Assessment of the nutritional status of lactating donkeys by an integrated approach as a tool for breeding management

ABSTRACT: The assessment of the nutritional status (NS) represents a complex task, because it depends by several factors. This study aims to define which factors mostly affect the lactating donkey’s NS, considering parameters that can be easily measured in field conditions; to implement the scoring system for neck adiposity specifically for donkey; and to evaluate the stockperson perception of lactating donkey’s NS. Fifty-three healthy lactating donkeys, 7 Martinafranca, 10 Ragusana, 2 Romagnola, and 34 crossbreeds were evaluated. Bodyweight (BW), lengths, girth and abdominal (waist) circumferences, neck length, neck height (NH), neck thickness (NT) and neck circumferences were measured, and body condition score (BCS) and fatty neck score (FNS) were rated. Also stockperson BCS evaluation was assessed. For each animal included in the study, oral cavity observation was performed and month of lactation was recorded.

A Principal Component analysis, performed including all the variables measured, revealed 3 principal components (PC) that together explained 84.37% of the variation of the NS among the lactating donkeys. PC1 revealed meaningful relations between BCS and neck measurements. Age and month of lactation seemed to be more independent factors affecting the NS. NH and NT had the strongest positive association with FNS ($r_s = 0.83; P < 0.001$). Mean NC:neck heigh ratio and Mean NC:neck thickness ratio had the strongest negative association with FNS ($r_s = -0.83; P < 0.001$) ($r_s = -0.82; P < 0.001$), respectively. No correlations were found between BCS and body morphometric measurements. Stockperson evaluation resulted to be influenced by abdominal (waist circumference) ($r_s = 0.41, P = 0.002$), in contrast to researchers’ assessment.
A significant inverse relationship was highlighted between BCS and the presence of dental abnormalities (Chi squared P < 0.05).

The overall adiposity is the most indicator for the NS evaluation: the assessment of FNS and BCS seem to improve the assessment of the NS. Body morphometric measurements are not adequate for the NS assessment of donkeys. NT was a suitable morphometric for assessment of neck regional adiposity. During NS evaluation resulted important to consider the inspection of mouth conditions and the stage of lactation. Breeders need additional training in how to properly evaluate the NS.

**Key words:** Donkey, nutritional status, body condition, management, fatty neck score
INTRODUCTION

The nutritional status of livestock has a great importance in the breeding farm. It influences their productivity, health, reproduction and welfare (Quaresma et al., 2013). Therefore, the assessment of the nutritional status (NS) is considered a fundamental indicator for the overall physical exam of livestock animals. In particular, several studies have shown its importance in dairy animal breeding (Mulligan et al., 2006). In the last few years the breeding of donkeys for the production of milk has created a lot of interest. This product is of growing relevance and scientific interest in Europe, where it is used for different purposes. It is proven that it can be a useful substitute foodstuff for children affected by cow’s milk protein allergy or multiple food intolerance (Monti et al., 2007; Monti et al., 2012) and a role of donkey milk for arteriosclerosis prevention and modulation of the immune response in elderly people has been suggested (Tafaro et al., 2007; Amati et al., 2010). The donkey milk has also been reported as probiotic food (Coppola et al., 2002) and it is widely used in Europe for cosmetic production (Cosentino et al., 2012). In addition, it has been showed that donkey milk possesses interesting antimicrobial that an important role in the improvement of the host defence in the infant newborn and infants which either cannot be nourished by human milk or are allergic to other milks. (Nazzaro et al., 2010). According to D'Alessandro and Martemucci (2011) these potential uses of donkey’s milk have shown a positive trend in donkey population, with an increase of the number of animals bred in Italy. Although several data covering the potential of donkey’s milk use is available, the information concerning the management and the assessment of lactating donkeys’ NS is lacking. It is widely recognized that the assessment of NS of livestock can represent a complex task (Leitch, 1962). It is described by many parameters
and is not simple to recognize which is the most important (Becvarova et al., 2009) since they are linked in an intricate series of interactions.

