UDC 636.39:591.175.612.39 https://doi.org/10.15407/animbiol21.01.021

COLOR CHARACTERISTICS OF GOAT MEAT UNDER DIETARY REGIME

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Color of goat meat is affected by energy and protein levels of diets. In this experiment the effects of three levels of metabolizable energy 0.8, 1.0 and 1.2 (2.0, 2.4 and 2.8 Mcal.kg DM) and three levels crude protein 0.8, 1.0 and 1.2 (12.6, 14.0 and 16.8 percent) on color to identified the optimum levels of dietary energy and protein for kid meat were established. Control groups and other experimental groups included 1, 2, 3, 4, 5, 6, 7, 8, and 9 fed by ration of energy to protein ratio of 1:1, 1:1.2, 1:0.8, 1.2:1, 1.2:1.2, 1.2:0.8, 0.8:1, 0.8:1.2 and 0.8:0.8 respectively. For this case meat samples of 27 kids fattened carcass were taken under completely randomize design with a factorial experiment of 3×3 (three levels of energy × three levels of protein) for 4 months fattening period. Three kids of each group (9×3 equal 27 kids) were randomly slaughtered and then after 24 hours longissimus dorsi (LD), infraspinatus (IS) and biceps femoris (BF) muscles were sampled for measuring color. The IS, LD and BF muscles were vacuum-packaged and put on a plastic hurdle (about 30 g) and conditioned for 1, 7 and 14 days in a chiller at 4 °C for measuring color.

Effects of different levels of energy and proteins were significant on L (lightness), a* (redness) and b* (yellowness) of kid meat color. In the present experiment the least square means of L*, a* and b* in the IS muscle were not affected by the time of display (1, 7 and 14 days). The post-mortem aging time were significantly increased L* of kid meat color in high energy and protein treatment (P≤0.05).*

It can be concluded that the diet with 2.8 Mcal/kg DM metabolizable energy and 12.2 percent crude protein (energy to protein ratio of 1.2:0.8) suggested as an appropriate diet for L meat but the diet with 2 Mcal/kg DM metabolizable energy and 16.8 percent crude protein (energy to protein ratio of 0.8:1.2) suggested as an appropriate diet for a* kid meat color.*

Keywords: KID MEAT COLOR, PROTEIN AND ENERGY LEVELS, *POST-MORTEM* AGING TIME

КОЛІРНА ХАРАКТЕРИСТИКА М’ЯСА КІЗ ЗАЛЕЖНО ВІД РІВНЯ ГОДІВЛІ

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Колір м’яса кіз залежить від вмісту енергії та протеїну в раціоні. У цьому експерименті встановлено вплив трьох рівнів обмінної енергії 0,8; 1,0 і 1,2 (2,0; 2,4 і 2,8 Мкал/кг сухої речовини) та трьох рівнів сирого протеїну 0,8; 1,0 і 1,2 (12,6; 14,0 і 16,8 %) на забарвлення м’яса для встановлення оптимального рівня енергії та протеїну в раціоні кіз. Дослід проведено на 9 групах кіз, яких утримували на раціонах зі співвідношенням енергії до протеїну 1:1; 1:1,2; 1:0,8; 1,2:1; 1,2:1,2; 1,2:0,8; 0,8:1; 0,8:1,2 і 0,8:0,8 відповідно. Було використано 27 рандомно відібраних кіз у факторному експерименті за схемою 3×3 (три рівні енергії × три рівні протеїну). Тривалість досліду — 4 місяці. Наприкінці досліду забивали по три тварини з кожної групи (3×9=27). Для оцінки кольору м’яса через 24 год після забою з туш відібрали зразки м’язової тканини: найдовший м’яз спини (longissimus dorsi, LD), підостьовий м’яз (infraspinatus, IS) і двоголовий м’яз стегна (biceps femoris, BF). Зразки мязової тканини (приблизно 30 г) вакуумно упаковували та витримували у холодильнику за температури +4 °С протягом 1, 7 і 14 діб.

