Table S1: Summary of the papers related to the influence of intrinsic factors on meat color.

Main Topic	Implications	Publication
Ultimate pH	Higher ultimate pH in meat is related to lower glucidic potential and lactate amounts, which can be affected by inadequate pre-mortem management of the animals	[44]
	Ultimate pH in meat is the most important discriminant in determining the final color of meat	[2]
	Higher ultimate pH in DFD meat was negatively related to glycolytic potential, color values, and oxymyoglobin concentration in meat, and positively related to deoxymyoglobin concentration and water-holding capacity	[24]
	Intermediate pH beef was associated with higher phosphorylation rates of myofibrillar proteins that could inhibit post-mortem proteolysis	[30]
	Higher mitochondrial content and higher mitochondrial activity in DFD beef could influence oxygen consumption and myoglobin oxygenation	[13]
	DFD severity degree showed a negative relationship with the glycolytic potential and lactate formation in post-mortem muscle and resulted in lower CIELab values in meat	[25]
	DFD meat had overall lower light reflectance, higher light absorbance, higher MRA, and lower lipid oxidation than normal-pH meat	[27]
	DFD meat had a wider lateral spacing of myofilaments and a lack of gaps between muscle fibers, which created less light scattering from the meat muscle	[28]
	Infrared temperature determination showed inconsistent results in predicting ultimate pH values and color in beef muscle	[34]
Age of the animals	Increased myoglobin amounts in tissues of older animals resulted in higher a* values	[40]
	Older animals produced higher iron contents in meat than younger animals, due to a more oxidative metabolism	[27]
	The lower growth rate in pasture-fed steers produced older animals with more oxidative muscles, which were responsible for altering the color of meat	[63]
	Increasing the slaughter age in cattle produced higher amounts of slow oxidative muscle fibers and less fast glycolytic fibers, which resulted in lower meat color values	[36]

	Increasing the slaughter age (three months on average) produced meat with lower L* and higher a* and b* values, due to higher pH in the meat of old animals	[39]
	Steers slaughtered at 30 months of age produced higher pH and a*, but lower L* values than steers harvested at 18 months of age	[42]
	Increasing the slaughter age in German Simmental cattle produced higher L* and had variable effects on a* values	[41]
	Increasing the slaughter age in cattle produced higher catalase, superoxide dismutase, and glutathione peroxidase activity, which was not enough for preventing oxidation processes in muscle	[35]
Muscle position	Improved LDH-B activity, MRA, and higher NADH concentrations in LL muscles were responsible for better color than in SM or PM	[15]
	Improved MRA and LDH activity in LL resulted in higher amounts of sarcoplasmic NADH in LL than in PM	[47]
	Ovine color-labile muscles had higher iron content and took less time for them to reach the threshold point below a*< 3.5, which determined consumer's rejection	[48]
	A higher abundance of glycolytic enzymes such as triosephosphate isomerase, ß-enolase, and creatine kinase in the OSM explained its improved color compared to ISM	[52]
	Higher GAPDH activity in ovine LL was responsible for NADH production, which could have been further used for metmyoglobin reduction, enhancing muscle color	[14]
	Smaller cytochrome c content found in the sarcoplasm of LL, due to lower mitochondrial damage by reactive oxygen species (ROS) suggested better color behavior than PM	[8]
	LL muscle was categorized as color stable due to lower oxygen consumption rates, higher myoglobin-reducing activity, and higher mitochondrial respiration ratio than PM	[9]
	LL muscle showed higher MRA and predominantly white fibers than PM	[51]
	LL exhibited higher color values, less lipid and protein oxidation, and higher MRA than PM in Bos indicus cattle	[45]

