مقایسه سه روش رنگ آمیزی مختلف برای توصیف مورفومتریک اسپرم آلپاکا

ISAS® CASA-Morph با استفاده از سیستم (Vicugna pacos)

چکیده. مورفومتری استفاده بیشتری از آنالیز عنبی بر روی آلپاکا می‌کرد. در این تحقیق، از تکنیک‌های مختلف رنگ آمیزی استفاده گردید. هر دو نمونه دارای همان نوع اشکال و شکل هستند، اما تعداد نواحی متفاوت در سطوح گرفته شده است. خلاصه می‌شود که هر دو روش بهترین نتایج را دادند. سپس، احتمالاً، استفاده از روشی بهتری از این دو روش برای بررسی مورفومتریک آلپاکا مورد نیاز است.

Comparison of three different staining methods for the morphometric characterization of Alpaca (Vicugna pacos) sperm, using ISAS® CASA-Morph system

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Abstract. Sperm morphometry is a part of the semen analysis based on CASA technology and has shown a big role in the...
prediction of male fertility. This analysis implies the use of stain techniques, although it has been shown that staining can make dramatic changes in the cell morphology in different species. The aim of the present work was to evaluate the differences in sperm morphology in Alpaca, introduced by the use of different stain techniques. Single ejaculates from five adult alpacas were used. Samples were recovered by deferent duct deviation surgery technique. Three stain techniques (i.e., Hemacolor, Harri’s Hematoxylin and Diff-Quik) were evaluated. Morphometric analysis was done using ISAS® v1 CASA-Morph system, at 100x bright field objective magnification and a digital video camera with a final resolution of 0.08 μm/pixel. Almost 200 randomly selected cells were automatically analysed per sample and stain technique, considering several sperm-head and midpiece parameters regarding size and shape. Almost all of the parameters showed different levels of difference among the employed techniques. In general, the largest cell heads were the ones stained with Harri’s Hematoxylin and the smallest ones were the ones stained with Diff-Quik. The discriminant parameters used to differentiate between animals better were the head width, area and acrosome percentage. In conclusion, like in other species, alpaca sperm morphometry results were found to be sensitive to the applied stain technique. This implies the necessity of referring clearly the stain technique used in each case to perform comparisons between different works on the same species. None of the employed techniques was superior to the others. In addition, the method used to obtain the samples showed its usefulness and simplicity for repeated samplings.

**INTRODUCTION**

Semen analysis is the way to determine the potential fertility of a male. Traditionally, sperm concentration, motility and morphology are the basic characteristics included in a spermiogram for all mammalian species, among which sperm morphology is most relevant with the genetics of the male (Landry et al., 2003; Sun, Ko & Martin, 2006; Kosova et al., 2014; Ray et al., 2017).

The early development of Computer Assisted Semen Analysis (CASA-Morph) technology allowed passing from the subjective morphology to the metric semi-automatic or full-automatic analysis of the spermatozoa in a sample (Casey et al., 1997; Barroso et al., 1999; Soler et al., 2005a; Yániz et al., 2015; Maroto-Morales et al., 2016).

Nevertheless, it was demonstrated that both fixatives (Sancho et al., 1998; Cooper, 2012) and staining techniques (Gago et al., 1998; Soler et al., 2005a; Maree et al., 2010; Banaszewska et al., 2015) could introduce dramatic changes in head sperm morphology, which is species-specific. This implies the necessity to analyse the effect of different staining techniques on sperm morphology prior to developing a scientific research, unless it is impossible to compare the results obtained from the application of diverse techniques in different species (Soler et al., 2015).

The sperm characterization in camelids is not so much developed as in other mammalian species (Valverde et al., 2016; Yániz et al., 2016; Soler et al., 2017), although some works were developed on sperm characterization in camels (Bravo et al., 1997; Bravo et al., 1999; Soler et al., 2014b, 2014c; Carretero et al., 2015; Laruta-Limachi et al., 2016; Carretero et al., 2017; Panahi et al., 2017; Meza et al., 2018). The aim of the present work was to evaluate the effect of three different staining techniques on alpaca sperm morphology analysed by CASA-Morph system.

