both structural and sensory properties. In young animals, the majority of the body consists of water, but with age, this accumulation changes in favor of protein and then fat. As the animal ages, the increase in heat-resistant collagen fibers causes a decrease in the tenderness of the meat [12]. Consumers generally prefer meat with a brighter red color, and this is related to the amount of myoglobin. Higher myoglobin synthesis and amount in young animals also positively affects the color of the meat [13].

Nutrition: Growth in livestock occurs mainly through the proliferation and growth of muscle cells. Protein is needed for the formation of these cells. Carcass mass is also affected by the ration energy level. It is stated that cattle fed with high-energy rations have higher carcass weights than those fed with low-energy rations [14]. While the dietary energy level increases intermuscular fat, it reduces the amount of heat-resistant connective tissue. This also improves the juiciness, tenderness and aroma characteristics of the meat. Low energy/protein levels in poultry reduce fatness, and rations containing low protein and fat reduce the water content of meat. On the other hand, it has been reported that carcass fatness increases with the use of grass silage in cattle fattening [15], but fatness is less in animals fed with silage at the beginning

of the fattening and silage and concentrated feed on the 135th day [16; 17]. It has also been reported that intensively fattened lambs contain high amounts of stearic acid and PUFA in their intramuscular fat, while semi-intensive fattened lambs have a more favorable fatty acid composition [17]. It is easier to intervene in the meat quality of poultry or monogastric animals by making changes in their rations than in ruminants. Microbial activities occurring in the rumen have the ability to transform nutrients in feed into different forms. Especially unsaturated fatty acids are most affected by this situation. Unsaturated fatty acids used in feed can be found in greater or lesser amounts in poultry meat. However, since the unsaturated fatty acids used in ruminant diets are saturated by biohydrogenation by rumen microorganisms, they are present in red meat as conjugated linoleic acid. Apart from the basic nutritional components, aromatic substances in the ration also change the sensory properties of meat. It is known that herbs with strong aromas such as thyme and rosemary improve the taste and smell of meat.

Season: Animals' energy needs increase in cold weather. Animals use this energy both to produce heat by keeping the metabolism dynamic and to insulate the excess energy by accumulating fat under the skin. Therefore, the meat of animals fed during the winter months is more fatty. The fatty acid composition and color of the meat of animals fed with fresh grass in spring and summer, when vegetation is abundant, also vary. It has been stated that broilers have darker, redder and yellower breast meat in winter compared to autumn [18]. In a similar study, 4th hour pH, a* and b* were found to be higher in winter than in autumn and summer [19]. The energy metabolism of animals is more active during the winter months, and the lactic acid released as a result lowers the pH of the meat, affecting the color and texture. In addition, the meat of animals that are stressed due to extreme temperatures in the summer months is also negatively affected by this situation.

Location of the muscle: As it is known, meat consumed as human food consists of muscles that provide animals with the ability to move. Therefore, overworked muscles in the body will become harder as they contract more. The forearms and hind legs of small and large animals, and the legs of poultry, have a harder structure than other parts because they work harder. However, M. longissimus dorsi, which is the least active muscle on the back in mammals, has the softest structure.

Conditions before slaughter: Slaughtering is a source of stress in itself. The time taken to transfer animals to the slaughterhouse, slaughterhouse conditions, waiting time for slaughter, waiting under the sun, hunger-thirst, fatigue and violence cause stress to animals. In case of stress; The secretion of hormones such as epinephrine, norepinephrine and cortisol increases. Accordingly, glucose in the blood and glycogen in the liver and muscles are rapidly consumed and lactic acid is produced. Under normal conditions, lactic acid released by anaerobic respiration of muscles is re-metabolized in the liver and heart. However, when animals are slaughtered in this state, acidic (pH 5.4-5.6) meat is obtained because lactic acid cannot be metabolized. These meats have a pale, sweaty appearance, with defects in color, water retention capacity and crispness [20].

1.2.2 Post-mortem factors

Temperature: Chemical events occurring in meat after slaughter occur faster with temperature. Enzymes that affect the chemical structure of meat are sensitive to temperature, and rapid cooling of the carcass will slow down the activity of these enzymes. In addition, since this process will limit the activities of microorganisms, it will also reduce nutrient loss and color change [21]. It has been determined that the cut resistance of aged meats at a temperature of 10-15 °C decreases compared to those at lower temperatures, but the microbial load increases with cooking loss and the color stability decreases [22].

Storage: It is important for human health to keep carcasses intact for a long time. It is generally stored at 4 °C. However, rapidly lowering the carcass temperature to this degree after slaughter damages the structure of the meat. Sarcomeres shorten in length due to the nerve's response to rapid cooling. These meats are hard, taste bad and have high water loss. A recent study showed that storage at 2 °C gave better results for both chicken breast and sirloin [23].

Processing: The processes applied to meat prepared to be presented to the consumer can affect the properties of the meat. While physical electrical stimulation, dry aging, dry curing, high pressure processing processes are applied; Techniques such as chemical fermentation, smoking, curing and marination are used. Electrical stimulation applied to meat improves crispness, meat color, taste and smell; It makes marbleization more visible, shortens the ripening period and extends the shelf life [24]. Events such as protein denaturation, hydrolysis or gelation that occur as a result of other processes affect the acceptance of meat by the consumer. Dry aging provides intensification of aroma, tenderness and juiciness in beef and umami taste in pork. While dry curing worsens the digestibility of pork; It causes tough, wrinkled, dark brown meat. High pressure processing improves the digestibility and texture of meat without losing nutrients, but it causes darkening in lamb meat. Alcohol, ketones and aldehydes formed by fermenting meat provide specific aroma. As a result of smoking, color, aroma and odor properties are improved, discoloration is prevented and amino acid digestion is improved. While curing and salting improves the texture profile, marination increases juiciness and tenderness [25].

Cooking time: Cooking process is applied to improve the safety and taste of meat as food. Although high-temperature cooking has been practiced for a long time, it deteriorates its nutritional and organoleptic properties; It causes loss of water, vitamins and fats. Its effect on proteins varies. It is stated that the digestibility of meats cooked at very high temperatures becomes difficult due to the formation of intra- and inter-molecular covalent bonds [25]. In addition, cysteine and tryptophan are destroyed during grilling, frying and roasting, deteriorating nutritional values.

2 Conclusion

Meat is an important nutrient in people's balanced and healthy diet. There are many factors that affect the nutritional composition, digestibility or other quality parameters of meat. These can be biotic or abiotic, and they can also form before or after slaughter. Since meat quality varies in line with consumer demands; It may vary depending on the person, region or country. Considering the acceptance status of the produced meat in the market, production within the information mentioned above will make its marketability even easier.

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