	Color-stable muscles showed lower oxygen consumption rates, myoglobin content and oxidative rancidity than muscles with lower color stability	[41]
	Higher mitochondrial-mediated metmyoglobin reduction was associated with improved color values in LL than in PM	[10]
	LL showed higher concentration of antioxidant proteins, which had an important role in preventing both lipid and myoglobin oxidation, compared to PM	[46]
Breed	Brahman cattle showed higher temperament variations than Angus cattle, which affected ADG values and resulted in lower muscle colors	[2]
	Lower L*, a* and b* values were obtained in Holstein Friesian meat compared to the criollo Caracu breed or Nellore cattle	[56]
	Braford cattle showed more excitable behavior than pure Hereford cattle, but no associations were observed with meat color	[55]
	Crossbreeding resulted in lower meat L*, a* and b* values than the pure breeds when animals were pasture-finished	[57]
	Nellore x Aberdeen Angus animals exhibited lower color values and higher pH values in meat when compared with pure Nellore cattle	[58]
	Aggressive behavior from native African Bos indicus cattle breeds, especially from Red Bororo cattle was correlated with higher injury frequency	[60]
	More bruises in crossbreed cattle were associated with higher pH values and lower meat color values	[61]
	Predominant Brahman animals and their crosses showed that 37% of the cattle had bruises on the carcass, due to nervous temperament and longer lairage times	[62]
Slaughter weight	Heavier carcasses from Charolais cattle, kept under similar experimental conditions showed higher a*, b* and C* values and lower L*; which suggested that genetics alone do not always produce carcasses with higher color readings	[20]
	Heavier carcasses showed faster pH decline and slower temperature decline, which passed through the hot-rigor temperature window (pH=6 at temperature >35°C)	[64]
	Significant lower L* values were recorded from bull's rather than from young bull's	[60]

	meat, even if bulls were 90 kilograms heavier than young bulls	
	Continuous growth of animals during the finishing phase produced heavier carcasses, which also resulted in higher L* and a* values	[37]
	Ad libitum concentrate offered to the animals from the start of the finishing phase produced heavier animals in less time than when concentrates were offered *ad libitum* in the middle of the finishing phase	[112]
Sex	Improved color scores were found in steers slaughtered in different seasons across one year, but no difference was observed between cows and bulls	[72]
	Animal gender status influenced meat color, which was related to different marbling and fat deposition values in LL of heifers and castrated cattle	[68]
	Bulls' meat had higher L* and a* values than heifers, despite of higher intramuscular fat amounts found in heifers	[38]
	Higher incidence of DFD meat in males than in females; however, when backfat carcass classification scores were low, female had higher incidence of DFD than male cattle	[67]
	The likelihood of obtaining DFD meat was higher for heifers than for steers. However, heifers that received MGA were less prone to problems related to DFD meat	[65]
	Bulls were more sensitive to stress parameters and showed faster glycogen depletion than heifers	[69]
	Steers showed a 47% higher incidence to have DFD-related problems in meat than heifers after animals traveled 36 hours to the abattoir	[70]
	Heifers showed more excitable behavior than steers; however, temperament was not related to meat color	[71]
	DFD beef had a higher metabolic activity that might result in higher MRA and lower color values	[29]
	HNE generation decreases both electron-transport-mediated MRA and NADH-dependent metmyoglobin reductase activity	[81]
	Lipid oxidation was related to pigment oxidation and to the generation of off-odors and off-flavors in meat	[73]
	Fresh meat's color and pH of were not influenced by α-tocopherol amounts	[91]

	Pasture-based animals had higher n-3 PUFA concentrations, which can increase the susceptibility to lipid oxidation processes	[75]
	α-tocopherol concentrations were effective in reducing the lipid oxidation values in beef muscle, which was higher for animals finished in grass-based diets	[76]
	There was a diet-related effect in vitamin E concentrations in the meat of grass-fed cattle, which resulted in higher protection against lipid oxidation	[43]
	Higher deposition of natural antioxidants in the meat of silage-based animals was a result of three-fold higher α- tocopherol concentration in grass-silage than in normal grass	[80]
	Vitamin C addition in minced meat reduced lipid oxidation processes in the meat from grain-fed cattle, but not in grass-fed animals	[74]

Table S2: Summary of the papers related to the influence of extrinsic factors on meat color.

