

Analysis of genetic structure of the Beagle population in the area of Cracow Branch of the Polish Kennel Club

Maciej Gierdziewicz^{1*}, Joanna Kania-Gierdziewicz¹, Bożena Kalinowska²

¹ Department of Genetics and Animal Breeding, University of Life Sciences in Cracow,
al. Mickiewicza 24/28, 30-059 Cracow, Poland

² Cracow Branch of the Polish Kennel Club, ul. Żywiecka 36, 30-427 Cracow, Poland

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Inbreeding and relationship are presented in the Beagle dog population as well as the contribution of founders and ancestors to the active population of Beagles recorded in the herdbook of the Cracow Branch of the Polish Kennel Club. From four-generation pedigrees of 84 Beagle dogs (29 males and 55 females) born in 1996-2007, one-generation pedigrees of 611 individuals (267 males and 344 females) were created. The inbreeding (F_x) and relationship (R_{xy}) coefficients were estimated for all 611 animals, for each sex separately and between sexes. For the active population of 84 animals, founders and ancestors were determined. Among all the animals, 13.75% (12.36% of males and 14.83% of females) were inbred; about 43% of those belonged to the active population. The mean F_x values for all and for inbred individuals amounted to 0.0068 and 0.0492, respectively (0.0070 for all males, 0.0066 for all females, 0.0565 for inbred males and 0.0445 for inbred females). About 12.28% of pairs were related. The mean R_{xy} was 0.0104 and 0.0848 for all and related pairs, respectively (0.0095 and 0.0926 in males, 0.0114 and 0.0807 in females, 0.0101 and 0.0853 between sexes). There were total of 222 founders and 54 ancestors. The effective numbers of founders and ancestors were 102 and 26, respectively. There were 29 main founders revealed. Four founders contributed from 2% to approx. 3% of genes while the others only 1-2%. Seven out of 34 main ancestors contributed from 4% to over 10% genes, and remaining ones - up to 4%. One individual was both main founder and main ancestor.

KEY WORDS: ancestors / Beagle / founders / genetic structure / inbreeding / relationship

Beagle is an old English breed, already known in the middle ages. The oldest information can be found in the songs of Scottish bard Ossian who lived in III Century.

*Corresponding author: rzgierdz@cyf-kr.edu.pl

One of the theories claims that Beagles came from the ancient Greece from where they arrived with the Romans to the British Islands. They may be descendants of the hounds which were brought to England by the Normans and Wilhelm the Conqueror in 1066. The name of the breed is of a mysterious origin. It is believed to have been derived from the word *beag* meaning “little” or an old French word *beguelle* meaning “ajar throat”. Barking of Beagles is very melodious. It sounds like a choir which is the reason for Beagles being sometimes called “singing dogs”. Queen Elisabeth is a great admirer of Beagles and has a big pack of them. Those were the pocket or miniature Beagles, sometimes called Elizabethian Beagles, so small that 10 of them could be put in one sack. Since then Beagles became very popular in Britain [Sutton 1972, Chwalibóg 2001, 2004, Brodowska 2004].

The first Beagles were brought to Poland in the seventies of XX Century from Czechoslovakia, Denmark and Finland and first Polish kennels were set up in the nineties. Beagles have become very popular in Poland which can be observed at present at any dog show. Since they were more and more popular, they finally became companion dogs. However, information on the genetic structure of their population in the area of Polish and regional Kennel Clubs is scarce. Facing the above the authors consider it useful to start supplying breeders with the selected data on the genetic structure of population of Beagles in Poland.

The aim of this study was to investigate the inbreeding and relationship in the whole population and also the founder and ancestor contribution to the active population of Beagle dogs bred in Cracow Branch of the Polish Kennel Club.

Material and methods

The material consisted of data on 84 pedigrees i.e. all the pedigree data on Beagle dogs available at Cracow Branch of Polish Kennel Club, in the form of standard four-generation pedigrees: 29 males and 55 females born in the years 1996-2007, further referred to as the active population. The 84 animals made up about 8% of the 1039 Beagle dogs (364 males and 675 females) registered in all branches of the Polish Kennel Club. The data included the 84 individuals mentioned above and their 527 ancestors - a total of 611 animals. The four-generation pedigrees were transformed to obtain one-generation ones. The coefficients of inbreeding (F_x) and relationship (R_{xy}) among all the 611 animals for each sex separately as well as between sexes were estimated according to Tier's [1990] algorithm with recursive modification [Gierdziewicz and Kania-Gierdziewicz 2007].