Among the methods that can be used to evaluate the NS, body condition score (BCS) method is one of the most frequently adopted. Different BCS scoring systems are known and they include the visual appraisal and palpation of the adipose tissue site by use of a 5 or 9-point scale (Burden, 2012; Pearson and Ouassat, 2000). Other indexes from anthropometric measurements are not applicable since body morphometric may vary within the same species even if many are proposed for horses and ponies (Carter et al., 2009; Pleasant et al., 2013) and donkeys (Mendoza et al., 2015). However, more objective techniques to measure subcutaneous fat and BCS correlation such as dilution techniques, computed tomography or dual-energy X-ray absorptiometry (Quaresma et al., 2013) present important limitations as they are expensive and not easily applicable on farm.

Nevertheless, the animal-based indicators such as BCS used to assess appropriate nutrition are an essential component of the equine welfare assessment (Dalla Costa et al., 2014) and for assessing NS which may be an indicator linked to the overall welfare and animal production (Ireland et al., 2012). According to Cappai et al. (2013) it is necessary to emphasize that a complete assessment of the NS is the result of the evaluation of several components like age, physiological status, body morphometry, adiposities site localization and extension, the status of dental board (Du Toit et al., 2008, Du Toit et al., 2009). Also, the stockperson plays an important role in maintaining and guaranteeing the NS, since they are essential to determining animal welfare and performance (Hemsworth and Coleman, 2000). According to the Equine health welfare strategy it is the keeper's responsibility to be able to recognize disease and seek for any veterinary assistance (Ireland et al., 2012)

Since nutritional assessment may have a direct impact on both dairy donkey production and welfare further investigations are needed. The objectives of this study focus on measuring and
defining parameters that are related to nutritional assessment that can be used by producers and clinicians. The aims of the study are: 1) to define which factors mostly affect the lactating donkey’s NS, considering parameters that can be readily assessed in order to provide economic, simple and rapid tools, for both clinician and breeder for performing a lactating donkeys’ NS evaluation; 2) to implement the scoring system for neck adiposity specifically designed for the donkey and evaluate the association between measurements for the assessment of the overall adiposity in donkey; 3) to evaluate the perception of the breeder of the lactating donkey’s NS.

**MATERIALS AND METHODS**

The institutional animal care and use committee statement should appear as the first item in MATERIALS AND METHODS and should specify which publically available animal care and use standards were followed (JAS).

*Population Description*

This study was conducted during the spring season (May to June). All the lactating donkeys present in dairy farms located in the North West of Italy were evaluated. The animal were kept in six breeding farms authorized from Italian’s goverment welfare rules for equids (OR ASL TO-CN) to produce and commercialize milk. All the donkeys included in this study were bred in semi-extensive farms with free access to drinking water and forages. Fifty-three healthy lactating donkeys, 7 Martinafranca, 10 Ragusana, 2 Romagnola, and 34 crossbreeds, of age (median (interquartile range)) 9 (7-12) years, estimated bodyweight (BW) 314.5 (269-350) kg and mean month of lactation 4±3 months were examined.

*Morphometric measurements*
The following body measurements were taken on each animal, using a soft measuring tape: 1) body length, measured from the point of the shoulder (intermediate tubercle of humerus) to the pin bone (ischiatic tuberosity); 2) body length, measured from the point of the shoulder (intermediate tubercle of humerus) to the point of the hip (tuber coxae) in centimetres (cm); 3) girth circumference, taken around the body, caudal to the elbow (olecranon tuber), two centimetres behind the highest point of the withers; 4) waist (abdominal) circumference, measured two-thirds of the distance from the point of the shoulder to the point of the hip; 5) neck length, from the poll to the highest point of the withers; 6) neck circumference (NC) at 0.25, 0.50, 0.75 of neck length; 7) neck height (NH) at 0.50 of neck length, taken from the dorsal midline of the neck to estimated differentiation between the crest (tissue apparent above the ligamentum nuchae) and neck musculature; 8) neck thickness (NT) at 0.50 of neck length, from the estimated differentiation between the crest and the neck musculature, from one side to the other of the neck.

Bodyweight (BW) was calculated using the formula suggested by Pearson and Ouassat (2000):

$$BW(\text{kg}) = \frac{[\text{girth(cm)}^{2.12} \times \text{length(cm)}^{0.688}]}{3801}$$

Four independent trained assessors rated the body condition score (BCS) from 1 (poor) to 5 (obese), using a scoring system previously established (Burden, 2012). The median of four scores rounded to nearest whole or half score increment was used for the analysis. Intra-class correlation coefficients for the reliability of individual assessors scores were 0.85 for BCS and 0.58 for FNS.

