ORIGINAL ARTICLE

Effect of nutritive level on carcass traits and meat quality of IHDH foals

Pasquale DE PALO, Alessandra TATEO, Aristide MAGGIOLINO and Pasquale CENTODUCATI

Department of Veterinary Medicine, University of Bari Aldo Moro, Valenzano, Bari, Italy

ABSTRACT

The present work describes the effect of nutritive level on horse carcass traits and on meat quality. Eighteen male Italian Heavy Draught Horse (IHDH) breed foals were employed in the study. Soon after foaling they were randomly subdivided into three groups according to three nutritive level classes: 150%, 180% and 200% of maintenance requirements. Live weight, hot carcass weight and dressing percentage of each animal were recorded. After slaughtering, meat samples were collected from Longissimus dorsi muscle. The right half carcass of each animal was then divided into cuts. Each one was subdivided into lean, fat and bones. Live weight, carcass weight and dressing percentage were not affected by nutritive level \((P > 0.05)\). Horses fed with the lower nutritive level showed a higher incidence of lean and a lower incidence of fat \((P < 0.01)\). Moreover, fatty acid profile was not affected by nutritive level \((P > 0.05)\). Probably the tendency of IHDH foals to concentrate adipogenesis in the subcutaneous district could explain the lack of influence of nutritive level on meat quality parameters and its influence on carcass and cut composition, which tend to be richer in fat.

Key words: fatty acid profile, horse, meat quality, nutritive level.

INTRODUCTION

Italian Heavy Draught Horse (IHDH) foals were traditionally raised in Italy as working horses. Mechanization and industrialization in agriculture in the 20th century shifted IHDH raising to meat production. For many years, in Italy horse meat consumption has been the highest among all European Community countries (Martuzzi et al. 2001). Currently the production of horse meat in Italy is mainly obtained from heavy breeds such as the IHDH. The horse’s suitability for meat production is also justified by good dressing percentages that this species has shown (Martin-Rosset et al. 1980; Robelin et al. 1984; Catalano et al. 1986; Manfredini et al. 1992; Badiani et al. 1993; Tateo et al. 2008; De Palo et al. 2013). Moreover, many studies on this horse breed demonstrated that this breed is particularly suitable for both meat (Tateo et al. 2005, 2009, 2013; De Palo et al. 2013) and milk production (Centoducati et al. 2012). Although horse meat is commercialized in a minority market, particularly developed in Italy (Tateo et al. 2008) and Spain (Franco & Lorenzo 2014), it has excellent nutritional properties, that is, it is low in fat if compared to beef, rich in iron (Franco et al. 2011) and with a high content of unsaturated fatty acids (Badiani et al. 1997; De Palo et al. 2013). There are many ways to improve the carcass weight, such as increasing slaughtering age (De Palo et al. 2013) or including a finishing period (Franco et al. 2013). Carcass and horse meat quality can be influenced by many factors, such as by breed (Juarez et al. 2009), finishing feeding (Sarriés & Beriain 2006) and age at slaughtering (De Palo et al. 2013).

The aim of this work was to study how different nutritive levels, applied from weaning to slaughtering age, could affect slaughtering parameters, carcass traits, cuts incidence and meat quality of IHDH foals slaughtered at 11 months.

MATERIALS AND METHODS

Animals

A total of 18 male IHDH breed foals were employed in the study, all of them born at the same farm. Soon after foaling
they were subdivided randomly into three groups, differing in nutritive levels administered from weaning to slaughter.

Table 1 Chemical composition (%DM) of diet fed to horses

| Item                | Concentrate | Oat hay |
|---------------------|-------------|---------|
| Chemical composition|             |         |
| DM                  | 87.6        | 88.4    |
| Crude protein       | 13.5        | 11.6    |
| Crude fibre         | 10.8        | 33.4    |
| Ether extract       | 3.2         | 2.9     |
| Ash                 | 7.0         | 11.1    |
| NDF                 | 27.9        | 54.5    |
| ADF                 | 13.2        | 40.9    |
| ADL                 | 2.5         | 7.2     |
| Horse FU (n/kg of DM)| 0.82        | 0.50    |
| DP (g/kg)           | 104.2       | 21.5    |

Table 1 Chemical composition (%DM) of diet fed to horses

ADF, acid detergent fibre; ADF, acid detergent lignin; DM, Dry matter; DP, digestible protein; FU, horse forage units calculated according to Martin-Rosset et al. (1994); NDF, neutral detergent fibre.

the ISO 1443:1973 method (ISO 1973) and ash was calculated with the ISO 936:1998 method (ISO 1998). Every muscle and subcutaneous tissue sample was homogenized with a mixture of chloroform and methanol (1:2, vol/vol) solution for the extraction of total lipids from intramuscular and subcutaneous fat, according to the method described by Bligh and Dyer (1959).