**MATERIALS AND METHODS**

**Broodstock conditions**

This study was conducted in the Investigation Center in South American Camelids (CICAS – La Raya), belonging to the Agrarian Sciences Faculty of the National University of San Antonio Abad del Cusco (UNSAAC) localized in Cusco, Peru.

The natural life area of this investigation is subalpine wet subtropical wilderness (Holdridge LR 1982). Bio-temperature range from 0 and 6°C with high currency frost, rainfall is in the range of 500-1000 mm and the most precipitation occurs during the months of December to March. The maximum and minimum temperatures are -7°C and 15 °C, respectively, with an average of 7.49°C.

The UNSAAC has not established a Bioethics Committee (which is being defined), but the Dirección de Investigación certifies that the protocols of the study were developed following the norm indicated on https://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm.

The study was conducted from October 2015 to March 2016 and on five Huacaya-breed male alpacas randomly selected, with a weight average of 56 Kg and an age average of 5 years. Animals were maintained to the same conditions of handling and feeding.

**Surgical technique**

Alpacas males were submitted to a deferent duct deviation surgery to collect the spermatozoa by friction of the epididymal tail and ductus deferens (Meza et al., 2018). In brief, before starting surgery, males were weighed to calculate the dose of anaesthetic agent, and were then tranquillized by promazil (Montana, Lima, Perú) at a dose of 1 ml/10 kg by deep intramuscular injection. After thirty minutes, a local lidocaine (1 mL per sensation point, Genfar, Bogotá, Colombia) was applied subcutaneously. After disinfecting the operation zone, small lateral cuts were made in the scrotal bag to
locate the ductus deferens. Then, the ductus was moved to the inner thigh zone, where a 2–3 cm subcutaneous cut was made.

During the post-operative treatment, bioflan (Myralis pharma, Sao Paulo, Brazil) at 12 to 12 hours (dose of 1 ml / 25 kg) and biomizona (Biomont, Lima Perú, dose of 1 ml / 10 kg), both for 3 days, were administered to animals. Scars were disinfected regularly to prevent possible complications.

**Semen collection**

Alpaca males were placed in a quiet place on lateral position and the semen collection area was disinfected. To stimulate the semen output, friction of the epididymal tail and ductus deferens was realized. Spermatozooids were conducted to the output of the fistula and collected into a 37°C pre-heated syringe. Semen was immediately placed in a graduated tube with 0.4 ml tris-based dilution medium at 37°. After collecting the semen, Vaseline was applied on the recovering area to prevent the fistula from drying. Collections were done close to the laboratory in order to facilitate the handling and transportation of samples.

**Sperm staining**

Hemacolor (Merck, Darmstadt, Germany), Diff-Quik (Baxter, Düdingen, Switzerland) and Harris’ Hematoxylin (Merck) were used to stain the smears from each sperm sample. First, two staining methods were applied, following kit recommendations. Hematoxylin staining was performed by a 30 min immersion of samples into stain and subsequent washing with tap water. All samples were air dried and permanently mounted on a slide with Eukitt mounting medium (O. Kindler GMBH & CO., Freiburg, Germany).

**Sperm morphometric analysis**

Morphometric analysis of sperm samples was performed using the ISAS® v1 (Proiser® R+D SL, Paterna, Spain) CASA-Morph system. Slides were examined and cells were captured, using a phase-contrast microscope (UOP-Proiser) equipped with a 100x bright field objective (AN 0.17) and a digital video camera (Proiser 782M). The array size of the video frame grabber was 768x576x8 bits and 256 grey levels. Resolution of images was 0.08 μm per pixel in both the horizontal and vertical axes. Two hundred sperm cells per sample, presenting no overlapping with other cells or with background particles, were randomly captured. Several sperm-head parameters of size (length, width, area and perimeter), shape (ellipticity, rugosity, elongation and regularity), midpiece area, width and insertion distance as well as angle between head and midpiece axis were measured (Soler et al., 2005; Fig. 1).