The stockpersons were asked to evaluate the body condition score according to a 5 point scale, with the help of a chart representing the different scores (bibliographic reference). The farmers rated the BCS through visual assessment and palpation of animals.
Even if a neck score was proposed by Mendoza et al., 2015 on a 0-4 points scale, The authors developed a new judgment system of the neck fat deposition (fatty neck score) based on 0-5 points scale as already developed for horses. The researchers judged the fatty neck score (FNS) with visual inspection and palpation of the fat deposition between the topline of the neck and the muscular line, as described in Table 1. This scoring system is based on a 6 point scale in the same way as proposed for horses (Carter et al., 2009).

**Oral cavity assessment**
Observation of oral cavity was performed to assess the presence of quidding and dental abnormality like sharp points and hooks. The same evaluator used a scale for assessment of the mouth conditions where 0 is “normal ”, 1 is “discrete teeth conditions and quidding ”, 2 is “poor ”.

**Statistical analyses**
The analysis was performed with IBM SPSS Statistics 21 software (IBM corp., 2012). Median (interquartiles) and mean values [± SD] were calculated for the following parameters: age, month of lactation and body measurements. A Principal Component Analysis PCA (correlation matrix, no transformation) was performed to reduce the variables to factors: data assumption was checked, Keiser-Meyer-Olkin (KMO) and Barlett’s test were performed to test the suitability of the data for structure detection. Factors with eigenvalues greater than 1 were considered. Ratios of girth:length, girth:BW, waist:length, waist:BW, waist:girth, 0.50 NC:neck length, 0.50 NC:neck height, 0.50 NC:neck thickness, mean NC: neck length, mean NC:neck height, mean NC:neck thickness were calculated. Mean NC was calculated as the average of 0.25 NC, 0.50 NC and 0.75 NC. Possible associations between variables were quantified using Spearman’s rank correlation coefficient (r_s).
Inter-observer reliability of researchers and farmers when assessing BCS was evaluated by intra-class correlations and Kendall’s Coefficient of concordance. Chi-squared test was used to investigate possible relations between researchers’-BCS with lactating donkeys’ mouth conditions.

RESULTS

A good suitability of data for PCA was valued (KMO = 0.80 and Barlett’s test, $P < 0.001$). The PCA was performed including all the variables measured on each animal that represent the most used parameters in the practice to evaluate the NS. It revealed 3 principal components that together explained 84.37% of the variation of the NS among lactating donkeys. Table 2 and Fig. 2 display the loadings of the variables on the first, second and third component and show how the different variables are related to each other. In particular, FNS, NT, BCS and NH present high positive loadings on the first component and seem to be related in the definition of the NS. Always on the first component, the presence of dental abnormalities shows high negative loadings and appears to negatively influence the NS. PC2 and PC3 are characterized by month of lactation and age respectively that probably have a more independent influence on the NS (Table 2).

Median BCS and FNS for lactating donkeys were 2.5 (2–3) and 2.5 (1.5–3) respectively. No significant correlations between morphometric measurements and BCS were found (Table 3), however, our results highlighted a positive and significant correlation between BCS and FNS ($P < 0.001$) (Table 3).

Moreover, FNS was positively associated with NH and NT ($P < 0.001$) and negatively associated with mean NC:neck height and mean NC:neck thickness ($P < 0.001$) (Table 4; Fig. 4). We found also other significant but lower correlations between FNS and 0.50 NC:neck height and 0.50 NC:neck thickness ($P < 0.001$) (Table 4; Fig. 5).
On the overall, our results suggest that the FNS developed in this study and described in Table 1 is the most explicative variable for describing the NS of lactating donkeys. Generally, the NT is proposed as an index of the neck adiposity. However, in consideration of anecdotal evidence, we proposed to measure not only the NT but also the NH as a parameter that could be associated to the FNS score. Both parameters are well associated to the score proposed ($P < 0.001$). For this reason, a reference range table of the NT according to the FNS score is proposed (Table 1).