Виявлено статистично вірогідний вплив рівня енергії та протеїну в раціоні на L (блідість), a* (червонуватість) та b* (жовтизну) м’яса. Середнє квадратичне відхилення різниць L* і b* у підостьовому м’язі не залежало від тривалості зберігання м’яса (1, 7 і 14 діб). У кіз, які отримували раціон з високим вмістом енергії та протеїну, спостерігали більшу блідість м’яса (P≤0,05).*

Раціон з вмістом обмінної енергії 2,8 Мкал/кг сухої речовини та 12,2% сирого протеїну (співвідношення енергії до протеїну 1,2:0,8) оптимальний для L (блідість), а раціон з вмістом обмінної енергії 2,0 Мкал/кг сухої речовини та 16,8% сирого протеїну (співвідношення енергії до протеїну 0,8:1,2) найкращий для a* (червонуватість).*

Ключові слова: КОЗИ, ПРОТЕЇНОВЕ ТА ЕНЕРГЕТИЧНЕ ЖИВЛЕННЯ, ПІСЛЯЗАБІЙНЕ ЗБЕРІГАННЯ М'ЯСА, КОЛІР М'ЯСА

ЦВЕТОВЫЕ ХАРАКТЕРИСТИКИ МЯСА КОЗ В ЗАВИСИМОСТИ ОТ УРОВНЯ КОРМЛЕНИЯ

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Цвет мяса коз зависит от содержания энергии и протеина в рационе. В этом эксперименте установлено влияние трех уровней обменной энергии 0,8; 1,0 и 1,2 (2,0; 2,4 и 2,8 Мкал/кг сухого вещества) и трех уровней сырого протеина 0,8; 1,0 и 1,2 (12,6; 14,0 и 16,8 %) на окраску мяса для установления оптимального уровня энергии и протеина в рационе коз. Опыт проведен на 9 группах коз, которых содержали на рационах с соотношением энергии к протеину 1: 1; 1: 1,2; 1: 0,8; 1,2: 1; 1,2: 1,2; 1,2: 0,8; 0,8: 1; 0,8: 1,2 и 0,8: 0,8 соответственно. 27 рандомно отобранных коз использовано в факторном эксперименте по схеме 3×3 (три уровня энергии × три уровня протеина). Продолжительность опыта 4 месяца. В конце опыта проводили убой трех животных из каждой группы (3×9 = 27). Для оценки цвета мяса через 24 ч после убоя из туш отобрали образцы мышечной ткани: длиннейшая мышца спины (longissimus dorsi, LD), подостная мышца (infraspinatus, IS) и двуглавая мышца бедра (biceps femoris, BF). Образцы мышечной ткани (примерно 30 г) вакуумно упаковывали и выдерживали в холодильнике при температуре +4 °С в течение 1, 7 и 14 суток.

Выявлено статистически достоверное влияние уровня энергии и протеина в рационе на L (бледность), a* (красноватость) и b* (желтизну) мяса. Среднее квадратическое отклонение различий L* и b* в подостной мышце не зависело от продолжительности хранения мяса (1, 7 и 14 суток). У коз, которые получали рацион с высоким содержанием энергии и протеина, наблюдали высшую бледность мяса ($P \leq 0,05$).*

Рацион с содержанием обменной энергии 2,8 Мкал/кг сухого вещества и 12,2 % сырого протеина (соотношение энергии к протеину 1,2:0,8) оптимальный для L (бледность), а рацион с содержанием обменной энергии 2,0 Мкал/кг сухого вещества и 16,8 % сырого протеина (соотношение энергии к протеину 0,8:1,2) наилучший для a* (красноватость).*

Ключевые слова: КОЗЫ, ПРОТЕИНОВОЕ И ЭНЕРГЕТИЧЕСКОЕ ПИТАНИЕ, ПОСЛЕУБОЙНОЕ ХРАНЕНИЕ МЯСА, ЦВЕТ МЯСА

The color of meat is one of the most important quality attributes influencing the consumer's decision to purchase. Such perceived freshness primarily determines the retail shelf life. Extending this period should improve retail sale ability. The color of meat depends of many factors such as concentration of haeminic pigments and particularly of myoglobin, the physical characteristics of the meat, essentially pH, and the chemical state of these pigments. Reduced (or deoxy) myoglobin is the purple pigment of deep muscle and of meat surface under vacuum [8].