**Sperm Statistical analysis**

For multiple comparisons between staining methods and animal sperm samples, normality distributions and variance homogeneity were checked by the tests of Kolmogorov–Smirnov and Levene, respectively. For samples that were normally distributed, one-way ANOVA was performed, followed by a Bonferrini a posteriori test. For non-normally distributed populations, the Kruskal–Wallis one-way ANOVA on ranks was performed. Moreover, considering only 250 randomly selected cells from those correctly analysed after each stain technique, Pearson’s correlation analyses between morphometric parameters were also done. All statistical calculations were performed using the SPSS v 23.0 (IBM SPSS Inc., Chicago, USA).

**RESULTS**

Head length, perimeter, acrosome and rugosity were different for each of the three stain techniques, the highest values being those of Harris’ Hematoxylin and the lowest being those of Diff-Quik. Also, the area of the midpiece was different for the three techniques, and in this case the highest value corresponded to Diff-Quik and the lowest to Hematoxylin. Values of the head area were not different for Hematoxylin and Hemacolor but higher than that corresponding to Diff-Quik. Ellipticity, Elongation and the distance of the midpiece insertion point were significantly higher for Hematoxilin and similar for the other two techniques. The midpiece width was similar for Hemacolor and Diff-Quik, and lower for Hematoxylin. Finally, the head width and the midpiece insertion angle showed no changes among stain techniques (Table 1, Fig. 2).

Regarding the differences among animals, most of the parameters showed differences for the different staining methods, however, Hemacolor was found to be more appropriate for discriminating purposes. In this case, head area, acrosome percentage and ellipticity were the best parameters for differentiating animals (Table 2).

**DISCUSSION**

Subjective evaluation of sperm morphology has been considered a key factor in the prediction of male fertility in a variety of species (Yániz et al., 2015, 2016). Only few studies have been performed with the aim of establishing standard morphological criteria to estimate the South American camelids sperm quality (Buendia et al., 2002; Schwalm et al., 2007; Morton et al., 2010; Ordoñez et al., 2012).
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Fig. 1. Morphometric parameters examined in this study.

Table 1. Shape and size morphometric values of alpaca spermatozoa associated with each staining technique.

|                  | Diff-Quick | Hemacolor | Hematoxylin |
|------------------|------------|-----------|-------------|
|                  | Mean       | SD        | Mean        | SD        | Mean       | SD        |
| N                | 5625       |           | 6954        |           | 5646       |           |
| Lenght (µm)     | 5.8<sup>a</sup> 0.01 | 5.8<sup>a</sup> 0.01 | 6.0<sup>b</sup> 0.01 |
| Width (µm)      | 3.2<sup>a</sup> 0.00 | 3.2<sup>a</sup> 0.00 | 3.2<sup>a</sup> 0.00 |
| Area (µm²)      | 15.1<sup>a</sup> 0.02 | 15.4<sup>b</sup> 0.02 | 15.6<sup>c</sup> 0.02 |
| Perimeter (µm)  | 17.0<sup>a</sup> 0.02 | 17.0<sup>a</sup> 0.02 | 17.9<sup>b</sup> 0.02 |
| Ellipticity     | 1.8<sup>a</sup> 0.00 | 1.8<sup>a</sup> 0.00 | 1.9<sup>b</sup> 0.00 |
| Rugosity        | 0.7<sup>b</sup> 0.00 | 0.6<sup>a</sup> 0.00 | 0.7<sup>b</sup> 0.00 |
| Elongation      | 0.3<sup>a</sup> 0.00 | 0.3<sup>a</sup> 0.00 | 0.3<sup>a</sup> 0.00 |
| Regularity      | 1.0<sup>a</sup> 0.00 | 1.0<sup>a</sup> 0.00 | 1.0<sup>a</sup> 0.00 |
| Widt-Mp         | 1.2<sup>a</sup> 0.01 | 1.2<sup>a</sup> 0.01 | 1.1<sup>b</sup> 0.01 |
| Area-Mp         | 3.2<sup>a</sup> 0.02 | 2.9<sup>b</sup> 0.02 | 2.6<sup>c</sup> 0.02 |
| d.h.-Mp         | 0.2<sup>a</sup> 0.0 | 0.2<sup>a</sup> 0.0 | 0.2<sup>a</sup> 0.0 |
| a.h.-Mp         | 8.9<sup>a</sup> 0.21 | 8.9<sup>a</sup> 0.21 | 8.6<sup>a</sup> 0.21 |