The water holding capacity (WHC) was measured using the centrifugation method, according to Bouton et al. (1971). A specimen of 0.3 g was collected from each sample and then was centrifuged at 30 000 × g for 1 h. After centrifugation, the samples were dried and weighed again, and the centrifugation loss was calculated as the difference in weight before and after centrifugation.

For cooking loss determination, cubic meat pieces with 1.5 cm per side were weighed (initial weight, Wi) and then cooked in plastic bags in a water bath at 80°C until they reached the internal temperature of 75°C, measured by a copper constantin fine-wire thermocouple fixed in the geometrical center of the sample (Model 55C-TT-T-30–36; Omega Engineering Inc., Stamford, CT, USA). Cooked samples were cooled, dried from fluids and reweighed (final weight, Wf). The cooking loss was calculated as a percentage of weight loss: ((Wi – Wf)/Wi) × 100 (Bertram et al. 2003).

Post-thawing losses were calculated as the difference in weight before freezing and after thawing. Each sample was weighed before the freezing process (initial weight, Wi) and after the thawing process. The post-thawing losses were calculated according to the following formula: ((Wi – Wf)/Wi) × 100.

Each cooked lean sample was tested for Warner-Bratzler Shear Force (WBSF). The samples were cooked in plastic bags up to an internal temperature of 70°C for 3 min in a water bath at 85°C (measured with a copper constantin fine-wire thermocouple, Model 55C-TT-T-30–36, Omega Engineering Inc., fixed in the geometrical center of the sample). The WBSF was measured using an Instron 1140 apparatus (Instron, High Wycombe, UK) interfaced with a computer, using a crosshead speed of 50 mm/min-1 and a load cell of 50 N. The cut sample had a cylindrical shape with a diameter of 1.27 cm. The cut was parallel to the muscle fiber direction. The force-deformation curve obtained was used to calculate meat hardness. Shear force was determined perpendicular to the fiber direction. Each sample was sheared three times and the arithmetic mean of the data registered from each sample was subjected to further statistical analysis.

Fatty acid methyl esters (FAME) were prepared by transesterification, using methanol in the presence of 3% hydrochloric acid in methanol (vol/vol). Fatty acid methyl esters were analyzed using a Trace GC Thermo Quest Gas Chromatograph (Thermo Electron, Rodano, Milan, Italy) equipped with a flame ionization detector. The derivatives were separated on a capillary column (Supelco SP-2380 fused-silica column, 30-m length, 0.25-mm internal diameter, and 0.20-mm film thickness). The injector and the detector temperatures were held at 260°C. Column oven program temperatures were as follows: T1 = 80°C hold 1 min; T2 = 150°C ramp at 15°C/min, hold 2 min; T3 = 220°C ramp at 5°C/min, hold 2 min; T4 = 250°C ramp at 15°C/min, hold 5 min. The flow rate of the carrier gas (He) was set at 0.8 mL/min. Identifications of FAME were based on the retention times of reference compounds (Sigma-Aldrich, St. Louis, MO, USA) and mass spectrometry. Fatty acid composition was expressed as the percentage of total FAME.

Slaughtering and treatment of samples

Live weight (LW) of each animal was measured 1 h before slaughter. They were slaughtered at 11 months old in a national accredited slaughterhouse, according to current EU regulations (Council Directive of the European Union 95/221EC).

After slaughter, hot carcass weight (CW) was measured and dressing percentage (DP) was calculated, then carcasses were kept in a chilling room at 4°C for 48 h. Samples of Longissimus dorsi (LD) muscle between the 13th and 18th thoracic vertebrae (about 500 g for each sample) were taken under the fiber direction. Each sample was sheared three times and after the thawing process. The post thawing losses were calculated according the following formula: ((Wi – Wf)/Wi) × 100.