The active population of 84 animals was considered as the reference population in founder and ancestor analysis. The total and effective numbers of founders and ancestors were estimated, and the founders and ancestors with the highest gene contribution to the reference population were identified. The effective number of founders (f_e) and the effective number of ancestors (f_a) were calculated according to Lacy [1989, 1995], as modified by Boichard *et al.* [1995, 1996, 1997].

Results and discussion

Relationship and inbreeding coefficients

Among all the 611 animals considered in the study, 84 individuals (13.75%) were inbred; 36 of them belonged to the active population. The F_x value for all, and for all inbred individuals was 0.0068 and 0.0492, respectively. The group of 267 males contained 33 (12.36%), while that of 344 females – 51 (14.83%) inbred individuals. The mean F_x value was 0.0070 and 0.0066, respectively, for all males and all females, and 0.0565 and 0.0445 for inbred males and inbred females (Tab. 1).

Table 1. Mean inbreeding (F_x) and relationship (R_{xy}) coefficients for Beagle dogs registered in Cracow Branch of Polish Kennel Club

Item	All animals			Inbred animals		
	N	F_x (%)	range (%)	N	F_x (%)	range (%)
Sex						
males	267	0.70	0-12.50	33	5.65	0.10-12.50
females	344	0.66	0-25.00	51	4.45	0.05-25.00
total	611	0.68	0-25.00	84	4.92	0.05-25.00
Comparison						
male-male	35511	0.95	0-61.10	3630	9.26	0.02-61.10
female-female	58996	1.14	0-67.10	8372	8.07	0.02-67.10
male-female	91848	1.01	0-67.10	10876	8.53	0.02-67.10
total	186355	1.04	0-67.10	22878	8.48	0.02-67.10

Mean inbreeding coefficients for inbred animals ranged from about 4.5% to almost 5.7%, depending on sex, but did not exceed the critical value of 12.5% [Wright 1921, 1922, 1931, Falconer 1984].

Drozd and Karpiński [1997] examined populations of 483 Rottweilers, 435 German Mastiffs, 546 German Boxers and 712 German Shepherds. Considering mean F_x values for sex groups of all males and all females of all the four breeds, the means estimated in that study ranged from 0.23% (German Shepherd females) to 1.44% (Rottweiler females); the results for inbred groups, when compared to ours, were lower for German Shepherds, higher for German mastiffs and roughly similar for the remaining two breeds, ranging from about 1.9% in German Shepherd females to almost 8.8% for German Mastiff males.

Jakubczak and Jeżewska [2000], who examined the level of inbreeding and its influence on reproductive and breeding performance in pastel fox, reported similar or even higher mean F_x values, especially for inbred animals.

Cole *et al.* [2004] also reported much higher values of inbreeding than in the present study; they found the average F_x to be about 25% in German Shepherds and around 15% in Labrador Retrievers, both working as guide dogs.

In a small population of Polish Hound breed, studied by Głazewska [2008], the level of inbreeding was also found higher than in the present investigation, ranging

from 30% to 40% and increasing with time, which resulted in health and reproduction problems.

Ólafsdóttir and Kristjánsson [2008] for a small and endangered population of Icelandic Sheepdog estimated the mean F_x at 21%, that was higher than in the present study. The authors suggested that such high inbreeding level may have caused frequent cases of hip dysplasia in these animals.

The values of inbreeding coefficient found in this study fall within the range of those of 61 dog breeds in France, which ranged from about 0.3% in Romagna Water dogs to 8.8% in Pyrenean Shepherds, as reported by Leroy *et al.* [2009].