Values with different letters in the same row are significantly different (P < 0.05).
The average value of normal and abnormal spermatozoa had been reported previously in alpaca submitted to the same surgery and collection methodology and was not calculated here again. The ejaculated spermatozoa had a greater proportion of normal spermatozoa, showing a percentage of 74.98% of normal forms and 25.02% of abnormalities (Quintano, 2001), and 75.87% of normal spermatozoa and 24.13% of abnormal spermatozoa (Cárdenas, 2002). Nevertheless, the classical subjective analysis approach has two main limitations, the high variability due to technicians (Eusteche & Auger, 2003) and the staining procedures (Soler & Cooper, 2016).

Regarding the sperm preparation, it is well known that the spermatozoa structure can be modified by fixation (Hardy, 1899), either air dried (Yeung et al., 1997; Soler et al., 2000) or using chemical fixatives (Sancho et al., 1998). This limitation implies that any conclusion about the real meaning of sperm morphology must be relative when analysed under these technical conditions (Soler & Cooper, 2016). The problem related to the technician variability was partially solved by the introduction of CASA-Morph systems, which analyse the sample in a quantitative way changing the classical morphological to the computerized morphometry approach (Yániz et al., 2015; Soler et al., 2016). CASA technology not only dramatically reduces the Coefficient of the Variance in the final results, increasing their reliability but also offers a big amount of quantitative morphometric data for use in a variety of studies (for revision look the special issue published by the Asian Journal of Andrology in 2016, Vol 18, issue 6).

In human beings, it was observed that spermatozoa, which was classified as normal following the criteria defined by WHO (WHO, 2010), showed statistically significant differences among individuals when morphometric analysis was done. This indicates the concept of what is “normal” must be revisited even in a species as the human being, in which an enormous effort in the definition and standardization of sperm morphology was performed for a long time (Bellastela et al., 2010).

Nevertheless, the use of CASA-Morph systems does not solve the problem of artefacts production during the staining procedure. This made it necessary to define a good protocol definition and a correct evaluation of its impact in the final morphometric results, as it was done in the present work. Depending on the species, the optimal stain for the sperm morphometric analysis using CASA-Morph systems were Diff-Quik (for goat, Hidalgo et al., 2003); Harris’ Hematoxyline (boar, García-Herreros et al., 2006; Cynomolgus monkey, Gago et al., 2000; stallion, Hidalgo et al., 2005) and Hemacolor (Soler et al., 2003). The recent introduction of Trumorph® was proposed as a new approach that prevents the staining

Table 2. Shape and size morphometric values of alpaca spermatozoa stained with Hemacolor for different animals.