The Kendall’s coefficient of concordance between researchers’ and farmers’ scores for BCS was low (0.28) showing a substantial disagreement between their evaluation. We only found a significant but rather low correlation between waist (abdominal) circumference and farmer’s-BCS ($r_s=0.41$, $P=0.002$) (Table 3).

An inverse relationship was pointed out when testing researchers’-BCS and mouth conditions (Chi squared $P<0.05$).

**DISCUSSION**

The NS is a fundamental indicator of health and welfare but, although in recent years the number of dairy donkey farms is increasing, its assessment has not been thoroughly investigated yet in this species. However, the evaluation of the NS is a complicated task, since different variables are used for measure the NS in producing animals. Thus, the mechanism that determines the NS is too complex to be explained only by correlation and univariate analysis. For this reason the PCA could help to identify which components are important to explain the NS. Then, a PCA analysis was performed including all the variables measured in this study that represent the most used parameters in the practice to evaluate the NS under different points of view. According to Table 2, three principal components were identified and
together they describe the 84.37% of the variation among the lactating donkeys included in our study. The component one has the high loading for FNS, NT, BCS and NH. Consequently, it could be identified as the overall adiposity status of the animal. In particular, the FNS is resulted as the main factor that describe the component one. However, it represents a regional fat deposition (Carter et al., 2009). Indeed, donkeys lay down fat stores in localized areas, especially on the neck, and these regional deposits can remain when overall weight is loss (Burden, 2012; Burden and Thiemann, 2015). The second component was described by the month of lactation. This factor should be always considered during the evaluation of the NS of dairy animals. In fact, the lactation period is an high demand period and consequently, if the animals are not adequately supported, they can lose their BW (Heidler et al., 2004; Mulligan et al., 2006; Roche et al., 2007). The third component includes the age of the animals that probably is an independent factor related to the animal and not to the NS (Michela potresti aggiungere un commento relativo ai dati grezzi della tabella?)

At the moment the most common method used to assess the NS, even in donkeys, is by evaluating the body condition score (BCS) and different BCS scoring systems, specific for donkeys, have been proposed and developed (Pearson et Ouassat, 2000; Burden, 2012). The BCS systems include both visual and palpation appraisal of adipose tissue and then, a score from 1-5 or 1-9, depending on which scale is used, is assigned (Pearson et Ouassat, 2000; Burden, 2012). The donkeys tend to be predisposed to depositing fat in localized areas: neck, rib cage and rump. However, when utilizing BCS as a source to measure the NS and or welfare, one must keep in mind that there is a certain level of subjectivity. Consequently, for improved evaluation of NS, it is best to combine several parameters along with BCS to evaluate the NS in lactating donkeys. In fact the NS is a complicated task because the status and the needs may change according to the stage of lactation and or gestation and or work level of the animal.
Body morphometrics have been proposed for evaluating the NS of animals (Becvarova et al., 2009). In particular, morphometric measurements are suggested to analyzed the NS of equines (Cappai et al., 2013; Martinson et al., 2014). Also, correlation were previously demonstrated between BCS and morphometric measurements (Carter et al., 2009; Dugdale et al., 2011).

However, when measuring the morphometric parameters and comparing the results in this study, we found that there was not a correlation to morphometric parameters and BCS in donkeys. On this regard, it is important not forget that the donkey is not a small horse, although both belong to Equidae family. They are different for many aspects, including, in particular, anatomical variation and physical conformation (Burden and Thiemann, 2015). This variability is not only interspecific, but also intraspecific. In fact, according to Kugler et al. (2008), taking an overview of the donkey population data in Europe, mostly the animals are crossbreeds that cannot be categorized into specific breeds. Also in our study the donkeys were mainly crossbreeds, in contrast to most other livestock breeds were pedigree and high genetic selection exist. All led to a development of much diversity, in particular several differences can be found, especially as far as body size is concerned. Therefore, unlike horses and ponies, the morphometric measurements, although more easily performed in the absence of trained evaluators, cannot provide an objective alternative for lactating donkeys’ NS evaluation.

