BREEDING BETTER LUSOS

By Dr António Andrade Vicente

PhD in Veterinary Science and International Judge of Lusitano horses

Following the invitation from Sue Durkan to write an article concerning the selection of the Lusitano horse based on morphology and functionality, I will try to present, in this document, a short resumé of a profound and extensive study on characterization and selection strategies for the Lusitano horse breed, presented as my PhD Thesis in Veterinary Science.

The horse has always been of extreme relevance in Portugal, and we can consider it of great importance for Portuguese history and consolidation of the territory. Portugal is one of the oldest states in Europe ("The Old Continent"), with more than eight hundred years of independence, and strong ethnic and cultural roots. We can consider that part of the success in establishing our territory, "The Lusitania", is due to a powerful ally that was, and is, the Lusitano horse (Cordeiro, 1989). Moreover, recent studies (Lopes et al., 2005; Royo et al., 2005; Lira et al., 2010) suggest the evidence of the Iberian Peninsula as a centre of horse domestication, and the importance and antiquity of the Lusitano horse, considered by many as one of the oldest breed of saddle horse. Thanks to the isolation of the IP, this extraordinary horse survived here and evolved over a period of about fifteen thousand years, almost entirely free from extraneous influences until quite recently (Cordeiro, 2011), selection always based on morphological, aesthetic and functional aspects, attached to human husbandry.

The Lusitano horse, saddle horse prototype, combining beauty and harmony in the model with a docile and generous temperament, easy, comfortable and agile movements with natural balance, is an example of versatility and adaptability to any climate, terrain or equestrian activity (Monteiro, 1983). The Lusitano Studbook (SB) was made official in 1967 and remained open for the entry of new registration of animals until 1989. From that year on, the SB was closed and only offspring from animals already registered in the SB were allowed to be registered as Lusitano horses.

Since the creation of the SB in 1967 until the present, before any stallion or mare is allowed to breed offspring that can be registered in the SB, they must satisfactorily perform a morpho-functional test consisting of an evaluation of morphology and gaits, comparing the animals to the breed standard, classified by a panel of experts (APSL, 2010).

Presently the Lusitano horse has spread worldwide and is well represented around the globe. Even if there are only about 5,000 breeding females worldwide, there are 32 different countries breeding and registering Lusitano horses. Besides Portugal, there is a very important nucleus in Brazil (where the largest number of breeders and studs are), France (where it is the main foreign breed), México, Spain, Italy, Belgium, the United Kingdom and many others.

Every year, Lusitano horse breeders are faced with the complex task of selecting the animals (male and/or female) to use as breeding stock that can transmit desirable traits to their offspring. Thus, breeders will try to identify genetically superior animals with the traits they seek, to use as breeding stock and thus transmit those desirable traits to their offspring. The Lusitano horse selection programme has, up to the present been essentially based on selecting animals upon phenotypic information (morphology and gaits) and genealogy (pedigrees), but it is also important to include other breeding objectives that concern the functionality of the animal. When it is desired to select a set of traits for the purpose of improving a given population, selection is most effective if it is based on the estimated breeding value for these genetic characteristics (Gama et al., 2004).

Olympic dressage horse Rubi, ridden by Goncalo Carvalho, ranked top breeding Luso in the world by ground breaking research to measure genetic breeding values for breeding good dressage horses

As breeding animals only transmit to their offspring half of their genes and not the environmental conditions to which it was subject, it is important for the breeder to know the genetic value of the animal, which is the value of an animal in a selection programme or what the animal may transmit to offspring. The phenotypic value of an animal for a given record (eg, morphological final score = 80 points or height at the withers = 1.60 m) can be an indicator of its genetic value, but also reflects the environmental conditions (breeder, year, month of birth, age, sex, diet, training method, etc.) to which it was subjected. Thus, the phenotypic information of an individual, by itself, may not be an accurate indicator of its genetic merit.

