Consumer visual appraisal and shelf life of leg chops from suckling kids raised with natural milk or milk replacer

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Abstract

BACKGROUND: The use of milk replacers to feed suckling kids could affect the shelf life and appearance of the meat. Leg chops were evaluated by consumers and the instrumental color was measured. A machine learning algorithm was used to relate them. The aim of this experiment was to study the shelf life of the meat of kids reared with dam's milk or milk replacers and to ascertain which illuminant and instrumental color variables are used by consumers as criteria to evaluate that visual appraisal.

RESULTS: Meat from kids reared with milk replacers was more valuable and had a longer shelf life than those reared with natural milk. Consumers used the color of the whole surface of the leg chop to assess the appearance of meat. Lightness and hue angle were the prime cues used to evaluate the appearance of meat.

CONCLUSIONS: Illuminant D65 was more useful for relating the visual appraisal with the instrumental color using a machine learning algorithm. The machine learning algorithms showed that the underlying rules used by consumers to evaluate the appearance of suckling kid meat are not at all linear and can be computationally schematized into a simple algorithm.

Keywords: rearing system; survival analysis; color; machine learning; muscles; appearance

INTRODUCTION

Goats are regarded worldwide as an important species due to their contributions to the development of rural areas and communities [1]. Spain has one of the largest goat populations in Europe, producing the 20 % of the goat milk and the 10.9 % of the kid meat in the European Union [2]. In addition to this, the sale of suckling kids makes up 20 % of the total income per goat on the dairy farm [3], and 80 % of this kid meat originates from the suckling kid category (*cabrito*) [4]. These suckling kids have a live weight of 10-11 kg and a carcass weight of 5-7 kg and are perceived by consumers to be a high-quality meat [5]. In fact, 88 % of European Union goats are raised extensively and slaughtered as kids, with carcass weights of between 5 kg and 11 kg [6]. When kid goats are reared with their dams, the availability of milk for cheese production is decreased. Therefore, some goat farmers remove the kids from their dams at a very young age and rear them with milk replacers. Milk replacers specifically formulated for kids can result in good daily weight gain. However, some farmers are disinclined to use milk replacers because that this type of rearing involves greater labor costs, although total costs are equal or greater than natural suckling systems [7, 8].

Meat color is an extremely important factor for influencing consumer purchase decisions, as it is deemed a visual measure of freshness and quality [9] and plays a major role in the purchase decision [10, 11]. In Mediterranean countries, some people believe that light colored meat lamb and goat comes from young animals. Spanish consumers in

particular thinks that meat from suckling kids and lambs had better sensory quality than older animals and they are willing to pay higher prices [12]. The meat color of young small ruminants is influenced by factors in the management system [13] such as breed, age/weight at slaughter, pH and the use of milk replacers [14]. In addition to the influence of milk replacer use on meat color, consumers' visual appraisal of kid meat quality is affected by the conditioning associated with their socio-demographic characteristics [15]. Accordingly, a fresh appearance and light color in lamb were more highly valued by traditional consumers [11] and can determine purchase intention. However, in other species such as beef, the influence of demographic factors on acceptability are less important [16].

In 1931, the Comite International de L'Eclairage (CIE) recommended the use of illuminant C. However, in current times, this illuminant has seemed inadequate due to a deficient spectral distribution in the ultraviolet region. The Illuminant A is frequently used in North America [17]. AMSA [18] recommended the use of the illuminant A when the detection of redness differences between treatments is the priority because illuminant A places more emphasis on the proportion of red wavelengths; this results in higher a* values than with the use of D65 [19]. However, kid meat has a low heminic pigment content, resulting in a pale meat with a low redness index [20]. Consequently, it is unclear which illuminant should receive preferential use to correctly relate the instrumental color of the kid meat with the visual appraisal of consumers.

In this article, we argue that consumers perform their visual appraisal of meat by means of knowledge that can be computationally schematized. This approach has been applied before to beef color, demonstrating that the relationship between CIEL*a*b* color variables and the perception of beef color by humans is not linear [21].