Consequently, in the present study were analyzed other factors that should be considered during lactating donkeys’ NS evaluation, in order to provide economic, simple and rapid tools, for both clinician and breeder. The FNS is the other parameter suggests to assess the NS, since it is evaluated during the BCS method. Our results show that FNS is well correlated with the BCS like described in other studies (Carter et al., 2009; Mendoza et al., 2015). However, as previously reported, we should keep in mind that it is an independent measurements of adiposity, since it represents a regional fat deposit (Carter et al., 2009, Burden, 2012, Giles et al., 2015) that it is not well investigated in donkeys. Our findings confirm that it is a regional
fat deposit that correlate with some of the morphological parameters of the neck dimension and for what it should be proposed a specific scoring scale. Either neck high (NH) and neck thickness (NT) are a suitable and objective morphometric measurements for the assessment of neck adiposity. However, in contrast to others studies, the FNS is not positive correlated with the ratio 0.50 NC:Neck height, Mean NC:Neck height, 0.50 NC:Neck thickness, Mean NC:Neck thickness (Table 4; Fig. 4; Fig. 5). On the contrary, it is significantly and negatively correlated with them. This result could be related to the fact that the shape of the neck of donkey is different from that of the horse. The donkey shorter neck and the more protruded manubrium support an heavy skull (Burden and Thiemann, 2015), leading to a remarkably thickness of the cutaneus colli muscle that even covers the middle one-third of the jugular furrow (Burnham, 2002). In our opinion, we used the NT for the evaluation of the FNS since, unlike the other equids, the adipose tissue tend to droop sideways to the crest of the neck (Burden, 2012). Using the population of lactating donkeys included in the present study, in was been possible to develop an objective scale of reference for the FNS, considering its strong association with NT (Table 1).

Furthermore, the findings of the study supports that mouth conditions and, in particular dental disorders, should be considered during the lactating donkeys’ NS evaluation. According to Rodrigues et al. (2013) dental disorders, like sharp points and hooks, are recognized as major but often unnoticed and so not treated disorders of equids, including horses and donkeys. Besides, several studies have demonstrated that dental disorders in donkeys are associated with poor body condition score and weight loss (Du Toit et al., 2008, Du Toit et al., 2009), as well as our results confirm, revealing a significant inverse relationship between BCS and mouth conditions. Interestingly, when the donkey dairy producers were asked to evaluate BCS, we did find that donkeys with a greater waist (abdominal) circumference have received a higher BCS from the
producer. Instead this finding was not true for the researchers whose were trained in BCS scoring. Probably the owners are misled by anatomical abdomen conformation of the donkeys. In fact, donkeys are anatomically characterized by pendulous abdomen (Pearson et al., 2001; Burden, 2012). Furthermore, this result suggests that, even though a correlation between morphometric measurements and BCS was not found, the producers may rely on morphometric measurements to evaluate BCS.

CONCLUSIONS

The difficulty to define and assess the NS it is been further elucidated, highlighting the importance to consider parameters that may be employed in field condition by both clinicians and breeders. According to the PCA analysis the overall adiposity is the most indicator for the NS evaluation. In particular, the assessment of FNS and BCS seem to improve the assessment of the NS. Therefore, although the FNS is an indicator of regional adiposity, showing a well correlation to neck morphometric measurements, it seems play also an important role in the NS definition. For this reason, a score specific for donkeys is proposed to judge this regional adiposity status. Furthermore, in contrast to other studies, the body morphometric measurements are not adequate for the NS assessment of donkeys. Moreover, during the examination of the donkey’s NS should be always include the inspection of the mouth condition, taking in account also the month of lactation. Instead, the age should be view as an independent factor that could influence the BCS, especially in older animals that actually were not involved in the present study.

The findings indicate also that breeders need additional training in how to properly evaluate the NS because the current points of measurement and assessment may in the end compromise the overall welfare of donkeys.
More study are required including an higher numbers of animals and considering also other variables that could affect the donkey’s NS assessment, like feeding and management, to investigate any relationship.

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### Table 1. Fatty neck scoring system for donkeys

<table>
<thead>
<tr>
<th>Score</th>
<th>Illustrations of individual fatty neck score</th>
<th>Description</th>
<th>Neck thickness range according to FNS (in cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><img src="image.png" alt="Image" /></td>
<td>Neck thin with absence of a visual and palpable crest.</td>
<td>&lt;14</td>
</tr>
</tbody>
</table>
1. Neck still thin with crest no visible, but slight filling felt with palpation. 