Meat color is largely a contribution of myoglobin, a heme protein found in muscles. In a well-bled muscle tissue, myoglobin constitutes 80–90 % of the total pigments present. Other heme proteins such as hemoglobin and cytochromes contribute little to the color of fresh meat [3, 5]. The myoglobin "pigment" has a purplish red color and this is the color of freshly cut meat. When a freshly cut surface of meat comes in contact with air, myoglobin is oxygenated and converted to oxymyoglobin, which gives meat a bright cherry red color. If only small quantities of oxygen are present, such as in a partial vacuum or a sealed semi-permeable package, myoglobin is converted to metmyoglobin through oxidation giving the meat a brown appearance [6, 19]. Formation of this brown color is a serious problem in merchandising meat because most consumers associate it with a product that has been stored too long. Hunter Lab color values, especially a* values, are a good indication of the redness of meat; the higher a* value, the redder the meat. The value of a color is an indication of the overall light reflectance or brightness. The color of meat is an impression seen by the eye and is influenced by the viewing conditions [11]. Factors such as the type and intensity of lighting, temperature, packaging film and the atmosphere within the package will affect the perceived color impression [14].

In general, a high myoglobin concentration results in more red color within skeletal muscle, as measured by the hue. The difference between red (dark) and white meat has been attributed to the protein concentration in particular muscles [7]. Meat color is objectively defined often in terms of the Hunter colorimetric co-ordinates, L*, a* and b* [16]. L* is the lightness component, indicating the black-whiteness of the meat. Its values range from 0 (all light absorbed) to 100 (all light reflected); a* spans from –60 (green) to +60 (red) and b* spans from –60 (blue) to +60 (yellow) [1, 19].

Visual analysis and instrumental measurements have not always correlated due to errors in training panelists and failing to manipulate physiochemical properties appropriately with instrumental analysis [9]. Visual appraisal by a panel enables inference on human perception of meat color and discoloration, but is subjective. Objective procedures, such as reflectance are more convenient and rapid but their quantitative relationship with human perception is less precise [2]. The sensitivity of instrumental and visual methods to color differences may not be the same and the consumer may not detect small color differences detected instrumentally [20]. However, discoloration as seen by the naked eye does not always correlate with instrumental data. A researcher noted that visual data revealed more rapid increases in discoloration percentages than metmyoglobin percentages [2]. Fat color in goat, sheep and beef meat is an important trait when it comes to consumer preference. Some markets prefer white fat while others prefer carcasses with fat with a more yellow tinge to it. Many countries which import beef from North America, such as those constituting the Asian market prefer beef with a hard white, as opposed to yellow fat [17, 18].

Materials and Methods

Experimental design. The total of 27 number kid meat samples were taken of fattened carcasses under complete randomizes design with a factorial experiment of 3×3 with 9 groups for 4 months fattening period. Three levels of metabolizable energy 0.8, 1 and 1.2 (2, 2.4 and 2.8 Mcal/kg DM) and three levels crude proteins 0.8, 1 and 1.2 (12.6, 14 and 16.8 percent). Control group and other experimental groups of 1, 2, 3, 4, 5, 6, 7, 8, and 9 were fed by ration of energy to protein ratio of 1:1, 1:1.2, 1:0.8, 1.2:1, 1.2:1.2, 1.2:0.8, 0.8:1, 0.8:1.2 and 0.8:0.8 respectively by total mixed ration. Three levels of metabolizable energy (2, 2.4 and 2.8 Mcal.kg DM) and three levels crude proteins (12.6, 14 and 16.8 percents) on color to identified the optimum levels of dietary energy and protein of indigenous kid meat. After slaughtered and *post-mortem* 24 hours were sampled of the *longissimus dorsi* (LD), *infraspinatus* (IS) and *biceps femoris* (BF) muscles the important muscles of carcass. The muscles were vacuum-packaged and put on a plastic hurdle (about 30 g) and conditioned for 1, 7 and 14 days in a chiller at 4 °C for measuring L*, a* and b* color. At the 1, 7 and 14 days *post-mortem*, *infraspinatus* muscle sample was weighed (approximately 30g) and put on a plastic hurdle. Then both items (meat samples on the plastic hurdle) were put into sealed polyethylene bags hermetically closed to prevent surface evaporative loss. Meat color is objectively defined often in terms of the Hunter colorimetric co-ordinates, L*, a* and b* [16]. L* is the lightness component, indicating the black-whiteness of the meat. Its values range from 0 (all light absorbed) to 100 (all light reflected); a* spans from –60 (green) to+60 (red) and b* spans from –60 (blue) to +60 (yellow) [1, 19].