Table 2. List of inbred animals from Beagle dog population with F_x of more than 6%.
Bolded are names of animals belonging to active population

Identity number	Name	Sex	F_x (%)
PKR.VI-7881	Octavia Old Glory	female	25.00
PKR.VI-5554	Ada z Lechickich Łąk	female	13.28
PKR.VI-3082	Pigi Dolby z Rydzyńskiego Lasu	female	12.50
U4263003U04	Dialynne Ambition	female	12.50
VDH/BCD 96-408	Dialynne Cassock	male	12.50
LOSH 0748221	Tosca het Hulterhof	female	12.50
PKR.VI-9130	Don Corleone Catulus	male	12.50
BL003294	Belvoir Hang Emhigh Jnr	male	12.50
PKR.VI-5548	Belvoir Magnumhotpursuit	male	12.50
PKR.VI-7430	Honorowa Hania Leo	female	11.72
PKR.VI-9447	Incognito Leo Libra	male	11.72
PKR.VI-7403	Daragoj Frank Zappa	male	10.94
SPKP 608/03	Daragoj Freddie Mercuri	male	10.94
PKR.VI-8515	Bajeczny Blondyn Polot	male	10.16
PKR.VI-8152	Barwny Bibelot Polot	male	10.16
PKR.VI-8629	Spotless Kolia	female	9.77
NHSB 2350509	Dialynne Gambit	male	9.38
PKR.VI-8153	Dumka Psi Eden	female	8.20
PKR.VI-8594	Emir Psi Eden	male	8.20
PKR.VI-4856	Milwa z Rydzyńskiego Lasu	female	7.81
PKR.VI-4349	Corsa spod Wierzchowskiej Groty	female	7.81
BR0002954	Beharim Impossibledream At Ardmore	female	7.81
PKR.VI-10085	Hotshot Xandrina	male	6.84
PKR.VI-10919	Only For You Xandrina	female	6.45
FIN1127498	Daragoj Charlotte Russe	female	6.25
FIN43411/00	Daragoj Crystal Rain	male	6.25
CLP/2547/01	Daragoj Crystal Chance	male	6.25
VDH/BCD/00316	Daragoj Country Classic	male	6.25
24332/94	Skansehoj's Katrine	female	6.25
PKR.VI-5241	Fliper Weinlinie	male	6.25
HM95261801	Barrister's Play Wright	female	6.25
PKR.VI-5242	Enigma Weinlinie	female	6.25
AKC HM81075801	Bayou Oaks Tiger Woods	male	6.25
PKR.VI-5908	Hosszufulu Filip	male	6.25

In Table 2 the Polish Beagles are listed with the F_x higher than 6%. Thirteen of those (six males and seven females) belonged to the active population. The highest F_x values were found in two females – *Octavia Old Glory* PKR.VI-7881 ($F_x=25\%$) and *Ada z Lechickich Łąk* PKR.VI-5554 ($F_x=over\ 13\%$). Next group of seven animals with four males and three females showed all the same values of inbreeding coefficient ($F_x = 12.5\%$).

The Beagle dog population included 186355 pairs, 22878 (12.28%) of which were related. The relationship coefficient for all and for related pairs amounted to 0.0104 and 0.0848, respectively. Among the 35511 pairs of males, related were only 3630 (10.22%). The mean R_{xy} values for this group were 0.0095 for all pairs and 0.0926 for related pairs. Among the 58996 pairs of females, 8372 (14.19%) related pairs were identified, with the mean R_{xy} values of 0.0114 and 0.0807 for all pairs and for related pairs, respectively. Out of the total of 91848 mixed male-female pairs, 10876 pairs (11.84%) were related. The R_{xy} values in this group were 0.0101 and 0.0853 for all pairs and related pairs, respectively (Tab. 1).

Drozd and Karpiński [1997] reported the values of R_{xy} in four dog breeds to range from 0.34% to 0.72% for all pairs and from 0.39% to 2.68% for related pairs, all being lower than those found in the present study. The values published by Leroy *et al.* [2009] for 61 dog breeds in France are lower than our present results (for all pairs) or similar (for related pairs). Those reported by Cole *et al.* [2004] for German Shepherds and Labrador Retrievers were lower for all pairs and much higher for related pairs (about 25% in German Shepherds).

Founder and ancestor contribution analysis

The total number of founders for the reference population of 84 animals was 222, and the total number of ancestors was 54. The effective numbers of founders and ancestors were 102 and 26, respectively (Tab. 3).

