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Study of the Population Structure in Schnauzer Dogs

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Abstract

The aim of this study was to evaluate the population structure of a Schnauzer dogs kennel. Pedigree data of 129 dogs were collected from a kennel in Southern Brazil. Dogs were divided into groups by height ("miniature", "standard", and "giant") and subsequently, into coat color subgroups ("not informed", "salt and pepper", "black", "white", and "black and silver"). Population parameters were estimated using the Contribution, Inbreeding, Coancestry (CFC), and RelaX2 programs. Three ancestral generations were traced from the kennel dogs, totaling 685 unique individuals. Of these, 42% were considered founders. The analysis of the effective number of founders, number of effective ancestors, and inbreeding coefficient means were77, 44.9, and 0.08 for the miniature group, 26, 11.7 and 0.05for the standard group, and 28, 9.9 and 0.12 for the giant group, respectively. The subgroup "salt and pepper" in the "giant" group showed the highest inbreeding coefficient (0.14) and the highest kinship coefficient (0.20). Monitoring inbreeding allows to control upcoming breeding to acquire desirable characteristics in the population minimizing risk of deleterious effects.

Keywords

Companion animal, Genetic improvement, Breeding, Inbreeding, Crossbreeding

1. Introduction

Schnauzer dogs were often used for rodent control in horse barns in Germany, making them excellent hunters and showing excellent temperament with horses [1]. However, the focus of selection on dog breeds has shifted, when dogs began to play a main role in accompanying their owners, aesthetic and behavioral traits became the main selection criteria in kennels [2]. Kennels are responsible for breeds maintenance through selective breeding, attempting to meet breed standards to obtain descendants with the best phenotypes, following guidelines stipulated by the International Federation of Cynophilia [1]. The fixation of interesting phenotypic patterns for a given breed often requires breeding animals with similar traits, which contributes to the crossing of related animals. Many kennels use related breeder dogs in order to maintain phenotypic standardization, which has restricted the entry of new genetic materials, contributing to the increase in inbreeding and loss of genetic diversity [3, 4]. There are reports of productive and reproductive losses due to homozygosity in livestock species, such as cattle and horses [5, 6], which has also been observed in dogs [7]. Thus, inbreeding may affect fitness and decrease the mean performance for economically important traits (e.g., fertility traits). In addition, canine species often go through population bottlenecks due to the temporary popularity of some breeds followed by periods of near extinction. This contributes to the decrease in genetic variability and increases the chances of recessive alleles interactions, which makes certain breeds more susceptible to genetic diseases [8]. To maintain genetic variability in dog population is necessary to establish preventive measures against the appearance of recessive genetic diseases, which may be achieved by breeding programs that can be useful to reducing the inbreeding rate per generation

[9]. Within this context, the study of population structure in dogs becomes an important tool for breeders to understand and learn how to manage genetic diversity, avoiding the undesired consequences of inbreeding. To the best of our knowledge, there are no studies investigating population parameters on Schnauzer dogs. Thus, the objective of the study was to estimate the population parameters of the biggest Schnauzer breeder in Brazil to assess its population structure.

2. Methods

The pedigree dataset of a Schnauzer population located in the South of Brazil was constructed using available herd books and pedigrees from Brazilian breeders. The reference population was composed of 101 females and 28 males. Thus, available genealogy information of these dogs was traced back and recorded, creating the pedigree of the whole population from 2006 to 2017. The created Schnauzer pedigree dataset contained 685 microchipped individuals (Table 1), including 308 males and 377 females. Breeder dogs were acquired from different countries and progeny is exported as well aiming to exchange specific characteristics and improve the genetic variation.

Table 1. The number of animals per generation sorted by size category

Dogs per Generation of Ancestors								
Size	Evaluated dogs	1	2	3	4	5	6	7
Miniature	73	205	97	63	45	29	19	8
Standard	30	40	20	14	14	8	9	2
Giant	26	44	22	13	11	12	7	3

Since 1995, this kennel has targeted to select racial standards. The individual mating control was carried out carefully and breeders' mating was recorded. Females in the fertile period were kept separated from males to avoid unrecognizable dates. As the couples were formed it was assumed that the specific male dated a specific female, and, thus, served for the proper control of the mating in the next generations.

Due to the existence of three well-established size lineages and without gene flow between them, genealogy records used in this study were created using the software RelaX2 [10], following information: Individual identity number; Male parent; Female parent; Date of birth; Country code (i.e., county of origin); Sex; Animal size, which was categorized in three groups: "miniature" (30 to 36 cm and 5 to 8.2 kg); "standard" (47 to 50 cm and 14 to 20 kg); and "giant" (65 to 70 cm and 34 to43 kg), and color, which was categorized into 5 subgroups: "not informed", "salt and pepper", "black", "white", and "black and silver".