The aim of this experiment was to study the shelf life of the meat of kids reared with dam's milk or milk replacers and to determine which muscles of the leg are more important in the visual appraisal by consumers and which illuminant and instrumental color variables are used by consumers as criterion to evaluate in their visual appraisal.

MATERIAL AND METHODS

Carcass sampling

Suckling male kids of the Cabra del Guadarrama breed reared with milk replacers (MR) or natural milk from their dams (NM) were selected from two farms. Fifteen MR kids and 16 NM kids were slaughtered following standard commercial procedures according to the European norms for the protection of animals at the time of killing [22]. Kids had a liveweight of 8.6 ± 0.27 kg and age of 40 - 45 d old (P>0.05). A head-only electrical stunning (1.00 A) was applied to the kids, which were then were exsanguinated and dressed with a hot carcass weight of 5.8 kg ± 0.17 kg (P>0.05). Carcasses were hung by the Achilles tendon and transported at 4ºC to the facilities of the CITA Research Institute at Zaragoza. Then, the carcasses were chilled for 24 h at 4ºC in total darkness. The right hind leg was separated from the carcass, vacuum packed and stored at -20ºC until sampling.

2.2. Color measurement of the chops

The shelf life of meat of suckling lambs and kid's goat are around a week[23, 24]. Because the very small size of legs of kids, only four of the leg chops were enough big to measure the color of the different muscles. Hence, the 31 frozen legs were sliced into four chops assigned to 8, 6, 3 and 1 days before the day of the visual appraisal by consumers (day 0). On the assigned day, the chops were thawed and placed in polystyrene trays covered with oxygen permeable film and then stored for 24 h at 4ºC in total darkness until the day of the visual appraisal. The *semimembranosus*, *semitendinosus* and *biceps femoris* muscles of the leg were located [25, 26], and their instrumental color measured. These muscles were selected because they are the muscles that represent most of the area of the chop. Color measurements were repeated two or three times depending on the reading area of the muscle. The spectrophotometer was rotated 90° on the horizontal plane, and the mean of these 2-3 readings was used for analysis [27].

Muscle colors were measured using a Minolta CM-2006d spectrophotometer (Konica Minolta Holdings, Inc, Osaka, Japan) in CIEL*a*b* space [28] with the specular component included, 0 % UV, an observer angle of 10º and zero and white calibration. The integrating sphere had a 52 mm diameter, and the measurement area (diameter of 8 mm) was covered with a CM-A149 dust cover (Konica Minolta Holdings, Inc, Osaka, Japan). The illuminants used were D65, C and A. The lightness (L*), redness (a*) and yellowness (b*) indexes were recorded using the software SpectraMagic NX (Minolta

Co. Ltd., Osaka, Japan), and the hue angle (h_{ab}) and chroma (C^*_{ab}) indexes were calculated as $h_{ab} = \tan^{-1}\left(\frac{b*}{a*}\right) \cdot 57.29$ and expressed in degrees as $C^*_{ab} = \sqrt{(a*)^2 + (b*)^2}$.

When the color of every chop was measured, four MR and four NM chops from each time of storage (1 d, 3 d, 6 d and 8 d), with values of L*, h_{ab} and C^*_{ab} for the three muscles representative of the 31 chops (Table 1), were selected for the visual appraisal of the consumers. L*, h_{ab} and C^*_{ab} were chosen because these parameters are similar to the color perception of human beings (Ripoll, Panea, & Albertí, 2012; Wyszecki & Styles, 1982).

Evaluation of the appearance of the chops

On the day of the visual appraisal, the eight chops were identified with 3 digit random numbers and randomly placed in a refrigerated island display case, Carrier Multinor 1540/80, with a display area of 1 m^2 (1.3 m x 0.8 m) (Carrier Refrigeración Ibérica SA, Spain) at 0-2 ºC. Samples were available from 8:00 am to 16:00 pm, and to avoid the possible effects of the order of presentation, and first-order and carry-over effects, the samples were moved randomly three times through the test day. The lightning was provided by LED bulbs with a luminous flux of 816 lumen, a color temperature of 4000 K, a color rendering index >80 and a standard deviation color matching equal to 3 MacAdam ellipses [29]. The illuminance on the surface of the chops was approximately 1300 lx, ensuring the minimum level of illuminance in areas with high visual requirements [30].