Meat proteins were measured with the ISO 937:1978 method (ISO 1978); intramuscular fat was determined with

Meat analysis

The classification of the lean meat in first and second quality cuts; steaks, loin, fore leg and
Collagen was extracted following the Sørensen (1981) method. Determination of 4-hydroxyproline was performed according to the procedure suggested by Kindt et al. (2003) using electrospray mass spectrometry (LCQ Thermo Electron, CA, Waltham, MA, USA) to avoid any derivatization step.

**Statistical analysis**

The collected data were subjected to analysis of variance (ANOVA) using the GLM by SAS software (SAS 1998), according to the following model:

\[ Y_{ij} = \mu + NL_i + \varepsilon_{ij} \]

where \( Y_{ij} \) represents the carcass and meat qualitative patterns, the dependent variables; \( \mu \) is the mean; NL is the effect of the \( i^{th} \) nutritive level \((i = 1, \ldots , 3)\), the independent variable; \( \varepsilon_{ij} \) is the error term.

Moreover, a post hoc test was performed using a Bonferroni test to compare means.

The results here reported are expressed as least square means and mean standard errors. The significance level was assessed to \( P < 0.05 \).

**RESULTS AND DISCUSSION**

Slaughtering performances are reported in Table 2. No effect of NL was evidenced on LW, CW and DP. LW and CW tended to increase with the increasing of NL but there was no statistical difference \( (P > 0.05) \). Franco et al. (2013), studying the effect of finishing diet in horses slaughtered at 15 months old, obtained similar results. They found an increasing trend of these parameters with the increasing of finishing diet but no statistical differences. Results reported are similar to those reported in the literature for other horse breeds like Barguete, Sanfratellano and Haflinger (Lanza et al. 2009) and Lusitano (Sarriès & Beriaín 2005).

Considering carcass composition, horses fed with a higher NL showed a higher incidence of the fore quarter and a lower incidence of the hind quarter \( (P < 0.001) \). Moreover, animals fed with lower NL showed higher incidence of lean and lower incidence of bone \( (P < 0.01) \). In contrast, other authors observed no influence of NL on fore and hind quarter incidence (Franco et al. 2013). In addition, these authors observed that there was no effect of feeding level on meat incidence and that animals fed with higher NL showed lower percentage of bone. Fat incidence, instead, increased with the increasing of NL, as observed by Franco et al. (2013).

Values registered for IHDH foals slaughtered at 11 months are similar to those reported in the literature in the same horse breed (Tateo et al. 2008; De Palo et al. 2013). IHDH foals showed the higher lean incidence \( (74.48\% \text{ to } 78.96\%) \) in horse meat production if compared to results reported in other horses like Polish horses \( (60.63\% \text{ to } 68.45\%) \) (Znamirowska 2005; Znamirowska & Stanislawczyk 2005) or Galician Mountain horses \( (69.70\% \text{ to } 70.15\%) \) (Franco et al. 2013). Observing first quality cuts incidence on the entire carcass there is no influence of NL \( (P > 0.05) \). Instead, horses fed with 200% of NL showed a first cuts incidence on fore quarter and hind quarter, respectively, lower \( (P < 0.001) \) and higher \( (P < 0.05) \).

Observing tissue composition (Table 3) of various meat cuts of the IHDH carcass it is clear that in all cuts fat incidence tended to increase with the increasing of NL \( (P < 0.001) \), except for bacon which showed a higher fat incidence in NL180% foals and lower in the NL200% foals \( (P < 0.001) \). In contrast, meat and bone incidence tended to decrease with the increasing of NL \( (P < 0.001) \), except for the fore leg which showed no influence of NL on this parameter \( (P > 0.05) \). Moreover, bacon showed a different trend of meat incidence;