After checking the correctness of pedigree records, pedigree analysis was performed applying CFC (Contribution, Inbreeding (F), Coancestry) according to Sargolzaei, Iwaisake, and Jacques Colleau [11] and RelaX2, according to Gutiérrez, Cervantes, and Goyache [10] software's. The structure of the population was characterized by the following parameters:

- Number of founders (*fo*), which refers to all ancestors with unknown parents.
- Effective number of founders (*fe*), which refers to the number of founders that would produce the same genetic diversity as the studied population.
- Number of effective ancestors (*fa*), which refers to the minimum number of ancestors needed to explain the genetic variability of the studied population, whether they are founders or not [12].
- Inbreeding coefficient (*F*), which quantifies homozygosity; rate of inbreeding per generation (ΔF) and was calculated by Meuwissen and Luo [13] algorithm.
- Kinship coefficient, which is defined by numbering the kinship matrix and representing the genealogical connection between individuals.

3. Results and discussion

Miniature Schnauzers are predominant in the population and acquired the greatest values of *fe* and *fa* of 77.3 and 44.9, respectively (Table 2). The evaluation of *fa*/*fe* ratio indicates the severity of a bottleneck effect, which results in a random reduction in the genetic variation of a population, it is more significative to small populations. If there have been no population/genetic bottlenecks, *fa* will equal *fe* and *fa*/*fe* ratio will be 1, thus the lower *fa/fe* ratio, the greater the bottleneck effect for the population. In the present study, the *fa*/*fe* ratio proved to be satisfactory for the three subpopulations being 0.58 for the miniature, 0.44 for the standard, and 0.34 for the giant sizes, demonstrating a loss of genetic variation due to founders' effect but at acceptable levels for a small population that is under high selection pressure. The results found in this study was superior to that found by Ács, Boko, and Nagy [14] investigating these parameters in a

Border Collie subpopulation in Hungary (0.17), these authors concluded that Border Collie had a genetic loss similar to what was found by Leroy *et al*. [15] in France, working with Pyrenean Shepherd (0.31), Braque de Saint-German (0.63), Dogue de Bordeaux (0.61), and Great Pyrenees Dog (0.66) breeds.

Table 2. The number of effective founders (*fe*), effective ancestors (*fa*), and effective ancestors to effective founder ratio (*fa/fe*) according to the size.

Size	*fe*	*fa*	*fa/fe*
Miniature	77.3	44.9	0.58
Standard	26.3	11.7	0.44
Giant	28.8	9.9	0.34

According to Machado-Schiaffino, Dopico, and Garcia-Vazquez [16], genetic bottlenecks can happen when the same animal is used several times on mating, a fact that occurs in a kennel when a male or female show specific interesting quality, especially those related to the coat characteristics. Also, dogs whose phenotype is desired and his/her offspring carry their characteristics are prone to be overused, making the next generation more related. To fix some characteristics in a population of dogs and produce a standardization related to specific kennels also is persuaded by the raisers, which justifies the results found in this study.

Inbreeding can limit the gene pool in a population, which contributes to deleterious genes becoming widespread and the pure breed, losing vigor. Reproductive traits are the most negatively affected, which goes against the interest of breeders that make profits with dogs that farrow easily and deliver larger litter [17]. As studied in cattle by Burrow [18] and in other animal species by Frankham [19], inbreeding depresses mating ability, female fertility, birth rate, survival rate, weaning rate, maternal ability, sperm motility and production, and percentage of normal cells, besides increasing the incidence of primary and secondary sperm defects and age for sexual maturity. Wildt *et al.* [20] concluded in a study with Foxhound, that the high homozygosity in males compromises the fertility of the group due to the poor quality of the ejaculate, also compromising the female's fertility along generations.

Among the different sizes, the miniature was the most representative. The kennel *fo* was estimated 70.9% for miniature dogs (*fo* = 205 dogs). The inbreeding coefficient in this group and in its respective colors subgroups was below 0.10, being the size group with the lowest percentage of inbred dogs (Table 3).

The standard size was the group that had the lowest mean inbreeding coefficient (0.05) and the lowest number of total dogs (107; Table 3). The subgroup of salt and pepper coat presented the highest percentage of inbred dogs among the subgroups of all sizes (29.5%). The black coat subgroup, on the other hand, had the smallest number of dogs, the lowest percentage of inbreeding (zero %), and the lowest inbreeding coefficient among the subgroups of all known colors and sizes (zero).

Table 3. Population size (N), number of founders (*fo*), percentage of inbred animals (%F), and mean inbreeding coefficients in inbred animals ($\bar{F}$), according to size and coat color of the dogs

Size	Color	N	*fo*	%F	$\bar{F}$
Miniature	Without record	132	-	0	0
	Salt and pepper	155	-	6.5	0.07
	Black	48	-	8.3	0.08
	White	54	-	5.5	0.06
	Black and silver	75	-	12	0.08
	Total	466	205	5.5	0.08
Standard	Without record	45	-	2.2	0.03
	Salt and pepper	44	-	29.5	0.05
	Black	17	-	0	0
	Total	107	40	13.1	0.05
Giant	Without record	34	-	0	0
	Salt and pepper	25	-	24	0.14
	Black	52	-	3.8	0.08
	Total	112	44	7.1	0.12

The giant size showed the highest mean inbreeding coefficient (0.125) that could be related to the high inbreeding coefficient of salt and pepper coat subgroup individuals (0.14), which presented the highest inbreeding coefficient of all subgroups and one of the highest percentages of inbred dogs (24%; Table 3).