The participation of naïve consumers in the experiment was voluntary and anonymous. Consumers were recruited among students and workers, without relation with the current research, of Aula Dei Campus. Personal data as identification or electronic mail were not required, and there was no financial compensation. Participants were clearly informed of aim of the study and gave implicit consent for research use of the supplied information according to European regulations [31]. Each consumer was provided with a form in which they were asked about their gender and age. Regarding the chops, the consumers were asked to evaluate from 1 (very bad) to 10 (very good) the color-based appearance of the chops. Additionally, they were asked about their purchase intention (yes/no). The leg chops displayed on the island case were evaluated by 56

respondents: 67.9 % female and 32.1 % male. Their ages were equally distributed by sex (P>0.05): 5.7 % were younger than 24 years, 26.4 % were between 26 and 40 years, 39.6 % were between 41 and 55 years, and 28.3 % were older than 55 years. Participants took 10-20 min to complete the required tasks.

Statistical analysis

Statistical analyses were performed with SAS 9.4 (SAS Institute Inc., EE.UU.) [32]. Instrumental color variables were analyzed using the GLM procedure with the rearing system, the time of storage and the muscle as fixed effects. Visual appraisal was analyzed using the GLM procedure, with the rearing system and the time of storage as fixed effects. Least square means were estimated, and differences were tested at a 0.05 level of significance. The Pearson correlations between the visual appraisal and the instrumental color of the three muscles with the two used standard illuminants were calculated with the residuals of each observation.

The association between the rearing system and time of display for the purchase intention was analyzed by a chi-square test. The meat shelf life according to the consumer's purchase intention was studied using the survival analysis of Kaplan-Meier with the LIFETEST procedure. The log rank test was used to examine the differences between the survival curves. The estimate of the shelf life was the median, that is, the day on which 50 % of the consumers rejected the samples.

A machine learning algorithm Cubist 2.09 [33] was used to generate rule-based predictive models from the color variables of the muscles studied. This algorithm uses the input data to generate a decision tree with linear functions in all leaves. The relative error magnitude is the ratio of the average error magnitude to the error magnitude that would result from always predicting the mean value; for useful models, this should be less than 1. The correlation coefficient measures the agreement between the cases' actual values for the target attribute and those values predicted by the model [33].

RESULTS

The leg chops selected to be exposed in the display case were representative of the other leg chops because they had similar L*, h_{ab} and C_{ab}^* values for each muscle (P>0.005) (Table 1).

The instrumental colors of the leg chops are shown in Table 2. The rearing system had a significant effect on every color variable, except C_{ab}^* (P=0.056).

Accordingly, MR had greater L*, b* and h_{ab} but lower a* (P<0.05). Values of a* and C_{ab}^* decreased with the time of display (P<0.05), but the other variables did not change with time (P>0.05). The three muscles differed in terms of a*, b* and C_{ab}^* (P<0.005). The muscles *biceps femoris* and *semimembranosus* had the same a* and b* values (P>0.05), although *semimembranosus* and *semitendinosus* muscles had similar C_{ab}^* values (P>0.05).

The visual appraisal of leg chops throughout the time of display is shown in Figure 1. The effect of the rearing system and the effect of time of display were significant (P<0.001), but the interaction was not (P=0.746). MR showed greater visual appraisal than NM over all times of display, with the exception of 6 days (P>0.05). Leg chops from both rearing systems decreased significantly in the visual appraisal from 1 d to 6 d. Visual appraisal at 8 d was also lower than that at 3 d (P<0.05). The visual appraisal of MR was always greater than 6, while the visual appraisal of NM was between 5 and 6 from the 6th day.