The genetic value of an animal represents its value as a breeder and can be interpreted as the genetic inferiority or superiority of a given trait, half of which will be transmitted to its offspring (**Figure 1**).

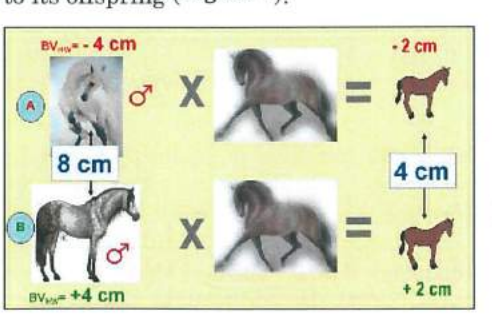


Figure 1 – Practical demonstration of the Breeding Value (BV) for Height at Withers (HW) in the Lusitano horse.

The breeding value has importance essentially in comparative terms. For example (**Figure 1**), if the male A has an estimated breeding value of -4 cm to the height at the withers and the male B has a genetic value of +4 cm, hopefully, when each of the males is mated with a female in the Lusitano population, the offspring will reflect half of the genetic merit of the father. Thus, it is expected that the son of the stallion A will have an inferiority of 4 cm (-4 cm) in height at the withers relative to offspring of stallion B, since ½ (-4 cm) - ½ (+4 cm) = - 4 cm. That is, on average, offspring from stallion A will be 4 cm lower than those from stallion B. The same reasoning can be made when we consider the breeding value of any other morpho-functional trait, such as a breeder's morphological grade marks or performance in Dressage.

The prediction of breeding values thus constitutes an essential step in the selection process, and the ideal methodology for those predictions is the BLUP (Best Linear Unbiased Prediction) - Animal Model, which incorporates information from all relatives and takes into account the appropriate fixed effects (Henderson, 1994).

BLUP – Animal Model, compared with phenotypic selection, has several advantages, which in practical terms means that the breeding value of an individual predicted by this methodology includes:

- Information of all its relatives (more or less distant by the inclusion of the relationship matrix);
- The genetic merit of the animals in the various matings;
- All productive/functional records available;
- The environmental effects that a record is subject to.

Through genetic evaluation with the BLUP - Animal Model, the aim is to estimate as accurately as possible the genetic value of each animal to the various traits of interest to the breeder, based on performance information (morphological, functional, etc) available (own and relatives), and taking into account the environmental effects that may mask the expression of its genetic potential (year and month of birth, sex, age of the animal, etc).

Thus, the compilation and analysis of aspects based on morphology and functionality in the Lusitano horse will allow more effective selection and consequently the genetic improvement of the population. As such it is intended herein to present the first results of the genetic evaluation for morphology (results from stallions and mares gradings) and for functionality in the discipline of Dressage, something unheard of in the Lusitano breed, but which is already common practice, for several years, in major worldwide Warmblood sports breeds.

In this study we used the genealogical database of the Portuguese National Stud Registry (RNE) and completed it with information given by the APSL (Portuguese Association of Lusitano horse breeders), and also data provided by the Portuguese Equestrian Federation (FEP), the International Equestrian Federation (FEI) and several national federations for Dressage results. After being edited and validated, the information contained a genealogy data file with 53,417 individuals (born between 1824 and 2009), a data file with 18,076 animals graded for the Studbook – breeding stock section (1967-2009), and a data file with 12,131 results from competition in Dressage of 759 Lusitano horses between 2000 and 2012.