| Nutritive level | Significance | SEM |
|----------------|-------------|-----|
|                |             |     |
| LW (kg)        |             |     |
| 150%           | 448.13      |     |
| 180%           | 456.45      |     |
| 200%           | 473.15      | n.s.|
| CW (kg)        |             |     |
| 150%           | 330.60      |     |
| 180%           | 329.42      |     |
| 200%           | 345.41      | n.s.|
| DP (%)         |             |     |
| 150%           | 73.71       |     |
| 180%           | 72.60       |     |
| 200%           | 72.99       | n.s.|
| Carcass composition (%) |         |     |
| Fore quarter   | 37.63a      | 35.43a  | 39.73a  | ***  | 0.33 |
| Hind quarter   | 62.70a      | 65.07a  | 60.60a  | ***  | 0.49 |
| Lean           | 78.96a      | 74.48a  | 74.73a  | ***  | 0.64 |
| Fat            | 11.82a      | 15.95a  | 15.52a  | ***  | 0.12 |
| Bone           | 9.25a       | 9.55    | 9.77a   | **   | 0.10 |
| Carcass composition (%) |         |     |
| 1st quality† on carcass | 59.26    | 60.57   | 59.65   | n.s.  | 0.51 |
| 1st quality on fore quarter | 55.13a   | 55.78a  | 49.15a  | ***  | 0.55 |
| 1st quality on hind quarter | 72.86a   | 73.52a  | 75.52b  |     | 0.64 |

Significance: ***\( P < 0.001 \), **\( P < 0.01 \), *\( P < 0.05 \), n.s., not significant. †1st quality cuts: Steaks I-VIII, Loin + Steaks IX-XVIII, fore leg and tenderloin. Different letters in the same line show statistical differences (A, B: \( P < 0.01 \); a, b: \( P < 0.05 \)).

© 2014 The Authors. Animal Science Journal published by Wiley Publishing Asia Pty Ltd on behalf of Japanese Society of Animal Science
it was higher in the NL200% foals and lower in the NL180% foals (P < 0.001). Franco et al. (2013), studying two different finishing periods on 15-month-old horses observed a similar trend in the entire carcass, a higher fat incidence and a lower bone incidence in animals fed with higher NL. The same trend was observed by Vestergaard et al. (2007) studying the effect of length of finishing period on beef carcass characteristics. They observed an increasing trend of fat incidence and a decreasing trend of meat and bone incidence with the increasing of NL.

The physicochemical parameters of foal meat are shown in Table 4. Nutritive level had no effects on intramuscular protein and intramuscular fat content (P > 0.05), but affected moisture and ash content which were respectively lower (P < 0.05) and higher (P < 0.001) in horses fed with the higher NL. Few data are reported in the literature about NL and its effect on chemical composition of horse meat. In particular, contrasting results were reported about moisture content. Some authors observed no effect of finishing diet intensity on moisture content (Franco & Lorenzo 2014); other authors observed a decrease in moisture content with the increasing of finishing diet (Franco et al. 2013). However, moisture content reported in this study is similar to that reported in the same horse breed (Tateo et al. 2008; De Palo et al. 2013), in Barguete and Hispano-Breton foals (Juarez et al. 2009) and in other horse breeds (Badiani et al. 1997; Sarriés & Beriain 2005), but lower than what observed in Sanfratellano and Haflinger horse (Lanza et al. 2009), in Galician Mountain foals (Franco et al. 2011, 2013; Franco & Lorenzo 2014) and in Polish horse meat (Znamirowska & Stanislawczyk 2005). Intramuscular fat content did not show any variation in the three NLs considered. These results are in contrast with that observed by Franco et al. (2013) and Franco and Lorenzo (2014) who reported a great increasing of intramuscular fat content in animals fed with a higher finishing diet. However, intramuscular fat values reported by these authors are very low if compared to data reported in this paper, that, instead, are similar to what reported by other authors (Devic & Stamenkovic 1989; Pomianowski et al. 1994; Sarriés & Beriain 2005).