The purchase intention of consumers at each time of display is shown in Figure 2. The rearing system and time of display were independent effects (P=0.997). The purchase intention was greater for MR than NM throughout the whole time of display. Hence, more than the 50 % of consumers purchased the MR leg chops at any time of display, while fewer than 50 % of consumers purchased NM leg chops at 6 and 8 d.

The median shelf life of leg chops (Table 3) estimated according the purchase intention was affected by the rearing system (P=0.005), but the sex and age of consumers did not have an effect (P>0.1). The global shelf life of leg chops was 6 d ± 0.6. However, the shelf life for MR was 8 d, while the shelf life for NM was 6.

Table 4 shows the significant correlations among the residuals of the visual appraisal with the color variables for each muscle and illuminant used. Significant correlations were not found for the color of *biceps femoris* and *semimembranosus* with any illuminant used for any color variable. Visual appraisal of leg chops did not correlate with a* or C_{ab}^* of the *semitendinosus* when measured with any of the three illuminants. Correlations using C and D65 provided similar correlations, but a* measured with illuminant A correlated more closely than when measured with C and D65. Conversely, C_{ab}^* when measured with illuminant A correlated less than when measured with C and D65. When the three muscles were averaged, L* was negative and highly correlated with visual appraisal, providing similar results to the three illuminants used.

The quality statistics of several models proposed by the machine learning algorithm are shown in Table 5. In this table, the color variables included in each model are also provided. The global model using the averaged color variables of the three muscles was measured with the three illuminants and had a relative error of 0.81, as well as a correlation between the real visual appraisal of consumers and the predicted values of 0.52. The models that used the colors of all three muscles and their averaged color variables when measured with D65 and C showed better statistical correlation. The use of both illuminants also provided better results than the use of the same model with illuminant A. Due to the good results found for illuminant D65, this illuminant was used to develop separate models with each muscle. As a result, these three models showed less consistent statistical results than the model that included the three muscles averaged and measured with illuminant D65; however, the results were still more similar than those which used illuminant A. Consequently, the best model was the model which used the color measurements for the three muscles and their average color, measured with the illuminant D65. The machine learning algorithm proposed two linear regression equations depending on the averaged L*. That is:

If L* ($\Box$) >40.77 then

Eq.1:

Visual appraisal = -11.2+12.418·h_{ab} ($\Box$)-4.185·h_{ab} (BF)-4.13·h_{ab} (SM)-3.821·h_{ab} (ST)-1.89·b* (ST) +1.73·$C_{ab}^*(ST)$ + 0.14·b* (ST)+0.14·a*(ST)

If L* ($\Box$) ≤40.77 then

Eq. 2:

Visual appraisal = -16.1+4.539·h_{ab} ($\Box$)-1.679·h_{ab} (BF)-1.428·h_{ab} (SM)-1.321·h_{ab} (ST)-0.65·b* (ST) +1.98·$C_{ab}^*(ST) - 0.21 ·$ a*(ST),

where BF is *biceps femoris*, ST is *semitendinosus*, SM is *semimembranosus* and $\Box$ is the averaged value of the three muscles.

Both eq. 1 and eq. 2 use the averaged h_{ab} and the h_{ab} of the three muscles, followed by the a*, b* and C_{ab}^* of the *semitendinosus,* which is the muscle with greater values of these variables.

DISCUSSION

Meat from suckling kids with very light carcass weight (approximately 5 kg) is characterized by high L* and low a* and b* values, resulting in a lighter, paler and duller meat [34, 35] compared with other meats such as beef, even for suckling kids with heavier carcasses [36, 37] and concentrate-fed kids [38]. Changes in the color of kid meat with increases in age/weight have been reported by other authors, especially the increase in redness intensity [39-41] and the decrease in lightness [41, 42] and hue angle [5].