| Animal        | Length-h (μm) | Width-h (μm) | Area-h (μm²) | Perimeter-h (μm) | Acrosome (%) | Ellipticity | Rugosity | Elongation | Regularity | Wdht-Mp (μm) | Area-Mp (μm²) | d.h.Mp (μm) | a.h.Mp (°) |
|---------------|---------------|--------------|--------------|------------------|--------------|-------------|----------|------------|------------|-------------|--------------|-------------|------------|
|               | 1             | 2            | 4            | 5                | 6            |             |          |            |            |             |              |             |            |
| Alpaca        | 5.8±0.03ab    | 5.9±0.03a    | 5.7±0.03b    | 6.1±0.03c        | 5.8±0.03b    |             |          |            |            |             |              |             |            |
|               | 3.5±0.02a     | 2.9±0.02b    | 3.3±0.02c    | 3.0±0.02b        | 3.1±0.02d    |             |          |            |            |             |              |             |            |
|               | 14.6±0.01a    | 14.4±0.10b   | 15.9±0.01c   | 15.0±0.01d       | 14.7±0.01ed  |             |          |            |            |             |              |             |            |
|               | 17.0±0.08a    | 16.6±0.08b   | 16.9±0.08ab  | 18.5±0.08c       | 16.7±0.09b   |             |          |            |            |             |              |             |            |
|               | 56.6±0.3ab    | 55.9±0.3b    | 57.7±0.3ac   | 58.9±0.3c        | 54.3±0.3d    |             |          |            |            |             |              |             |            |
|               | 1.7±0.01a     | 2.0±0.01b    | 1.8±0.01c    | 2.1±0.01b        | 1.9±0.01d    |             |          |            |            |             |              |             |            |
|               | 0.7±0.004a    | 0.6±0.004b   | 0.7±0.004c   | 0.6±0.004d       | 0.7±0.004e   |             |          |            |            |             |              |             |            |
|               | 0.2±0.003a    | 0.3±0.003b   | 0.3±0.003c   | 0.3±0.003b       | 0.3±0.003d   |             |          |            |            |             |              |             |            |
|               | 1.0±0.002a    | 0.9±0.002b   | 0.9±0.002c   | 0.9±0.002b       | 0.9±0.002b   |             |          |            |            |             |              |             |            |
|               | 1.1±0.03a     | 1.1±0.03a    | 1.2±0.03b    | 1.2±0.03b        | 1.3±0.02c    |             |          |            |            |             |              |             |            |
|               | 2.7±0.04a     | 2.7±0.04a    | 3.3±0.04b    | 2.8±0.04a        | 3.3±0.04b    |             |          |            |            |             |              |             |            |
|               | 0.2±0.01a     | 0.1±0.02b    | 0.2±0.01c    | 0.2±0.01a        | 0.2±0.01a    |             |          |            |            |             |              |             |            |
|               | 9.9±0.4ac     | 9.6±0.4ac    | 6.4±0.4b     | 10.3±0.4a        | 8.2±0.5c     |             |          |            |            |             |              |             |            |

Values with different letters in the same row are significantly different (P < 0.05).
process, allowing the analysis of sperm morphology in live cells (Soler et al., 2014a, 2015). The images obtained by this method showed big differences as compared with classical methods, which introduce different levels of artefact production. When the use of CASA-Morph technology is available for morphometric analysis, it will be needed to revise the classical concepts related to sperm morphology and morphometry (Soler et al., 2016).

Finally, it is necessary to compare the results obtained under similar technical conditions, e.g., using artificial vagina or using the new method proposed here. In general, the cells analysed here were shorter and thinner than those observed after artificial vagina sampling, using the Hemacolor staining (Buendía et al., 2002). This can be due to the fact that two different CASA-Morph systems were used or most probably because, as it was shown in different species, there are differences among spermatozoa from the epididymis directly and post-ejaculation (Yeung et al., 1997; Pérez-Sánchez et al., 1998; Gago et al., 1999, 2000; Soler et al., 2000). Therefore, it is necessary to consider collecting methods and/or the origin of the sample before performing any morphometric data comparison.

It can be concluded that, as in other species, alpaca sperm morphometry is sensitive to the stain technique used, making it necessary to refer to the employed technique when comparison between different works is done. In any case, it is not possible to conclude that any of the techniques used here can be considered better than others. However, based on previous works, we decided to use Hemacolor as a reference. Finally, the method to obtain the samples used here showed to be useful and simple for repeated samplings.

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REFERENCES
Banaszewska, D., Czubaszek, M, Walczak-Jędrzejowska, R. and Andraszek, K. 2015. Morphometric dimensions of stallion sperm head depending on the staining method used. – Bull. Vet. Inst. Pulawy 59: 263-270.
Barros, G., Mercan, R., Ozgur, K., Morshed, M., Kolm, P., Coetzee, K., Kruger, T. and Oehninger, S. 1999. Intra- and inter-laboratory variability in the assessment of sperm morphology by strict criteria: impact of semen preparation, staining techniques and manual versus computerized analysis. – Human Reprod. 14: 2036-2040.