Thus, in the first place, our aim is to make a genetic evaluation for morphology, considering all the data when animals were graded for the Studbook (**Table 1; Figure 2**), with the prediction of breeding values for this population, based on the methodology BLUP - Animal Model (Gama et al, 2004; Henderson, 1994). In addition to the grading,

Item	Coef.
Head and Neck (HN)	1
Shoulder and Withers (SW	1
Chest and Thorax (CT)	1
Back and Loin (BL)	1.5
Croup (CR)	1
Legs (LE)	1.5
Overall Impression (OI)	1.5
Gaits (GA)	1.5
Final Score (FS)	10

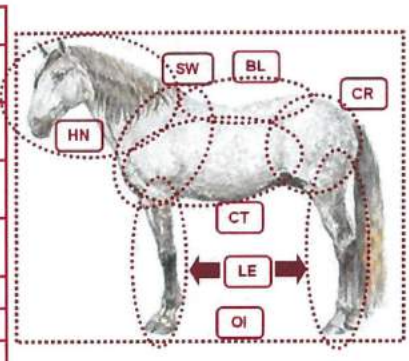


Table 1 & Fig 2 – Items for grading morphology for Studbook Approval

animals are also measured for height at withers. The model used for this study is presented in **Figure 3**.

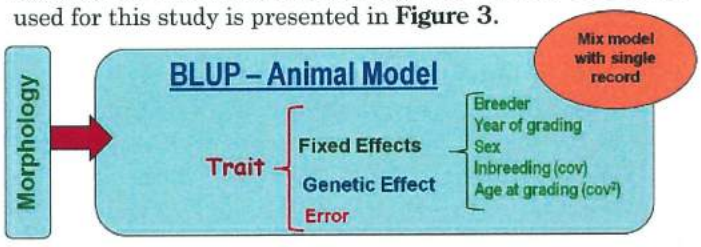


Figure 3 – Model of analysis for genetic evaluation of morphology in the Lusitano horse

After a morphological analysis, we performed a study of the performance in dressage (expressed as percentage scores) using a BLUP mix model with repeated records. Initially we obtained estimates of genetic parameters of the study, and later the predictions of the genetic value of each animal. The animal model (**Figure 4**) included the fixed effects of the event (combination of date and place of the competition), competition level (from Preliminary to Grand Prix), sex and also the linear effect of inbreeding, and linear and quadratic effects of age at the test. The random effects considered were the genetic value of the animal and its permanent environmental effect.

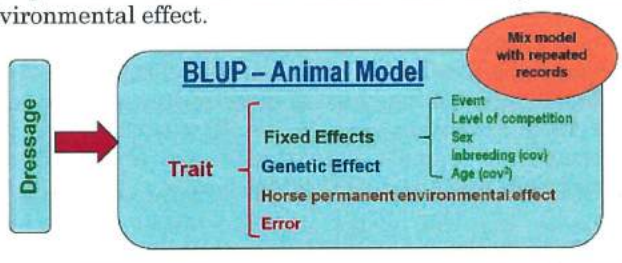


Figure 4 – Model of analysis for genetic evaluation of performance in dressage for the Lusitano horse

Descriptive statistics and the genetic parameters (heritability - h^2), obtained for morphological classification when grading candidates for inclusion in the studbook of Lusitanos approved for breeding, are presented in **Table 2**.

We can observe there are animals scored in the Studbook with height at the withers (HW) that varies between 1.40m and 1.78m, and final score (FS) between 44.5 points and 97 points. The scores attributed to partial morphology and gaits ranged between 4 and 10 points, with average values per item between 6.68 pts (legs) and 7.48 pts (chest and ribcage). Also note that Head and Neck was the item with greater variation (CV = 11.12%) followed by the score for gaits.

The heritability (h^2), which is of major importance in selection and genetic improvement, that essentially measures the transmission to the offspring of a given characteristic, was high for height at the withers (0.61) and medium/low for the different items of morphological classification, ranging between 0.18 (Head and Neck) and 0.07 (Legs).