Diet strongly affects the meat color of preruminants such as suckling lambs and kids [37, 43]. The lightness of meat is influenced by pH and protein structures [44] more than diet [45]. Hence, milk replacer does not affect the L* of fresh kid meat, independent of the measured muscle [35, 46, 47]. However, frozen/thawed meat could show a different behavior due to the denaturalization of sarcoplasmic proteins. In agreement with our results, De Palo, Maggiolino, Centoducati and Tateo [35] found that the *longissimus thoracis* of kids fed with goat milk had lower b* and h_{ab} than that of those fed with milk replacer. Additionally, they also did not find differences in C_{ab}^*. The use of milk replacers affects the color of *semimembranosus* by decreasing b* [47] compared with natural goat milk. However, the composition of the goat milk is dependent on the management system of the goats [48], and this influences the color of meat, especially a*.

Meat discoloration is produced during storage as deoxymyoglobin is converted to metmyoglobin. Meat discoloration is important because this meat cannot be sold easily [49]. Therefore, increases in h_{ab} and decreases in C_{ab}^* have been used as indicators of red meat discoloration [16, 21, 35, 44, 50-52]. This is in agreement with the results of our study, which showed a decrease in a* and C_{ab}^*. However, Ozcan, Yalcintan, Tölü, Ekiz, Yilmaz and Savaş [37] studied the meat color of Gokceada suckling kids raised extensively and concluded that while a* and b* seemed not to change from 1 d to 5 d, L* decreased slightly. Morales-De la Nuez, Falcón, Castro, Briggs, Hernández-Castellano, Capote and Argüello [34] did not report changes in L* and a* of meat from Majorera kids stored for 7 days; however, b* and h_{ab} increased while C_{ab}^* decreased. Changes in h_{ab} and C_{ab}^* with storage time can be a result of the oxidation of myoglobin to metmyoglobin and the loss of heminic pigments due to the freeze/thaw process.

Some studies of diverse muscle colors for lamb [53] and beef [26] reported greater differences in L* than in a* and b* between the studied muscles. Regarding a* and b*, Torrescano, Sánchez-Escalante, Giménez, Roncalés and Beltrán [54] found results similar

to those in our study with frozen beef. However, these authors also found differences between the three muscles in L*. M. *biceps femoris* could have lower C_{ab}^* because it has more type IIb (white) fibers, while *semitendinosus* and *semimembranosus* have fiber types IIa and IIb (red) in almost the same proportions [55].

Consumers showed a clear preference for MR meat, demonstrating that kid meat with greater L* and h_{ab} is preferred [12]. In addition, the discoloration of kid meat and the rejection of consumer are shown to relate to C_{ab}^* rather than h_{ab}, likely due to the paleness of this kind of meat. Other authors also reported the importance of the relation between the visual appraisal of meat and ratios between a* and b* instead of individual trichromatic coordinates [21, 50, 56]. There is consistency between the existing correlations and the rules proposed by the machine learning algorithm. A strong relationship between visual color assessment and L* has been reported previously [57-59]. Consumers used L* as a principal cue to evaluate the suckling kid meat, but as a threshold or boundary rather than as the source for their complete evaluation. In addition to L*, consumers assessed the appearance of whole chop rather than individual muscles and focused on h_{ab}. h_{ab} and C_{ab}^* have been reported, together with L*, as variables easily interpretable by human beings. Conversely, b* is not intuitively related with the color of meat [21, 44, 60], and its use by evaluators is complex [61]. Khliji, van de Ven, Lamb, Lanza and Hopkins [62] used only L* and a* to score fresh lamb meat, but when browning was studied, the 630/580 nm ratio was included in the ranking models. Holman, van de Ven, Mao, Coombs and Hopkins [16] found that a* provided the best prediction of consumer acceptance of beef color, but the use of h_{ab} and C_{ab}^* improved precision. It seems clear that a* is the best cue to assess fresh meat. However, when browning or discoloration appears, the best parameters to assess meat are those that consider a* and b* together, e.g., b*/a* or a*/b* ratios, h_{ab}, C_{ab}^*, or reflectance ratios such as 630/580 nm. Regarding the illuminants used, illuminant A focuses on red wavelengths and is recommended to relate the visual assessment to instrumental color [18]. However, D65 was more useful to find a relationship between the visual appraisals of the light and pale meat of goat kids. Results for illuminant C were closer to D65 because the illuminants differed in the ultraviolet region, which is not visible.