Bellastella, G., Cooper, T.G., Battaglia, M., Stroße, A., Torres, I., Hellenkemper, B., Soler, C. and Sinasi, A. 2010. Dimensions of human ejaculated spermatozoa in Papanicolaou-stained seminal and swim-up swarms obtained from the Integrated Sene Analysis System (ISAS®). – Asian J. Andrology 12: 871-879.

Bravo, P.W., Flores, D. and Ordóñez, C. 1997. Effect of repeated collection on semen characteristics of alpacas. Biol. Reprod.57: 520-524.

Bravo, P.W., Pacheco, C., Quispe, G., Vilcapaza, L. and Ordóñez, C. 1999. Deflagellation of alpaca semen and the effect of dilution rates on artificial insemination outcome. – Arch. Andrology 43: 239-246.

Buendía, P., Soler, C., Paolìchì, F., Gago, C., Urquida, B., Pérez-Sánchez, F., Bustos-Obregón, E. 2002. Morphometric characterization and classification of alpaca sperm heads using the Sperm-Clas Analyzer® computer aided system. – Theriogenology 57: 1207-1218.

Carretero, M.L., Fumuso, F.G., Miragaya, M.H., Herrera, C. and Giuliano, S.M. 2015. Effect of seminal plasma in Llama glama sperm. – Reprod. Fertility Develop. 27: 223.

Carretero, M.L., Giuliano, S.M., Arratza, C.C., Santa cruz, R.C., Fumuso, F.G. and Neild, D.M. 2017. Comparison of two cooling protocols for llama semen: with and without collagenase and seminal plasma in the medium. – Andrologia 49: e12691.

Casey, P.J., Gravance, C.G., Davis, R.O., Chabot, D.D. and Liu, L.K.M. 1997. Morphometric differences in sperm head dimensions of fertile and subfertile stallions. – Theriogenology 15: 575-582.

Cooper, T.G. 2012. Comment on the morphology of spermatozoa in air-dried seminal smears. – Int. J. Androl. 35: 105-106.

Eustech, F. and Auger, J. 2003. Inter-individual variability in the morphological assessment of human semen: effect of the level of experience and the use of standard methods. – Human Reprod. 18: 1018-1022.

Gago, C., Pérez-Sánchez, F., Yeung, C.H., Tablado, L., Cooper, T.G. and Soler, C. 1998. Standardization of sampling and staining methods for the morphometric evaluation of sperm heads in the Cynomolgus monkey (Macaca fascicularis) using computer-assisted image analysis. – Int. J. Androl. 21: 169-176.

Gago, C., Pérez-Sánchez, F., Yeung, C.H., Tablado, L., Cooper, T.G. and Soler, C. 1999. Morphological characterization of ejaculated Cynomolgus monkey (Macaca fascicularis) sperm. – Amer. J. Primatology 47: 105-115.

Gago, C., Soler, C., Pérez-Sánchez, F., Yeung, C.H. and Cooper, T.G. 2000. Effect of Cetrorelix on sperm morphology during maturation trough the epididymis in the Cynomolgus macaque (Macaca fascicularis). – Amer. J. Primatology 51: 103-117.

García-Herreros, M., Aparicio, L.M., Barón, F.J., García-Marín, L.J. and Gil, M.C. 2006. Standardization of simple preparation, staining and sampling methods for automated sperm head morphology analysis of boar spermatozoa. – Int. J. Androl. 29: 553-563.

Hardy, W.B. 1899. On the structure of cell protoplasm. – J. Physiol. 24: 158.

Kosova, G., Holataling, J.M., Ohlander, S., Niederberger, C., Prins, G.S. and Ober, C. 2014. Variants in DPF3 and DSCAML1 are associated with sperm morphology. – Genetics 31: 131-137.

Hidalgo, M., Rodríguez, I. and Dorado, J. 2006. Influence of staining and sampling procedures on goat sperm morphology using the Sperm Class Analyzer. – Theriogenology 66: 996-1003.