Table 3. Total number of founders and ancestors and effective number of founders (f_a) and ancestors (f_e) for reference population of 84 animals (active breeding population) of Beagle dogs

Founders		Ancestors	
total	f_a	total	f_e
222	102	54	26

The founder group with the biggest gene contributions, shown in Table 4, included 29 animals (13 males and 16 females). The top four founders contributed from 2 to about 3% of genes. The first and second position were occupied by the male *Dialynne Gamble* 0223BF and the female *Kittoch Garland* (F1284201F06), both with a contribution of 2.86% genes. Next two animals: the male *Ernie Envoi von Rechpeg* (ZB Nr. 684) and the female *Foltos Bogarfulu Alin* (CLP/BEA/3/86)

Table 4. Founders with more than 1% gene contribution to reference population of 84 Beagle dogs registered in the Cracow Branch of Polish Kennel Club (the name of the animal being both a main founder and a main ancestor is printed in italics)

Identity number	Name	Sex	Contribution (%)
0223BF	Dialynne Gamble	male	2.86
F1284201F06	Kittoch Garland	female	2.86
ZB Nr. 684	Ernie Envoy von Rechperg	male	2.29
CLP/BEA/3/86	Foltos Bogarfulu Alin	female	2.29
AKCSBHD472651	Echo Run Jumping Jack Flash	male	1.72
AKCSBHD639536	Loverly Too Hot To Touch	female	1.72
PKR.VI-III-527	Ingrid Jut	female	1.60
MET.Beagle 308	Nevitox-Ami	male	1.60
L5556604L03	Crickhollow Cristabel At Roff	female	1.60
MET.Beagle 183	Batus-Falvi Piszze-Poty	female	1.60
DKK 14839/87	Magic Noire Sunshine Baroness	female	1.47
SF32534/88	Daragoj Sabrina	female	1.29
FKK SF2664088	Daragoj Jumping Jack	male	1.29
SKK SF2823487	Daragoj Piece Of Gold	female	1.29
DKK 17495/84	Red Baron Blue Moon	male	1.28
DKK 04474/86	Magic Noire Just	male	1.28
AKCHC 586911	Buglair The Prsident	male	1.28
DKK 30644/85	Trewint Quester	male	1.28
KC M2149602M02	Trewint Impulse	female	1.28
DKK 20686/76	Mildred	female	1.28
MET.Beagle392	Batus-Falvi Fani	female	1.23
2387BR	Dialynne Nimrod Of Ramlacim	male	1.17
3535BS	Tod Darn Hot For Tragband	female	1.17
MET 275/89	<i>Budapest Beagle Boogie-Woogie</i>	female	1.15
VDH/BCD 83-101	True Line's Decent Cardigan	male	1.14
VDH/BCD 83-128	True Line's Galactic Ely	female	1.14
0417BX	Buttermere Barleycorn	female	1.13
CLP/BEA/12/88	Denny Tergy	male	1.04
SPKP 4/88	Fandango Fortunata	female	1.04
	total		43.40

contributed 2.29% each. The other main founders brought contributions of up to 2%. About 44% of the genetic variation in the reference population can be explained by the contribution of the 29 main founders (Tab. 4).

Table 5 shows the main ancestors with more than 1% of gene contribution. Thirty-four animals (20 males and 14 females) were identified as main ancestors. Among those, seven individuals (5 males and 2 females) made the highest gene contribution to the population – from 4 to over 10%. The largest contributor was the male *Will Murphy of Justine's Pack* CLP/BEA/230/94 (10.27%), closely followed by males *Barrister's Play Bill* PKR.VI-9408 (6.55%) and *Budapeszt Beagle Bongo* CLP/BEA/225/93 (6.4%) and by the female *To Tam To Tu Tel Quel* PKR.VI-5282

Table 5. Ancestors with more than 1% gene contribution to reference population of 84 Beagle dogs registered in the Cracow Branch of Polish Kennel Club (the name of the animal being both a main founder and a main ancestor is printed in italics)