CONCLUSIONS

Meat from kids reared with milk replacers was more valuable and had a longer shelf life than meat from kids reared with natural milk.

Consumers used the color of the whole surface of the leg chop, then the color of *semitendinosus*, to assess the appearance of meat. Lightness and hue angle were the primary cues used to evaluate the suckling kid meat. Both of these parameters were more important cues than the redness index when fresh and discolored meats were shown together. Illuminant D65 was more useful in relating the visual appraisal to the instrumental color using a machine learning algorithm.

The machine learning algorithms showed that the underlying rules used by consumers to evaluate the appearance of suckling kid meat are not at all linear and can be computationally schematized into a simple algorithm.

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Figure 1. Visual appraisal of leg chops of kids from two rearing systems through 8 days of display.
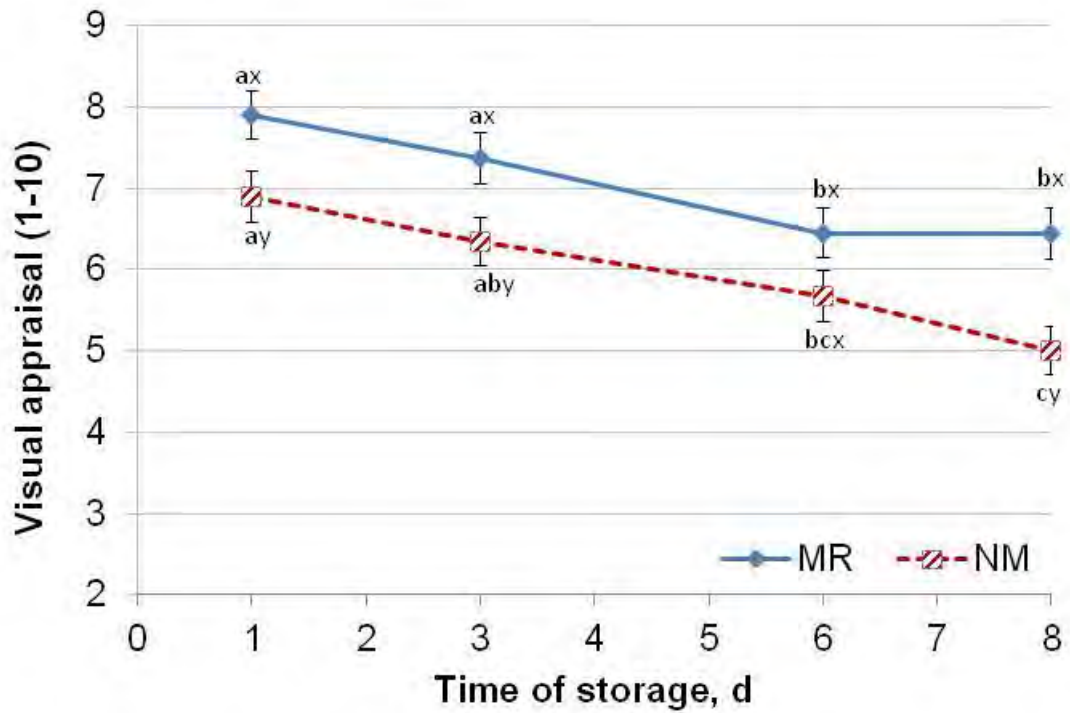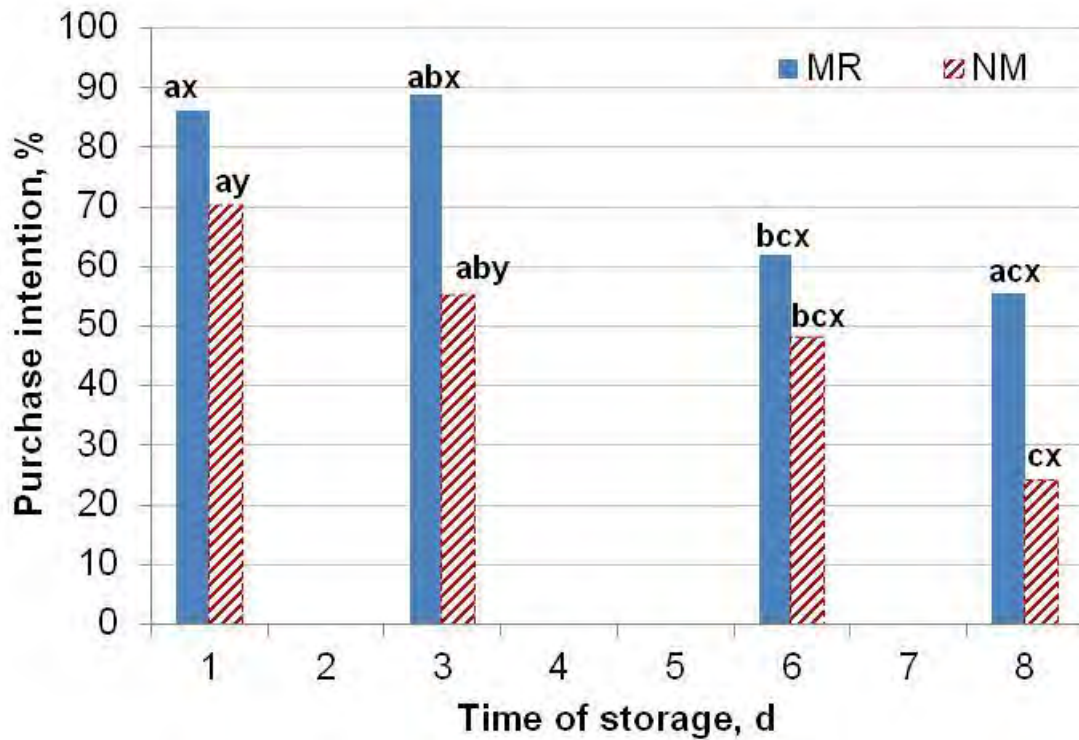