The color measurement was carried out on each sample using the ColorFlex® system (*Hunterlab*, Reston, VA) with D65 illuminant and 10° standard observer. The instrument was calibrated against black and white reference tile prior to use. A total of three readings of the L, a, b values and spectral reflectance (400–700 nm) were collected from different sites of each sample and averaged [9, 10].

Statistical analysis. The experiment was a completely randomized design. Color characteristics of goat meat in different *post-mortem* aging periods were analyzed using the MIXED procedure of Statistical Analysis System package (SAS) ver. 9.1 (SAS Institute Inc. Cary, NC) with time as a repeated measure. Most interactions between treatment and time were no significant and, thus, were not reported. Differences were considered significant at $P<0.05$. Results are expressed as mean±S.E.M.

Results and Discussion

The color of the fresh and aged (1, 7 and 14 days) IS, LD and BF muscles are presented in tables 1, 2 and 3. The different levels of energy and protein in *post-mortem* aging periods hadn't effects on L* (lightness), a* value (redness), b* values (yellowness) of the LD, IS and BF muscles.

Table 1

Color in infraspinatous muscle (IS) of goats meat under different treatments and *post-mortem* aging period (n=27)

Color characteristics of goat meat										
		L*			a*			b*		
Muscle	Treatments	1 day	7 day	14 day	1 day	7 day	14 day	1 day	7 day	14 day
Infraspinatus (IS)	1	34.7^{ab*}	35.8^{ab}	37.7^{a}	13.8^{ab}	14.3^{ab}	14.9^{ab}	7.83^{a}	8.12^{a}	8.21^{ab}
	2	36.1^{a}	36.9^{a}	38.3^{a}	13.2^{ab}	12.8^{b}	13.4^{b}	8.08^{a}	8.61^{a}	9.19^{a}
	3	34.6^{ab}	35.4^{ab}	36.4^{ab}	13.8^{ab}	14.4^{ab}	15.2^{ab}	7.47^{a}	7.78^{a}	8.09^{b}
	4	30.9^{b}	31.5^{b}	31.3^{b}	15.3^{a}	15.8^{a}	16.8^{a}	7.44^{a}	7.58^{a}	7.88^{a}
	5	37.1^{a}	37.7^{a}	38.9^{a}	12.8^{b}	12.6^{b}	13.3^{b}	8.22^{a}	8.63^{a}	8.59^{ab}
	6	30.4^{b}	30.8^{b}	32.3^{b}	15.7^{a}	16.2^{a}	17.7^{a}	7.31^{a}	7.49^{a}	7.64^{b}
	7	34.6^{ab}	35.6^{ab}	36.5^{ab}	13.9^{ab}	15.1^{ab}	14.2^{ab}	8.02^{a}	8.77a	8.95^{ab}
	8	38.2^{a}	39.4^{a}	40.8^{a}	12.7^{b}	12.4^{b}	12.3^{b}	8.14^{a}	8.33^{a}	9.37^{a}
	9	34.3^{ab}	35.6^{ab}	36.9^{ab}	14.2^{ab}	14.6^{ab}	15.5^{ab}	7.94^{a}	8.56^{a}	9.21^{a}
	±SEM	1.53	1.74	1.78	0.81	0.89	0.94	0.45	0.48	0.39

Note: in this and the following tables *a,b — Means within columns with different superscripts are different among treatments (P≤0.05). L* — lightness, a* — redness, b*— yellowness.