Table 3  Cuts incidence (%) and their tissue composition (%) of foals fed with low nutritive level (150%), medium nutritive level (180%) and high nutritive level (200%)

| Nutritive level | Significance | SEM |
|-----------------|--------------|-----|
| 150%            | 180%         | 200%|
| Hind leg        |              |     |
| Meat (%)        | 17.42 A      | 15.32 B | 22.67 C ||**||0.15 |
| Fat (%)         | 76.73 A      | 71.27 B | 71.47 C ||**||0.69 | |
| Bone (%)        | 16.05 A      | 19.47 B | 14.52 C ||**||0.31 | |
| Neck            | 9.53 Aa      | 8.98 Bb | 8.43 Cb ||**|0.17 | |
| Meat (%)        | 80.28 Aa     | 77.37 Ab | 71.45 Bb ||**|0.90 | |
| Fat (%)         | 5.33 A      | 11.12 Bb | 16.93 Cb ||**|0.35 | |
| Bone (%)        | 14.73 A      | 12.02 Bb | 11.92 Cb ||**|0.48 | |
| Briskets I-VIII | 5.70 A      | 6.42 B | 5.58 C ||**|0.05 | |
| Meat and bone (%) | 90.88 Aa | 82.32 Bb | 76.62 Cb ||**|0.61 | |
| Fat (%)         | 9.45 A      | 18.18 Bb | 23.72 Cb ||**|0.57 | |
| Briskets IX-XVIII | 7.20 Aa | 6.85 Ab | 5.53 B ||**|0.08 | |
| Meat and bone (%) | 77.67 Aa | 79.77 Bb | 70.31 Cb ||**|0.66 | |
| Fat (%)         | 22.67 A      | 22.57 Bb | 27.32 Cb ||**|0.30 | |
| Steaks I-VIII   | 5.00 A      | 4.75 B | 3.08 C ||**|0.06 | |
| Meat and bone (%) | 94.76 Aa | 94.87 Bb | 89.97 Cb ||**|0.90 | |
| Fat (%)         | 5.56 A      | 5.63 Bb | 10.37 Cb ||**|0.38 | |
| Loin + steaks IX-XVIII | 10.40 Aa | 8.47 Bb | 8.68 Cb ||**|0.13 | |
| Meat and bone (%) | 98.17 Aa | 94.47 Bb | 88.63 Cb ||**|0.92 | |
| Fat (%)         | 2.16 A      | 6.03 Bc | 11.70 Cc ||**|0.42 | |
| Bacon           | 9.21 A      | 9.60 Ab | 7.02 Bb ||**|0.13 | |
| Meat (%)        | 56.63 A      | 49.73 Bb | 64.67 Cb ||**|0.68 | |
| Fat (%)         | 43.80 A      | 50.77 Bb | 35.67 Cb ||**|0.73 | |
| Fore leg        | 32.17 A      | 36.42 Bb | 36.35 Cb ||**|0.35 | |
| Meat (%)        | 77.58 A      | 75.88 Bb | 76.80 Cb | n.s.|0.62 | |
| Fat (%)         | 9.21 A      | 14.33 Bb | 13.38 Cb | ***|0.21 | |
| Bone (%)        | 13.50 A      | 11.28 Bb | 10.18 Cb | ***|0.20 | |
| Tenderloin      | 2.76 A      | 2.55 Bb | 2.27 Cb | ***|0.04 | |
| Meat (%)        | 93.18 A      | 85.60 Bb | 79.97 Cb | ***|1.03 | |
| Fat (%)         | 7.15 A      | 14.90 Bb | 20.37 Cb | ***|0.66 | |

Significance: ***P < 0.001, **P < 0.01, n.s., not significant. Different letters in the same line show statistical differences (A, B, C: P < 0.01; a, b: P < 0.05).
Tateo et al. 2008; Juarez et al. 2009; De Palo et al. 2013). This lack of variation of intramuscular fat content could be explained by the tendency of horses, depending on their genetics, to concentrate adipogenesis in the subcutaneous district rather than in the intramuscular one (Rossier & Berger 1988; De Palo et al. 2012). Ash content tends to increase with increasing NL (P < 0.001). Also Franco & Lorenzo (2014) observed an effect of finishing diet intensity on NL; however, these values are similar to that reported by other authors (Devic & Stamenkovic 1989; Pomianowski et al. 1994; Sarriés & Beriain 2005; Tateo et al. 2008; Juarez et al. 2009; De Palo et al. 2013).