Table 2 - Descriptive statistics and genetic parameters (h^2 - heritability) when grading Lusitano horses for the Studbook (N – number of horses; SD - standard deviation; CV - coefficient of variation)

Trait		N	Mean	SD	CV(%)	Min	Max	h^2
Height at withers (cm)		16955	157.8	4.05	2.56	140	178	0.61
Final Score (pts)	Coef.	18076	71.39	4.94	6.92	44.5	97	0.18
Head and Neck	1	17139	7.24	**0.81**	**11.12**	4	10	**0.18**
Shoulder and Withers	1	17139	7.47	*0.62*	*8.28*	5	10	0.13
Chest and Thorax	1	17139	**7.48**	0.67	8.97	4	10	0.12
Back and Loin	1.5	17139	6.93	0.73	10.46	4	10	0.15
Croup	1	17139	7.29	0.71	9.7	4	10	0.14
Legs	1.5	17139	*6.68*	0.69	10.28	4	10	*0.07*
Overall Impression	1.5	17139	7.17	0.71	9.94	4	10	0.14
Gaits	1.5	17139	7.27	0.78	10.72	4	10	0.16

After the estimation of the genetic parameters for morphology in the Lusitano, we could then perform the desired genetic evaluation of this breed, in order to obtain estimates of genetic values for all the animals comprising this population. With this study we can obtain various rankings of genetic merit, depending on their genetic value estimated for different traits (final score, height at the withers, gaits, etc.).

Note that these estimates of breeding values are dynamic, meaning they can and must be frequently updated (on a semi-annual or annual basis) and, as each time we provide more and more morphological information of animals graded for the Studbook, the estimates will be more precise and the rankings can change (in this study we only used data until 2009).

Table 3 presents the ranking of the estimated genetic merit of the best 15 Lusitano stallions for morphology, placed in order from the highest genetic breeding value (BV) for the Final Score (FS expressed in points). At the top of the FS ranking we can find the famous stallions Xaquiro and Riopele, with a high BV for morphology and gaits, with very strong accuracy, given the large number of offspring and relatives they have.

Xaquiro (CI), top ranked stallion for morphology and functionality. He and 18 of his descendants - including his grandson Rubi; his daughter He-Xila, (Rubi's mother); five of Rubi's offspring and Rubi's half brother - also feature in the table of the top 22 dressage sires and dams, which adds dressage performance to the calculation.

Riopele, (right) ranked 2nd - he is also one of the top 22 dressage sires and dams

©António Vicente

In addition to the breeding value for the FS, we can also observe the breeding value estimates for height at the withers (in cm), showing the genetic potential of a particular stallion for size that can be transmitted to his offspring, and also BV for the gaits. For these three characteristics, we also present the accuracy of the estimates of BV (Acc), which is higher when there is more information available about the animal (results, his relatives, etc). For information, the animals' year of birth is also presented.

In an analogous way we can develop rankings of genetic merit for any of the ten traits analyzed in morphology by gender, by year of birth, global etc, and we present in **Table 4** the ranking of the top 15 Lusitano stallions in relation to the BV of height at withers (HW). For information, the animals' year of birth is also presented.

Table 3 - Ranking of the genetic merit of Lusitano stallions for morphology in respect of Final Score (FS in points), Height at withers (HW in cm) and Gaits (in points), ranked by the Breeding Value (BV) for FS and respective accuracy of the estimates in % (Acc).

HORSE	Birth Year	FS		HW		Gaits	
		BV	Acc (%)	BV	Acc (%)	BV	Acc (%)
XAQUIRO	1980	***6.75***	**92**	2.48	**97**	**1.73**	**91**
RIOPELE	1998	6.7	75	3.94	89	1.38	73
HOSTIL	1989	6.34	82	3.11	93	1.22	80
SARILHO	1999	6.13	69	4.31	86	0.84	66
ZICO	1981	6.12	89	2.42	95	0.78	87
TOLEIRAO	2000	6.03	64	2.66	84	1.17	63
SPARTACUS	1999	5.98	73	2.83	88	1.42	71
COXIXO	2007	5.97	70	1.25	76	1.42	69
ARAGAO	2005	5.95	62	2.08	71	1.38	61
CAMPARI II	2007	5.85	63	1.78	71	1.14	62
XIQUE	2003	5.79	58	3.01	69	1.18	57
MARIALVA	1993	5.69	69	**-0.2**	84	1.02	68
TIXAQUIR	2000	5.68	73	2.59	86	1.35	71
SOBERANO	1999	5.6	69	**6.49**	87	1.09	66
EQUADOR	2009	5.58	58	1.97	68	1.06	57

Table 4 - Ranking of the genetic merit of Lusitano stallions for morphology in respect of the Breeding Value (BV in cm) for Height at Withers (HW in cm) and the Accuracy of the estimates (Acc).