Main Topic	Main Ideas	Publication
Slaughtering season	Prolonged showering time (2 hours, water temperature 10-15°C) during winter increased animal pre-mortem stress and resulted in lower color values in meat	[103]
	Cattle had lower L*, a*, and b* values and higher pH during the summer months than in any other season	[104]
	Significantly lower L*, a*, and b* values were recorded in meat during the hot season than those from the cool season	[105]
Production systems and feeding	Changing the management system in the animals after weaning for 145 days produced meat with lower L* and higher a* for the intensive system, possibly due to higher pH and higher myoglobin content in their meat	[77]
	At similar carcass weight, concentrate-fed cattle showed higher L* and similar a* and pH values than grass-fed animals	[83]
	The highest meat a* values were attained at 0.8 % BW concentrate implementation in grass-based diets	[82]
	Grazing periods up to 98 days during the finishing phase had no effects on meat color	[84]
	Confinement in cattle resulted in significantly higher L* values in meat and higher non-significant a* scores	[89]

	Increasing the feeding intensity during growing and finishing did not show differences in pH or meat color	[85]
	Significant lower L* and a* values were recorded for grass-fed compared to grain-fed cattle	[86]
	Significant higher L* and non-significant a* values were recorded in the meat of grass-fed cattle	[87]
	Grain-based diets in cattle resulted in higher slaughter weight than grass-based diets	[88]
	Extensive systems produced a higher amount of type I red muscle fibers, due to higher vascularization and more oxidative metabolism than intensive-systems	[90]
Pre-mortem stress	Lairage time and improper desensitization can increase the risk of obtaining DFD meat, while fatter animals with improved backfat thickness decreased the risk of high-pH meat	[97]
	Animals that traveled long distances and spent short lairage times showed higher enzymatic activity (creatine kinase and lactate dehydrogenase); however enzymatic activity was related to animal stress, but not related to meat quality	[32]
	More than 17 hours of lairage time was the optimal treatment to recover muscle glycogen levels and thus, to prevent the incidence of DFD meat in bulls	[31]
	Higher HSPA1A and cortisol levels were recorded when more than a single shot was used for stunning the animals	[102]
	There was no effect on pH, meat color, or WBSF when increasing lairage time from 3 to 12 hours, probably due to slow ruminant digestion	[59]
	More temperamental cattle showed higher plasma cortisol and glucose amounts	[56]
	Fasting duration during lairage time did not affect meat color or meat ultimate pH, but feeding the animals before slaughtering increased carcass weight by 1.2%	[95]
	Increased transportation times produced higher meat pH, which was related to depleted glycogen stores in muscle	[98]
	Extreme weather conditions and the mixing of strange animals increased the rate of incidence of DFD meat	[67]
	Increasing the stress factors such as longer transportation or lairage times also	[106]

	increased the incidence of obtaining DFD meat in the hot season	
	Short transportation periods increased animal stress, however, the amounts of LDH and CK collected in blood showed no associations with meat color	[33]
	After long transportation distances (1800 km), lairage times of 72 hours reduced the incidence of DFD by 40%, instead of 90% when lairage time was only 24 hours or 60% when animals rested for 48 hours.	[94]
	Reducing lairage time from 18 to 3 hours did not affect meat pH, due to journeys lesser than 6 hours	[100]
	There were no significant effects on meat pH values when animals were not stunned or electrically or percussively stunned	[101]
Chilling rates	Fast chilling of carcasses negatively affected the textural properties in lamb carcasses and had reduced color values than samples chilled by the conventional method	[110]
	High-rigor temperature increased muscles' shrinkage and improved light scattering, which produced brighter muscle color	[109]
	ISM muscle showed better color values than OSM, probably due to slower chilling rates which caused a faster pH decline	[53]
	Rapid temperature fall in beef carcasses might result in slow glycolysis and high pH values, which can result in DFD meat	[96]
	The high-rigor temperature might occur more frequently in grain-based cattle, due to the production of heavier and fatter animals than in grass-based production systems	[107]
	As animals spent more time under feedlot production systems, carcasses had a higher risk of experiencing high-rigor temperatures	[108]
	Under commercial conditions, carcasses were more susceptible to experiencing cold-shortening than high-rigor temperatures	[111]