Regarding rheological parameters, no significant (P > 0.05) differences were found among groups and only WBSF was slightly influenced by NL. However, Boleman et al. (1997) suggested the following categories for beef steaks on the grounds of the shear force measured with WB test: tender from 2.77 to 3.58 kg; moderate 4.08 to 5.40 kg; and tough 5.90 to 7.21 kg. According to this classification IHDH foal meat shear force shown in the present study implies that it belongs to the moderate category.

Fatty acid profile is reported in Table 5. Only a few significant differences were found in fatty acid profile of intramuscular fat. In particular, horses fed with lower NL showed a higher content of C12:0, of saturated fatty acids (SFA) and higher SFA/polyunsaturated fatty acids (PUFA) values (P < 0.05). However, intramuscular fatty acid profile showed a prevalence of SFA (45.36% to 47.75%). Mono-unsaturated fatty acids (MUFA) and PUFA content were similar. By studying the intramuscular fat composition of IHDH foals slaughtered at 11 months, Tateo et al. (2008) found the same distribution shown in the present study. These results agreed with results reported by De Palo et al. (2013), Lanza et al. (2009) and Juarez et al. (2009). Other authors found MUFA (Renon et al. 1977; Badiani et al. 1997; Franco et al. 2013) or PUFA (Payne 1971; Jankowska et al. 1996) as the predominant fatty acids. Palmitic acid (C16:0) was the most present in horse meat and it was the predominant one within the SFA, as observed by other authors (Tateo et al. 2008; Lanza et al. 2009; De Palo et al. 2013). Differences in fatty acid distribution in intramuscular fat between the different breeds investigated in the literature could be due to many factors. A hypothesis could be the differences in the activity of the desaturases and the elongase enzymes between breeds (Wood et al. 2008). However, horse meat showed a great quantity of UFA, and this parameter is not affected by nutritive level.

Table 4  Chemical composition and rheological properties of meat of foals fed with low nutritive level (150%), medium nutritive level (180%) and high nutritive level (200%)

| Nutritive level | Significance | SEM |
|-----------------|--------------|-----|
| 150%           | 180%         | 200%|
| Moisture (g/100 g) | 71.26a | 71.32a | 68.98a | * | 0.82 |
| Protein (g/100 g) | 21.90 | 21.24 | 20.81 | n.s. | 0.48 |
| Fat (g/100 g) | 2.96 | 3.11 | 3.15 | n.s. | 0.38 |
| Ash (g/100 g) | 1.36a | 1.38b | 2.02** | *** | 0.08 |
| Water-holding capacity (%) | 18.05 | 19.49 | 18.80 | n.s. | 0.55 |
| Post-thawing losses (%) | 9.06 | 7.27 | 8.69 | n.s. | 0.78 |
| Collagen solubility (%) | 18.52 | 21.46 | 20.41 | n.s. | 0.78 |
| WBSF on cooked meat (kg) | 4.78a | 5.31b | 5.38b | * | 0.18 |

**Significance:** ***P < 0.001, *P < 0.05, n.s., not significant. Different letters in the same line show statistical differences (A, B: P < 0.01; a, b: P < 0.05). WBSF, Warner-Bratzler Shear Force.

Table 5  Fatty acid profile (% of fatty acids methyl esters) from Longissimus dorsi muscle of foals fed with low nutritive level (150%), medium nutritive level (180%) and high nutritive level (200%)

| Nutritive level | Significance | SEM |
|-----------------|--------------|-----|
| 150%           | 180%         | 200%|
| C 12:0 | 1.61a | 1.28b | 1.45 | * | 0.18 |
| C 14:0 | 6.09 | 5.34 | 5.60 | n.s. | 0.21 |
| C 14:1 | 1.40 | 1.36 | 1.40 | n.s. | 0.12 |
| C 16:0 | 33.28 | 31.77 | 32.53 | n.s. | 1.08 |
| C 16:1 | 1.25 | 1.11 | 1.14 | n.s. | 0.09 |
| C 18:0 | 6.81 | 7.02 | 6.55 | n.s. | 0.21 |
| C 18:1 | 25.80 | 26.01 | 25.44 | n.s. | 1.22 |
| C 18:2 | 1.06 | 1.27 | 1.17 | n.s. | 0.09 |
| C 18:2 n6 | 17.71 | 18.82 | 18.04 | n.s. | 0.95 |
| C 18:3 n6 | 0.91 | 0.66a | 1.12b | ** | 0.09 |
| C 18:3 n3 | 4.48 | 4.50 | 4.31 | n.s. | 0.28 |
| C 20:4 n6 | 0.77 | 0.56 | 0.67 | n.s. | 0.11 |
| C 20:5 n3-6 | 0.23 | 0.23 | 0.22 | n.s. | 0.03 |
| SFA | 47.75a | 45.36b | 46.12 | * | 1.43 |
| MUFA | 23.84 | 28.47 | 25.30 | n.s. | 1.01 |
| PUFA | 28.44 | 25.82 | 27.94 | n.s. | 1.56 |
| SFA/MUFA | 1.68 | 1.60 | 1.70 | n.s. | 0.14 |
| SFA/PUFA | 1.99a | 1.74b | 1.84 | * | 0.21 |