HORSE	Birth Year	HW	BV	Acc.
MALIBU ESTREL (BRA)	1988	175	**9.63**	0.79
SEDAL	1999	**178**	9.23	0.8
HORIZONTE PIT (BRA	1986	169	9.08	0.85
TALENTO WR (BRA)	1999	169	9	0.81
QUEBOM HM (BRA)	1996	176	8.94	0.83
KUBLAYKHAN TOP (BRA)	1985	165	8.91	0.86
PASTOR	1996	174	8.7	0.81
QUIRON	1997	173	8.36	0.85
CAMACHO HOR (BRA)	1989	171	8.34	0.81
P-IPSOS BUSSY (FR)	1996	177	7.86	0.77
SOLAR PINHAIS (BRA)	1998	171	7.84	0.83
XANGÔ DO ARETE (BRA)	2002	170	7.81	0.81
VIDAGO	1972	168	7.8	**0.96**
PERALTA PINHA (BRA)	1996	172	7.72	0.82
BAFEJADO	1983	173	7.51	0.82

Thus the Lusitano horse breeders may have at their disposal a large amount of information and relevant data to assist them in the selection and breeding options, with regard to morphological assessment. This information is available to members of the APSL for their animals and for the best ones in the ranking on their reserved area (http://www.cavalo-lusitano.com/en/stud-books-lusitano-horse/apsl-members-access-to-stud-book).

As mentioned before, a similar analysis was performed for Lusitano horses in Dressage competition. Descriptive statistics and genetic parameters for dressage are shown in **Table 5**.

Note that we were able to compile a relevant file with results of Lusitano horses in dressage competition, with more than 12,000 results of 759 different Lusitano horses (between 2000 and 2012), with an overall average score of approximately 63%. The estimated h^2 of 0.32 tells us that it is possible to select animals more objectively, based on dressage performance, with a good repeatability (0.60). After these preliminary analyses and the estimation of dressage genetic parameters, a genetic evaluation for the Lusitano horse in dressage was performed to obtain the main breeding values (BV) of the population.

Table 5 – Descriptive statistics and genetic parameters for Dressage in Lusitano horses.

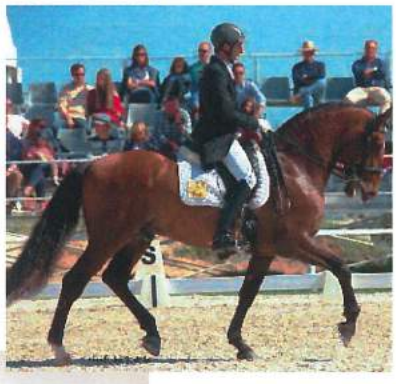
Item	Dressage
Number of Records	12131
Number of horses	759
Mean±SD (%)	62.74±4.47
Minimum %	37
Maximum %	89.6
Coef. Variation (%)	7.13
H^2	0.32
R_e	0.6

SD – Standard deviation; h^2 – heritability; r_e – repeatability.

After the BLUP analysis we were able to determine the genetic merit in dressage for all the Lusitano horses, and **Table 6** shows the ranking of the estimated genetic merit of the best 22 Lusitanos horses in Dressage, placed in order of the highest breeding value (in %). In addition to the breeding value for Dressage, we can also observe the estimated breeding value for the height at the withers (in cm). For both features, the accuracy of the estimates is also presented, which reflects the amount of available information. For reference, the score given to each horse in the studbook grading is also shown and also their height at the withers.