Hidalgo, M., Rodríguez, I., Dorado, J., Sanz, J. and Soler, C. 2005. Effect of simple size and staining methods on stallion sperm morphology by the Sperm Class Analyzer. – Vet. Med-Czech 50: 24-32.

Landry, C., Geyer, L.B., Arakaki, Y., Uehara, T. and Palumbi, S.R. 2003. Recent speciation in the Indo-West Pacific: rapid evolution of gamete recognition and sperm morphology in cryptic species of sea urchin. – P. Roy. Soc. B.Biol. Sci. 270: 1839-1847.

Laruta-Limachi, F., Loza-Murguía, M.G. and Delgado-Callisaya, P.A. 2016. Microscopic evaluation of semen characteristics llama (Lama glama) cryopreserved two dilutors. – J. Selva Andina Anim. Sci. 3: 8-21.

Maree, L., du Plessis, S.S., Menkveld, R. and van der Horst, G. 2010. Morphometric dimensions of the human sperm head depend on the staining method used. – Human Reprod. 25: 1369-1382.

Maroto-Morales, A., García-Álvarez, O., Ramón, M., Martínez-Pastor, F., Fernández-Santos, M.R., Soler, J. and Garde, J.J. 2016. Current status and potential of morphometric sperm analysis. – Asian J. Andrology 18: 863-870.

Meza, A., Caldeira, C., Valverde, A., Ordóñez, C., Ampuero, E., Cucho, H. and Soler, C. 2018. Sperm kinematic characterization of alpaca (Vicugna pacos L.) during reproductive season. – Reprod. Dom. Anim. 53: 1415-1423.

Morton, K.M., Thomson, P.C., Baillie, K., Evans, G., and Maxwell, W.M.C. 2010. Quality parameters for alpaca (Vicugna pacos) semen are affected by semen collection procedure. – Reprod. Dom. Anim. 45: 637-643.

Ordóñez, C., Ampuero, E., Cucho, H. and Calcho, G. 2012. Caracterización morfológica de los espermatocoides de alpacas usando el integrated sperm analysis system (ISAS®). – Spermoval 2: 67-68.

Panahi, F., Nasari-Nasliai, A., Seyedaraghi, F., Araoosi, T., Razavi, K. and Moosavi-Movahedi, A.A. 2017. Supplementation of tris-based extender with plasma egg yolk of six avian species and camel skim milk for chilled preservation of dromedary camel semen. – Anim. Reprod. Sci. 184: 11-19.

Pérez-Sánchez, F., Tablado, L. and soler, C. 1998. Quantitative changes in sperm head morphology during passage through the male excurrent duct system of the rabbit. – Mol. Reprod. develop. 51: 203-209.
Ray, P.F., Metzler-Guillemain, C., Mitchell, M.J., Arnoult, C. and Couton, C. 2017. Genetic abnormalities leading to qualitative defects of sperm morphology or function. – Clin. Genet. 91: 217-232.

Sancho, M., Pérez-Sánchez, F., Tablado, L., de Monserrat, J.J. and Soler, C. 1998. Computer assisted morphometric analysis of ram sperm heads: evaluation of different fixative techniques. – Theriogenology 50: 27-37.

Schwalm, A., Gauly, M., Erhardt, G. and Bergmann, M. 2007. Changes in testicular histology and sperm quality in llamas (Lama glama), following exposure to high ambient temperature. – Theriogenology 67: 1316-1323.

Soler, C. and Cooper, T.G. 2016. Foreword to Sperm morphometrics today and tomorrow special issue in Asian Journal of Andrology. – Asian J. Androl. 18: 815-818.

Soler, C., Pérez Sánchez, F., Schulze H., Bergmann, M., Oberpenning, F., Yeung, C.H. and Cooper, T.G. 2000. Objective evaluation of the morphology of human and epididymal sperm heads. – Int. J. Androl. 23: 77-84.