MR, milk replacer; NM, natural milk from dams

a, b, different letters indicate significant differences among times of display within a rearing system

x, y, different letters indicate significant differences among rearing systems

Figure 2. Purchase intention for leg chops of kids from two rearing systems through 8 days of display.

MR, milk replacer; NM, natural milk from dams
a, b, c, different letters indicate significant differences among times of display within a rearing system
x, y, different letters indicate significant differences among rearing systems

Table 1. Significance of the representability test for selected chops.

	L*	h_{ab}	C^*_{ab}
Population of chops (P)[1]	0.093	0.062	0.767
Muscle (M)	0.267	0.145	0.332
P*M	0.785	0.851	0.601

[1] Population of chops: selected chops vs. the whole population of chops.
The test was performed with the values measured with illuminant D65.

$$h_{ab} = \text{hue angle} = \tan^{-1}\left(\frac{b*}{a*}\right) \cdot 57.29; \quad C^*_{ab} = chroma = \sqrt{(a*)^2 + (b*)^2}$$

Table 2. Instrumental color of leg chops from kids reared with milk replacer (MR) or natural milk from their dams (NM).

	L*	a*	b*	h_{ab}	C^*_{ab}
Rearing system					
MR	42.35	7.98	6.37	38.26	10.23
NM	39.65	9.36	5.48	30.02	10.94
s.e.	0.439	0.203	0.267	1.223	0.252
Time of storage					
1 d	40.27	9.88[a]	6.68	34.34	12.04[a]
3 d	40.98	8.85[b]	6.16	34.41	10.85[b]
6 d	41.02	8.19[bc]	5.44	33.08	9.91[bc]
8 d	41.71	7.77[c]	5.41[b]	34.73	9.54[c]
s.e.	0.619	0.287	0.378	1.730	0.357
Muscle					
biceps femoris	41.48	8.23[b]	5.29[b]	32.08	9.85[b]
semimembranosus	40.46	8.42[b]	5.40[b]	33.27	10.08[a]
semitendinosus	41.06	9.37[a]	7.07[a]	37.07	11.83[a]
s.e.	0.536	0.282	0.304	1.498	0.303
Significance[†]					
Rearing system	<0.001	<0.001	0.025	<0.001	0.056
Time of display	0.452	< 0.001	0.069	0.911	0.001
Muscle	0.409	0.006	<0.001	0.063	<0.001