**Significance:** **P < 0.01, *P < 0.05, n.s., not significant. MUFA, mono-unsaturated fatty acids; PUFA, poly-unsaturated fatty acids; SFA, saturated fatty acids.
Conclusions
Generally, NL had no effect on fatty acid profiles, chemical composition and rheological properties of IHDH foal meat. Some differences were observed for carcass composition and for cuts incidence on carcass. Live weight at slaughtering, carcass weight and dressing percentage were not affected, although there was a slight live weight improvement with the increasing of NL. From data obtained on the quality of IHDH foal meat, it can be deduced that it is characterized by low intramuscular fat content and by a good UFA content. Also texture traits showed good meat tenderness in all studied theses. Carcasses of animals fed with higher NL showed a higher fat incidence and a lower lean incidence. From this study, it seems to be better to feed horses with a medium NL (180%) to obtain the better compromise for a good production from both a quality and a quantity point of view. Probably, the tendency of IHDH foals to concentrate adipogenesis in the subcutaneous district could explain the lack of influence of NL on meat quality parameters and its influence on carcass and cuts composition, which tend to be richer in fat.

All these findings in the present paper contributed to the description of horse meat physicochemical, chemical and nutritional composition and they represent another point which can be useful to extend knowledge about this product.

ACKNOWLEDGMENTS
The authors want to thank Dr Calzaretti Giovanna and Mr D’Onghia Francesco for their skilled help in meat sampling and in several laboratory analyses.