Table 2

Color *longissimus dorsi* (LD) of goats meat under different treatments and *post-mortem* aging period (n=27)

Color characteristics of goat meat										
		L*			a*			b*		
Muscle	Treatments	1 day	7 day	14 day	1 day	7 day	14 day	1 day	7 day	14 day
longissimus dorsi (LD)	1	33.3^{ab*}	34.2^{ab}	35.4^{ab}	12.5^{ab}	12.7^{b}	13.3^{ab}	8.23^{ab}	8.64^{ab}	9.13^{ab}
	2	34.1^{a}	35.2^{a}	37.3^{a}	11.6^{b}	11.4^{ab}	10.9^{b}	8.56^{ab}	9.42^{a}	9.77^{a}
	3	32.8^{ab}	33.4^{ab}	34.7^{ab}	12.5^{ab}	12.8^{b}	13.4^{ab}	7.99^{b}	8.25^{b}	8.69^{ab}
	4	31.4^{ab}	30.8^{b}	32.3^{b}	14.5^{a}	14.9^{a}	15.6^{a}	7.84^{b}	8.11^{b}	8.34^{b}
	5	35.2^{a}	36.7^{a}	39.8^{a}	11.4^{b}	11.1^{b}	11.3^{b}	8.12^{ab}	8.43^{ab}	8.39^{b}
	6	29.8^{b}	30.4^{b}	31.2^{b}	15.3^{a}	15.8^{a}	16.3^{a}	7.81^{b}	7.99^{b}	8.24^{b}
	7	33.9^{ab}	34.4^{ab}	35.8^{ab}	12.1^{ab}	11.8^{b}	11.1^{b}	8.44^{ab}	8.67^{ab}	8.89^{ab}
	8	36.1^{a}	37.3^{a}	37.7^{a}	10.8^{b}	10.4^{b}	10.1^{b}	9.34^{a}	9.56^{a}	9.95^{a}
	9	32.7^{ab}	33.6^{ab}	34.1^{ab}	13.2^{ab}	13.6^{ab}	14.1^{ab}	8.34^{ab}	8.69^{ab}	9.01^{ab}
	±SEM	1.27	1.39	1.65	0.97	0.76	1.06	0.39	0.42	0.44

Table 3

Color in *biceps femoris* (BF) of goats meat under different treatments and *post-mortem* aging period (n=27)

Color characteristics of goat meat										
		L*			a*			b*		
Muscle	Treatments	1 day	7 day	14 day	1 day	7 day	14 day	1 day	7 day	14 day
Biceps femoris (BF)	1	33.4^{ab}*	34.3^{ab}	36.1^{ab}	15.4^{ab}	15.2^{ab}	16.4^{ab}	8.76^{a}	8.92^{a}	9.32^{ab}
	2	34.7^{ab}	35.1^{ab}	36.9^{ab}	14.8^{ab}	14.5^{ab}	13.7^{ab}	9.14^{a}	9.67^{a}	9.97^{a}
	3	32.1^{b}	34.1^{ab}	35.8^{ab}	15.7^{ab}	15.9^{ab}	16.6^{ab}	8.89^{a}	9.65^{a}	9.34^{ab}
	4	28.9^{b}	31.1^{b}	31.6^{b}	16.4^{a}	17.1^{a}	17.8^{a}	8.44^{a}	8.68^{a}	8.77^{b}
	5	37.5^{a}	38.1^{a}	38.5^{a}	14.3^{ab}	14.1^{ab}	14.7^{ab}	8.72^{a}	9.32^{a}	9.78^{ab}
	6	28.4^{b}	30.1^{b}	31.4^{b}	17.5^{a}	18.1^{a}	18.4^{a}	8.11^{a}	8.36^{a}	9.08^{ab}
	7	33.7^{ab}	35.2^{ab}	36.1^{ab}	14.9^{ab}	15.2^{ab}	14.4^{ab}	8.92^{a}	9.66^{a}	9.93^{a}
	8	37.3^{a}	37.8^{a}	39.2^{a}	13.2^{b}	12.6^{b}	12.1^{b}	9.32^{a}	9.53^{a}	9.81^{ab}
	9	31.9^{b}	33.7^{ab}	35.3^{ab}	15.1^{ab}	15.6^{ab}	16.1^{ab}	9.16^{a}	9.77^{a}	9.96^{a}
	±SEM	1.71	1.61	1.88	1.18	1.46	1.66	0.56	0.48	0.39