The number of founders in the present population (289 out of 685 dogs) means 42.1%, much greater that than the population studied by Leroy *et al*. [15], who found that 15% of founder dogs (1,321 out of 8,812 animals) for French Bulldog considering dogs from several tutors, not from a single kennel. In individual analysis, the miniature size showed the highest range of inbreeding among its individuals (from 0.03 to 0.25), the standard size showed an intermediate-range (from 0.007 to 0.187), and the giant size showed the lowest range (from 0.07 up to 0.125).

Up to seven generations were evaluated for ΔF. The miniature size presented ΔF from the third generation (0.074); however, in the sixth generation, there was a decrease in ΔF (0.020). The standard size also showed ΔF in the third generation (0.011) and in the sixth generation, there was an increase in its ΔF (0.022). The giant size, on the other hand, presented ΔF only in the fifth generation (0.058) and showed a decrease in ΔF in the sixth generation (0.039; Table 4).

The miniature and standard groups showed a mean inbreeding coefficient below 0.10, demonstrating certain maintenance of population diversity, explained by the greater number of miniature and standard animals. However, some dogs in these groups have their inbreeding coefficients close to the acceptable limit of 0.10.

In the evaluation that was carried out, giant size dogs and salt and pepper coat obtained a mean inbreeding coefficient of 0.14 (Table 3), considered high. The giant size had a small population, and the salt and pepper color there was smaller than the other coat colors, making genetic distancing difficult in the choice of mating. The inbreeding is probably due to the popularity of the black coat in the giant size Schnauzers and the salt and pepper coat in the miniature size.

The giant size dogs showed a high inbreeding coefficient (0.12), but it is noteworthy that the breeder seeks dog with greater distance in kinship to maintain genetic diversity, but reported to face difficulties in acquiring giant size breeder dogs, especially those of the salt and pepper subgroup, which is the possible explanation for the high inbreeding coefficient noticed.

It was estimated that 5.5% of individuals are inbred in the population of dogs in the miniature group, 13% in the standard group, and 7% in the giant group, percentages above that found by Karjalainen and Ojala [21] for the Finnish Hound (3.12%), but similar to that found by the same authors for Finnish Spitz Dog (7.16%).

The dogs of the miniature group showed a greater range of inbreeding (from 0.03 to 0.25), whereas the standard size showed an intermediate-range (from 0.007 to 0.187) and the standard size showed the smallest range (from 0.07 to 0.125), probably because this population had the smallest number of animals. Some dogs showed a very high value for inbreeding coefficient, but still below that found in Finnish Hound (0.375) and Finnish Spitz Dog (0.523)in a study in Finland.

When analyzing the kinship coefficient between animals separated by size and coat color subgroups, the relationship between animals of the same size and coat color (from 0.025 to 0.201) was much higher than when compared with animals of the same size and different coat colors (from 0 to 0.072; Table 5).

Table 4. Rate of inbreeding per generation according to size

	Generation					
Size	1	2	3	4	5	6
Miniature	-	-	0.074	0.046	0.024	0.020
Standard	-	-	0.011	0.037	0.007	0.022
Giant	-	-	-	-	0.058	0.039

Table 5. Mean relationship between subgroups of coat color and size

Size	Color	Salt and pepper	Black	White	Black and silver
Miniature	Salt and pepper	0.025	0.001	0.001	0.007
	Black	0.001	0.066	0.000	0.002
	White	0.001	0.000	0.072	0.000
	Black and silver	0.007	0.002	0.000	0.053
Standard	Salt and pepper	0.140	0.032	-	-
	Black	0.032	0.160	-	-
Giant	Salt and pepper	0.201	0.013	-	-
	Black	0.013	0.072	-	-

In practice, according to breeders report the Schnauzer dog mating is made to acquire size and coat color, which creates subgroups within a population. This proves to be true when were analyzed the kinship coefficient in these subgroups of size and coat color, as well as the measures of interaction between them. The kinship coefficient with the same coat color within the same group of size ranged from 0.025 to 0.201. When given the same coefficient between different coat color subgroups, there was a variation from 0 to 0.032 (Table 5), demonstrating that the dogs have little interaction between the subgroups.

4. Conclusion

The population of Schnauzer dogs evaluated in this study presented a low percentage of inbred animals, especially for the groups of miniature and standard sizes. The highest kinship coefficient is found among dogs of the same size and coat color, reinforcing the direction of breeders for the maintenance and formation of coat types. The data indicates the need for monitoring mating on giant-sized Schnauzer dogs, especially salt and pepper color, which have higher inbreeding coefficients. The identification of dogs with high inbreeding levels will allow planning next mating (throughout more genetically distant breeders) so that future generations do not have their population structure compromised and so that there is a better selection of new dogs introduced in the breeding stock, thus contributing to animal welfare, avoiding genetic diseases related.

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