Identity number	Name	Sex	Contribution (%)
CLP/BEA/230/94	Will Murphy Of Justine's Pack	male	10.27
PKR.VI-9408	Barrister's Play Bill	male	6.55
CLP/BEA/225/93	Budapest Beagle Bongo	male	6.40
PKR.VI-5282	To Tam To Tu Tel Quel	female	6.25
CLP/BEA/13/88	Dixy Tergy	male	4.58
PKR.VI-6384	Dufosee Guinevre	female	4.32
CLP/BEA/1846/2000	Xailo het Hulterhof	male	4.02
CLP/2547/01	Daragoj Crystal Chance	male	3.57
0114 BT	Soloman Of Dialynne	male	3.37
PKR.VI-8972	Csavargo Pomy	male	2.98
PKR.VI-7403	Daragoj Frank Zappa	male	2.98
PKR.VI-5241	Fliper Weinlinie	male	2.86
PKR.VI-10293	Flex Ajkin dvor	male	2.33
MET 275/89	<i>Budapest Beagle Boogie-Woogie</i>	female	2.31
PKR.VI-6470	Dream Come True English Matricaria	female	2.08
PKR.VI-5389	Shelaft Billy Whizz Of Dialynne	male	2.08
PKR.VI-9524	Benita Połkrza	female	1.79
CLP/BEA/619/96	Tobby het Hulterhof	male	1.67
SPKP 2/88	True Line's Esteemed Rothbury	female	1.64
OHZB 1609	Erskine-Earl Of Stonebridge	male	1.56
NHSB 2350509	Dialyne Gambit	male	1.51
PKR.VI-9504	Alexa At Old Glory Xandrina	female	1.34
PKR.VI-1901	Bonny Laciata Sfora	male	1.26
SPKP 13/91	Alina Ludmanka	female	1.26
PKR.VI-10374	Posibly Dream z Krainy Szczęścia	female	1.19
ANKC 4100081651	Brevari Hidden Agenda	male	1.19
AKC HM 81075801	Bayou Oaks Tiger Woods	male	1.19
PKR.VI-5242	Enigma Weinline	female	1.19
SPKP 724/05	Csavargo Luca	female	1.15
PKR.VI-10919	Only For You Xandrina	female	1.15
PKR.VI-11633	Csavargo Gerda	female	1.12
CLP/BEA/585/96	Ginna Tergy	female	1.12
PKR.VI-5908	Hosszufulu Filip	male	1.08
PKR.VI-9906	Żel z Damastawka	male	1.04
	total		90.40

(6.25% contribution). The next three ancestors, male *Dixy Tergy* CLP/BEA/13/88, female *Dufosee Guinevre* PKR.VI-6384 and another male *Xailo het Hulterhof* CLP/BEA/1846/2000 accounted for about 4.58%, 4.32% and 4.02% of genes, respectively. The gene contributions of nine ancestors (seven males and two females) ranged from 2% to 4%, while remaining main ancestors contributed only 1-2% of genes. A total of 34 main ancestors contributed over 90% of genes to the gene pool of the reference population (Tab. 5).

Only one individual was found to be both main founder and main ancestor. It was the female *Budapest Beagle Boogie-Woogie* MET 275/89. This name is printed in italics in Tables 4 and 5.

The effective numbers of founders (f_e) and ancestors (f_a) of the Beagle dog population, estimated in the present study, are similar to those reported by Cole *et al.* [2004] for much larger populations of German Shepherd dogs and Labrador Retriever dogs working as guides.

Compared to the values calculated for Beagles in the present study, the gene contribution of some founders to the population of Polish Hound breed assessed by Głażewska [2008] was much higher.

Leroy *et al.* [2009] found that the effective number of ancestors (f_e) and effective number of founders (f_a) of 61 dog breeds in France ranged from 10 (in Barbets) to 656 (in poodles) for f_e , and from 9 to 209 for f_a . The size of the reference population was 112 and 8808 animals for Barbets and for poodles, respectively. Our current results fall within the above range, though they were estimated on a smaller reference population (only 84 animals).

Summing up, though the results presented here are not concerning the whole Polish Beagle population, it may be concluded that at present it is not endangered with high inbreeding and relationship level. To avoid future problems it should be enough to observe the general rule of not mating closely related animals.

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