MR, milk replacer; NM, natural milk from dams; s.e., standard error

[†] Interactions were not significant ($p > 0.05$).

h_{ab} = hue angle = $\tan^{-1}\left(\frac{b*}{a*}\right) \cdot 57.29$; C^*_{ab} = chroma = $\sqrt{(a*)^2 + (b*)^2}$

Table 3. Shelf life of leg chops according to the purchase intention of consumers estimated by survival analysis.

	Strata	Median, d	s.e.	Significance
Rearing system	MR	8	1.0	0.005
	NM	6	0.8	
Sex	Women	6	0.6	0.112
	Men	6	0.9	
Age, yr.	<25	6	2.3	0.655
	26-40	6	1.2	
	41-55	6	1.0	
	>55	6	1.2	

MR, milk replacer; NM, natural milk from dams

Table 4. Pearson correlations of the residuals of visual appraisal and instrumental color for each muscle and illuminant.

Muscle	*Semitendinosus*						Muscles average[1]		
Illuminant	D65		C		A		D65	C	A
Color variable	a*	C_{ab}^*	a*	C_{ab}^*	a*	C_{ab}^*	L*	L*	L*
Correlation (r)	0.17	0.21	0.16	0.21	0.19	0.19	-0.22	-0.22	-0.21
Significance	0.012	0.001	0.015	0.002	0.004	0.005	0.001	0.001	0.002

[1] Correlations between the average L* of the three muscles.

$$C_{ab}^* = chroma = \sqrt{(a*)^2 + (b*)^2}$$

Only significant correlations with P < 0.05 are shown. *Biceps femoris* and *semimembranosus* color variables were not significantly correlated with visual appraisal and these data are not shown in the table.

Table 5. Statistics for the tested machine learning models.

| | Global[1] | Iluminant[2] | | | Muscles[3] | | |
		D65	C	A	BF	SM	ST
Average error	1.2	1.2	1.2	1.3	1.3	1.2	1.2
Relative error	0.81	0.79	0.79	0.85	0.86	0.80	0.80
Correlation (r)	0.52	0.55	0.55	0.49	0.47	0.50	0.50
Variables included in each model in the algorithm							
	L* ($\square^4$-D65)	L* ($\square^4$)	L* ($\square^4$)	b* (ST)	L*	a*	L*
	b* (SM-D65)	h_{ab} ($\square^4$)	h_{ab} ($\square^4$)	b* (BF)	a*	h_{ab}	a*
	h_{ab} (SM-	h_{ab}	h_{ab} (SM)	h_{ab}	b*	C^*_{ab}	b*
	L* (ST-D65)	h_{ab} (ST)	h_{ab} (ST)		h_{ab}		h_{ab}
	a* (ST-D65)	h_{ab} (BF)	h_{ab} (BF)		C^*_{ab}		
	h_{ab} (ST-A)	C^*_{ab}	C^*_{ab} (ST)				
		a* (ST)	a* (ST)				
		b* (ST)	b* (ST)				

[1] Data for the five color variables of the three muscles measured, with the three illuminants used as inputs.

[2] Data for the five color variables of the three muscles and the averaged color measured, with each illuminant used as input.

[3] Data for the five color variables of each muscle measured with the D65 illuminant used as input.

[4] ($\square$), Average color variable for the three muscles.

BF, *biceps femoris*; SM, *semimembranosus*; ST, *semitendinosus*;
Semitendinosus

h_{ab} = hue angle = $\tan^{-1}\left(\frac{b*}{a*}\right) \cdot 57.29$; $C^*_{ab} = chroma = \sqrt{(a*)^2 + (b*)^2}$