We can observe by the analysis of **Table 6** that the top genetic ranking in dressage is well represented by Lusitano horses that competed or are still competing at the highest level in dressage, and with good results from them and/or their relatives.

We cannot fail to mention the Lusitano stallion, Rubi, known worldwide by his performance in Grand Prix and leader in the global ranking of genetic evaluation for dressage, with a estimated breeding value of + 6.03%, which is more than 2 genetic standard deviations above the mean. Directly connected to this important stallion there are all his relatives, (He-Xila - mother; Beirão, Coronel, Coroado, Berinjela, Caramulo - offspring) also with high genetic indexes.



Rubi's son Beirão, placed 5th in the ranking

Rubi's son Coronel, (right) placed 7th in the ranking

Another Rubi son, Coroado, ranked 12th

In conclusion, the genetic evaluation with the BLUP - Animal Model can be considered as the more precise selection methodology currently in practice, taking into account the genetic improvement objectives of the Lusitano horse in Portugal and worldwide. Only in this way can we be more objective in the selection of the breeding stock to be used in the future matings, and it reveals that it is fundamental to carry out genetic evaluations for morphology and functionality routinely on an annual basis, to maximize the genetic progress in the Lusitano breed.

Table 6 – Ranking of the genetic merit of the top 22 Lusitano stallions for dressage in respect of the Breeding Value.

HORSE1.62	SEX	BREEDER	FS	HW	Birth Year	BV_DRES	Acc_DRES	BV_HW	Acc_HW
RUBI	M	COUDELARIA DE ALTER	72	1.65	1998	**6.03**	0.79	2.77	0.83
BARILOCHE	M	JOÃO PEDRO RODRIGUES	78.5	1.66	2006	**6.01**	0.73	2.61	0.66
ZAIRE	M	D. PEDRO PASSANHA	76	1.7	2004	**5.66**	0.74	2.61	0.66
OXALIS MEIA	F	COUDELARIA DA MEIA LUA	74.5	1.71	1995	**5.4**	0.75	4.06	0.79
BEIRAO	M	COUDELARIA DE ALTER	69.5	1.71	2006	**5.19**	0.73	2.9	0.64
ZIRCON	M	CASA CADAVAL	73.5	1.62	2004	**5.14**	0.7	1.28	0.67
CORONEL	M	COUDELARIA DE ALTER	74.5	1.61	2007	**5.09**	0.74	3.36	0.64
QUIXOTE	M	COUD. MONTE VELHO	73.5	1.66	1997	**5.04**	0.76	0.88	0.87
TALISCO	M	PEDRO FERRAZ DA COSTA	72.5	1.67	2000	**4.95**	0.77	1.81	0.86
SPARTACUS	M	COUDELARIA DE STA. MARGARIDA	81	1.64	1999	**4.94**	0.8	3.12	0.88
ROUXINOL	M	JOÃO PEDRO RODRIGUES	76	1.62	1998	**4.9**	0.65	3.34	0.87
COROADO	M	COUDELARIA DE ALTER		1.68	2007	**4.9**	0.71	1	0.65
HE-XILA	F	COUDELARIA DE ALTER	77	1.6	1989	**4.89**	0.62	0.93	0.87
ALTIVA	F	SOC. QUINTA DAS TERRAS	72.5	1.69	2005	**4.83**	0.71	5.8	0.8
XAQUIRO	M	CIPARQUE	80	1.63	1980	**4.73**	0.87	2.68	0.97
BARLAVENTO	M	MARIA ROSA OLIVEIRA SANTOS	73	1.6	2006	**4.62**	0.75	1.99	0.68
PAJEU	M	COUDELARIA DE ALTER	72.5	1.62	1996	**4.62**	0.72	0.04	0.82
UTIL	M	PAULO CAETANO	70.5	1.62	2001	**4.56**	0.75	1.05	0.85
BERINJELA	F	COUDELARIA DE ALTER	76.5	1.61	2006	**4.55**	0.56	3.27	0.66
DRAGAO	M	SOC. QUINTA DAS TERRAS	80	1.66	2008	**4.41**	0.71	5.88	0.66
REGENTE	M	JULIO E GUILHERME BORBA	66	1.64	1998	**4.38**	0.62	3.83	0.81
CARAMULO	M	COUDELARIA DE ALTER	75	1.65	2007	**4.37**	0.56	3.42	0.68
		Mean	**74.5**	1.65					