2. Neck with moderate deposition of fat. Noticeable appearance of a crest, with fat deposited fairly evenly from poll to withers. Crest easily cupped in one hand and bent from side to side.

3. Neck enlarged and thickened. Crest is palpable from poll to withers and fills cupped hand and begins to make longitudinal fat deposit to both sides of the neck.

4. Neck very enlarged and thickened. Crest grossly thickened with fat deposits from poll to withers, forming longitudinal bands of fat on the both neck sides. Crest cannot easily bent from side to side.

5. Neck very enlarged and thickened. Crest very thickened with hard fat deposits, rounded along the two sides of the neck.

Table 2. PCA of quantitative data calculated from correlation matrix for lactating donkeys sampled

<table>
<thead>
<tr>
<th></th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Age</td>
<td>-0.224</td>
</tr>
<tr>
<td>Month of lactation</td>
<td>-0.208</td>
</tr>
<tr>
<td>BCS&lt;sup&gt;b&lt;/sup&gt;</td>
<td><strong>0.896</strong></td>
</tr>
<tr>
<td>Morphometric measurement</td>
<td>researchers’-BCS (n = 53)</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td></td>
<td>$r_a$</td>
</tr>
<tr>
<td>BW$^c$</td>
<td>0.15</td>
</tr>
<tr>
<td>Girth</td>
<td>0.15</td>
</tr>
<tr>
<td>Waist (abdominal)</td>
<td>0.22</td>
</tr>
</tbody>
</table>

For each parameter, the higher loadings are bold typed.

Body condition score

Fatty neck score

Table 3. Associations of body condition score (BCS) with morphometric measurements of body adiposity
<table>
<thead>
<tr>
<th>Morphometric measurement</th>
<th>FNS (n = 53)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( r_s )</td>
</tr>
<tr>
<td>Girth:Length</td>
<td>-0.02</td>
</tr>
<tr>
<td>Girth:BW</td>
<td>0.13</td>
</tr>
<tr>
<td>Waist:Length</td>
<td>0.11</td>
</tr>
<tr>
<td>Waist:BW</td>
<td>0.13</td>
</tr>
<tr>
<td>Waist:Girth</td>
<td>-0.13</td>
</tr>
<tr>
<td>FNS(^d)</td>
<td>0.84</td>
</tr>
</tbody>
</table>

\(^{a}\) Spearman rank correlation coefficient.
\(^{b}\) P value for a test of the null hypothesis that the variables are independent.
\(^{c}\) Bodyweight
\(^{d}\) Fatty neck score

**Table 4.** Associations of fatty neck score (FNS) with morphometric measurements of neck adiposity
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50 NC:Neck length</td>
<td>0.35</td>
<td>0.011</td>
</tr>
<tr>
<td>Mean NC:Neck length</td>
<td>-0.01</td>
<td>0.925</td>
</tr>
<tr>
<td>0.50 NC:Neck height</td>
<td>-0.58</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean NC:Neck height</td>
<td>-0.83</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Neck Height 0.50</td>
<td>0.83</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0.50 NC:Neck thickness</td>
<td>-0.68</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean NC:Neck thickness</td>
<td>-0.82</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Neck Thickness 0.50</td>
<td>0.83</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

\(^a\) Spearman rank correlation coefficient.

\(^b\) P value for a test of the null hypothesis that the variables are independent.

\(^c\) Neck circumference at 0.25 neck length

\(^d\) Neck circumference at 0.50 neck length

\(^e\) Neck circumference at 0.75 neck length

\(^f\) Average of 0.25 NC, 0.50 NC, 0.75 NC

485 486 487 488 489 490 491 492 493 494 495 496 497 498

499

500
Figure 3. Linear relationship of neck thickness at 0.50 and fatty neck score (A) (P < 0.001). Linear relationship of neck height at 0.50 and fatty neck score (B) (P < 0.001)
Figure 4. Linear relationship of Mean NC:Neck thickness and fatty neck score (P < 0.001) (A). Linear relationship of mean NC:Neck height and fatty neck score (P < 0.001) (B).
Figure 5. Linear relationship of 0.50 NC:Neck thickness and fatty neck score ($P < 0.001$) (A). Linear relationship of 0.50 NC:Neck height and fatty neck score ($P < 0.001$) (B).