Effects of different levels of energy and protein on color of infraspinatous (IS) muscle in most of groups were significant (P≤0.05), but *post-mortem* aging time of different levels of energy and protein were not significant. Effects of dietary energy and protein treatments in different *post-mortem* aging periods on color in the IS muscle was found to be significant in table 1. In the present experiment the least square means of L* (lightness), a* value (redness) and b* values (yellowness) in the IS muscle were not affected by the time of display (1, 7 and 14 days). The *post-mortem* aging time were significantly increased L* of kid meat color in high energy and protein treatment (P≤0.05). Increasing post mortem aging days reduced L* an all treatments. The different levels of energy and protein significantly increased a* value from fresh IS muscle. Increasing the *post-mortem* aging periods decreased a* and at seven days in the IS muscle and at 14 days *post-mortem* (P≤0.05). This confirmed report by Kannan [12] reported that the *post-mortem* aging period decreased redness of shoulder of chevron cuts, also discoloration of chevron occurred within four to eight days post mortem. This is important because meat color is the main factor affecting ruminant meat acceptability at retail [15]. Chevon has been reported to have lower L* and higher a* than lamb, mainly due to the amount of marbling (intramuscular fat) of goat carcasses is lower than lamb [3, 13].

Different levels of energy and protein were affected on color of *longissimus dorsi* (LD) muscle in most of groups and significant (P≤0.05), but *post-mortem* aging time of different levels of energy and protein were not significant. Effects of dietary energy and protein treatments in different *post-mortem* aging periods on color in the LD muscle was found to be significant in table 2.

In the present experiment the least square means of L* (lightness), a* value (redness) and b* values (yellowness) in the LD muscle were not affected by the time of display (1, 7 and 14 days). The *post-mortem* aging time were significantly increased L* of kid meat color in high energy and protein treatment (P≤0.05). Increasing *post-mortem* aging days reduced L* an all treatments. The different levels of energy and protein significantly increased a* value from fresh LD muscle. Increasing the *post-mortem* aging periods decreased a* and at seven days in the LD muscle and at 14 days *post-mortem* (P≤0.05). Gatlellier reported mixed-diet finishing Charolais heifers were known to have better color in post mortem aging periods [8]. This confirmed report by Kannan [12] reported that the *post-mortem* aging period decreased redness of shoulder of chevron cuts, also discoloration of chevron occurred within four to eight days *post mortem*. This is important because meat color is the main factor affecting ruminant meat acceptability at retail [15].

Different levels of energy and protein were affected on color of *biceps femoris* (BF) muscle in most of groups were significant (P≤0.05), but *post-mortem* aging time of different levels of energy and protein were not significant. Effects of dietary energy and protein treatments in different *post-mortem* aging periods on color in the BF muscle was found to be significant in table 3.

In the present experiment the least square means of L* (lightness), a* value (redness) and b* values (yellowness) in the BF muscle were not affected by the time of display (1, 7 and 14 days). The *post-mortem* aging time were significantly increased L* of kid meat color in high energy and protein treatment (P≤0.05). Increasing *post-mortem* aging days reduced L* an all treatments. The different levels of energy and protein significantly increased a* value from fresh BF muscle. Increasing the *post-mortem* aging periods decreased a* and at seven days in the BF muscle and at 14 days *post mortem* (P≤0.05). Yong [18] reported that color shelf life of the meat from silage fed animals was extended by *post-mortem* aging periods. This confirmed report by Kannan [12] reported that the *post-mortem* aging period decreased redness of shoulder of chevron cuts, also discoloration of chevron occurred within four to eight days *post mortem*.

Conclusion

In general, it can be concluded that the diet with 2.8 Mcal per each kg DM metabolizable energy and 12.2 percent crude protein (energy to protein ratio of 1.2:0.8) suggested as an appropriate diet for L* meat but the diet with 2 Mcal per kg DM metabolizable energy and 16.8 percent crude protein (energy to protein ratio of 0.8: 1.2) suggested as an appropriate diet for a* kid meat color.

Perspectives of the future investigations. Appropriate of metabolizable energy and crude protein in kid goat diet extended color of meat that influencing the consumer's decision to purchase. Such perceived freshness primarily determines the retail shelf life extending this period should improve retail sale ability.

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