Soler, C., de Monserrat, J.J., Gutiérrez, R., Núñez, J., Núñez, M., Sancho, M., Pérez-Sánchez, F., and Cooper, T.G. 2003. Use of the Sperm-Class Analyser® for objective assessment of human sperm morphology. – Int. J. Androl. 26: 262-270.

Soler, C., Gadea, B., Soler, A.J., Fernández-Santos, M.R., Esteso, M.C., Núñez, J., Moreira, P.N., Núñez, M., Gutiérrez, R., Sancho, M. and Garde, J.J. 2005a. Comparison of three different staining methods for the assessment of epididymal red deer sperm morphology by computerized analysis with ISAS® – Theriogenology 64: 1236-1243.

Soler, C., Gafner, P., Nieschlag, E., de Monserrat, J.J., Gutiérrez, R., Sancho, M., Buendía, P., Álvarez, J.G., Behre, H.M. and Cooper, T.G. 2005b. Use of the integrated semen analysis system (ISAS®) for morphometrics analysis and its role in assisted reproduction technologies. – Revista Int. de Androl. 3: 112-119.

Soler, C., García-Molina, A., Sancho, M., Contell, J., Núñez, M. and Cooper, T.G. 2014a. A new technique for analysis of human sperm morphology in unstained cells from raw semen. – Reprod. Fertil. Dev. 28: 428-433.

Soler, C., Sancho, M., García, A., Fuentes, M.C., Núñez, J. and Cucho, H. 2014b. Ejaculate fractioning effect on llama sperm head morphology as assessed by the ISAS® CASA system. – Reprod. Dev. Anim. 49: 71-78.

Soler, C., Sancho, M., García-Molina, A., Núñez, J., Parrávez, V.H., Contell, J. and Bustos-Obregón, E. 2014c. Llama and alpaca comparative sperm head morphometric analysis. – J. Camelid Sci. 7: 48-58.

Soler, C., García-Molina, A., Contell, J., Silvestre, M.A. and Sancho, M. 2015. The Trumorph system: the new universal technique for the observation and analysis of the morphology of living sperm. – Anim. Reprod. Sci. 158: 1-10.

Soler, C., Cooper, T.G., Valverde, A. and Yániz, J.L. 2016. Afterword to sperm morphometrics today and tomorrow special issue in Asian Journal of Andrology. – Asian J. Androl. 18: 895-897.

Soler, C., Contell, J., Bori, L., Sancho, M., García-Molina, A., Valverde, A. and Segarvall, J. 2017. Sperm kinematic, head morphometric and kinetic-morphometric subpopulations in the blue fox (Alopex lagopus). – Asian J. Androl. 19: 154-159.

Sun, F., Ko, E. and Martin, R.H. 2006. Is there a relationship between sperm chromosome abnormalities and sperm morphology? – Reprod. Biol. Endocrinol. 4: 1.

Valverde, A., Areán, H., Sancho, M., Contell, J., Yániz, J., Fernández, A. and Soler, C. 2016. Morphometry and subpopulation structure of Holstein bull spermatozoa: variations in ejaculates and cryopreservation straws. – Asian J. Androl. 18: 851-857.

World Health Organization (WHO). 2010. ‘WHO Laboratory Manual for the Examination and Processing of Human Sperm.’ 5th edn (WHO: Geneva).

Yániz, J.L., Soler, C. and Santolaria, P. 2015. Computer assisted sperm morphometry in mammals: a review. – Anim. Reprod. Sci. 156: 1-12.

Yániz, J.L., Capistrós, S., Vicente-Fiel, S., Hidalgo, C.I. and Santolaria, P. 2016. A comparative study of the morphometry of sperm head components in cattle, sheep, and pigs with a computer-assisted fluorescent method. – Asian J. Androl. 18, 840-843.

Yeung, C.H., Pérez-Sánchez, Soler, C., Poser, D., Kliesch, S. and Cooper, T.G. 1997. Maturation of human epididymal spermatozoa (from selected epididymides of prostatic carcinoma patients) with respect to their morphology and ability to undergo the acrosome reaction. – Human Reprod. Update 3: 205-213.

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