REFERENCES
Badiani A, Manfredini M, Nanni N. 1993. Qualità della carcassa e della carne di puledri lattoni. Zootecnica e Nutrizione Animale 19, 23–31.
Badiani A, Nanni N, Gatta PP, Tolomelli B, Manfredini M. 1997. Nutrient profile of horsemeat. Journal of Food Composition and Analysis 10, 254–269.
Bertram HC, Andersen HJ, Karlsson AH, Horn P, Hedegaard J, Nørgaard L, Engelsen SB. 2003. Prediction of technological quality (cooking loss and Napole Yield) of pork based on fresh meat characteristics. Meat Science 65, 707–712.
Bligh EG, Dyer WJ. 1959. A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology 37, 911–917.
Boleman SJ, Boleman SL, Miller RK, Taylor JF, Cross HR, Wheeler TL, et al. 1997. Consumer evaluation of beef of known categories of tenderness. Journal of Animal Science 75, 1521–1524.
Bouton PE, Harris PV, Shorthose WR. 1971. Effect of ultimate pH upon the water-holding capacity and tenderness of mutton. Journal of Food Science 36, 435–439.
Catalano AL, Miraglia N, De Stefano C, Martuzzi F. 1986. Produzione di carne da cavalli di diverse categorie. Obiettivi e Documenti Veterinari 7, 69–73.
Centoducati P, Maggiolino A, De Palo P, Tateo A. 2012. Application of Wood’s model to lactation curve of Italian Heavy Draught horse mares. Journal of Dairy Science 95, 5770–5775.
De Palo P, Maggiolino A, Centoducati P, Tateo A. 2012. Colour changes in meat of foals as affected by slaughter-age and post-thawing time. Asian-Australasian Journal of Animal Science 25, 1775–1779.
De Palo P, Maggiolino A, Centoducati P, Tateo A. 2013. Slaughtering age effect on carcass traits and meat quality of IHDH foals. Asian-Australasian Journal of Animal Science 26, 1637–1643.
De Palo P, Maggiolino A, Lestingi A, Tateo A. 2009. Comparison between carcasses of artificially suckled I.H.D.H. (Italian Heavy Draught Horse) foals slaughtered at 6 months and traditional carcasses obtained by foals slaughtered at 11 and 18 months. Italian Journal of Animal Science 8, 700–702.
Dević B, Stamenković T. 1989. Basic characteristics of the horse meat and the possibilities for its processing. Tehnologija mesa 30, 232–237.
Franco D, Crescente S, Vazquez JA, Gomez M, Lorentzo JM. 2013. Effect of cross breeding and amount of finishing diet on growth parameters, carcass and meat composition of foals slaughtered at 15 months of age. Meat Science 93, 547–556.
Franco D, Lorentzo JM. 2014. Effect of muscle and intensity of finishing diet on meat quality of foals slaughtered at 15 months. Meat Science 96, 327–334.
Franco D, Rodriguez E, Purrinos L, Crescente S, Bermudez R, Lorentzo JM. 2011. Meat quality of ‘galician Mountain’ foals breed. Effect of sex, slaughter age and livestock production system. Meat Science 88, 292–298.
ISO (International Organization for Standardization). 1973. Determination of Total Fat Content. ISO R-1443-1973. International Standards Meat and Meat Products. International Organization for Standardization, Genève, Switzerland.
ISO (International Organization for Standardization). 1978. Determination of Nitrogen Content. ISO R-937-1978. International Standards Meat and Meat Products. International Organization for Standardization, Genève, Switzerland.
Jankowska B, Korzeniowski W, Kwiatkowska A. 1996. Fatty acid composition of horses tissues depending on their position in the carcass. Polish Journal of Food and Nutrition Sciences 5, 41–49.
Juarez M, Polvillo O, Gomez MD, Alcalde MJ, Romero F, Varela M. 2009. Breed effects of carcass and meat quality of foals slaughtered at 24 months of age. Meat Science 83, 224–228.
Kindt E, Gueneva-Boucheva K, Rekhter MD, Humphries J, Hallak H. 2003. Determination of hydroxyproline in plasma and tissue using electrospray mass spectrometry. Journal of Pharmaceutical and Biomedical Analysis 33, 1081–1092.
Lanza M, Landi C, Scerra M, Galofaro V, Pennisi P. 2009. Meat quality and intramuscular fatty acid composition of Sanfratellano and Hallinger foals. Meat Science 81, 142–147.
Manfredini M, Badiani A, Nani N. 1992. Rese di macellazione, sviluppo dei componenti del quinto quarto e
características quantitativas e qualitativas das carcassas de puledro e caballo. *Agricola Ricerca* **14**, 23–40.

Martin-Rosset W, Boccard R, Jussiaux M, Robelin J, Trillaud-Geyl C, Nicolas N, *et al.* 1980. Rendement et composition des carcasses du poulain de boucherie. *Bulletin Technique Centre de Recherches Zootechniques* **41**, 57–64.

Martin-Rosset W, Vermorel M, Doreau M, Tisserand JL, Andrieu J. 1994. The French horse feed evaluation systems and recommended allowances for energy and protein. *Livestock Production Science* **40**, 37–56.

Martuzzi F, Catalano AL, Sussi C. 2001. Caratteristiche e caballo. *Agricola Ricerca* **14**, 23–40.

Martin-Rosset W, Boccard R, Jussiaux M, Robelin J, Trillaud-Geyl A. 1984. Caractéristiques des carcasses et qualité de la viande de cheval. In: Jarrige R, Martin-Rosset W (eds), *Le Cheval*, pp. 601–610. INRA, Paris.

Rossier E, Berger C. 1988. La Viande de Cheval: Des Qualités Indiscutables et Pourtant Meconnues. *Cahiers de Nutrition et de Diététique* **23**, 35–40.

Sarriés MV, Beriain MJ. 2005. Carcass characteristics and meat quality of male and female foals. *Meat Science* **70**, 141–152.

Sarriés MV, Beriain MJ. 2006. Colour and texture characteristics in meat of male and female foals. *Meat Science* **74**, 738–745.