FS – Final Score (in points); HW – Height at withers (in cm); BV_Dress – breeding value for Dressage (in %); Acc_Dress - estimated accuracy for Dressage; BV_HW - breeding value for Height at withers (in cm); Acc_HW - estimated accuracy for Height at withers.

Bariloche, grandson of Xaquiro, ranked 2nd

Zaire, grandson of Xaquiro, ranked 3rd

Oxalis, daughter of Xaquiro, ranked 4th

Talisco, son of Xaquiro, ranked 9th

With these kind of studies of the Lusitano breed we can be more objective in choosing the stallions and mares to breed with and to produce more offspring, not only for the conformation and gaits and dressage, but also for other equestrian disciplines such as Working Equitation, Driving, Show jumping, bullfighting, etc. But to perform those kind of analyses we need to collect reliable and systematic information in these areas.

If you are interested in a more profound approach to the subject, you can read my PhD Thesis on: http://pecuaria.pt/conteudo.php?idart=1255

Acknowledgements:
We would like to express thanks to RNE - Fundação Alter Real; Associação Portuguesa de Criadores do Cavalo Puro-Sangue Lusitano (APSL); Jump-Off and Federação Equestre Portuguesa (FEP) for providing the data used in this study. We would also like to express thanks to Rui Pedro Godinho for providing such amazing pictures of Lusos in Dressage.

References:

APSL 2010. Studbook Regulations. Associação Portuguesa de Criadores do Cavalo Puro-sangue Lusitano. Cascais, Portugal.

Cordeiro A.R. 1989. Cavalo Lusitano: O filho do vento. Edições Inapa, Lisboa, 231 pp.

Cordeiro A.R. 2011. Evolution of the Lusitano horse. Proceedings of the 1st International Congress of the Lusitano Horse. Torre do Tombo, Lisboa, Portugal.

Gama L.T, Matos C.P. and Carolino N. 2004. Modelos Mistos em Melhoramento Animal. Arquivos Veterinários, N°7, Direcção Geral de Veterinária - Ministério da Agricultura, do Desenvolvimento Rural e Pescas, Portugal.

Henderson, C. R., 1994. Applications of Linear Models in Animal Breeding. Third printing. University of Guelph, Canada.

Lira J., Linderholm A., Olaria C., Brandstrom Durling M., Gilbert T.P., Ellegren H., Willerslev E., Liden K., Arsuaga J.L. and Gotherstrom A. 2010. Ancient DNA reveals traces of Iberian Neolithic and Bronze Age lineages in modern Iberian horses. Mol. Ecol. 19: 64-78.

Lopes M.S., Mendonça D., Cymbron T., Valera M., Costa-Ferreira J. and Câmara Machado A. 2005. The Lusitano horse maternal lineage based on mitochondrial D-loop sequence variation. Anim. Genet. 36: 196-202.

Monteiro J. 1983. O Cavalo Lusitano: Contributo para o seu Estudo. Boletim Pecuário. Ano XLIX: 3-205.

Royo L., Álvarez I., Beja-Pereira A., Molina A., Fernández I., Jordana J., Gómez E., Gutiérrez J.P. and Goyache F. 2005. The origins of Iberian horses assessed via mitochondrial DNA. J.

Vicente, A. 2015. Characterization and selection of the Lusitano horse breed. Doctoral Thesis in Veterinary Science. Faculdade de Medicina Veterinária da Universidade de Lisboa.

Photography: Rui Pedro Godinho