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Ctenocephalides felis felis vs. *Ctenocephalides canis* (Siphonaptera: Pulicidae): some issues in correctly identify these species

Ctenocephalides felis felis vs. *Ctenocephalides canis*: (Siphonaptera: Pulicidae): algumas questões para identificar corretamente estas espécies

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Abstract

Ctenocephalides felis felis is one of the most important ectoparasites of dogs and cats throughout the world, because of its geographical distribution, dual parasitological action as an infesting agent and a vector of diseases, the economic losses and the acquired resistance against common insecticides. In Brazil, it surpasses *Ctenocephalides canis* in distribution, number of host species infested, prevalence and epidemiological importance. However, in some studies the species have been misidentified on the basis of their morphological characters included in taxonomic keys. The morphological variations of chaetotaxy, especially those on the dorsal margin of the hind tibia and lateral metanotal area (LMA), found in certain specimens, have sometimes been erroneously treated as hybrids, in spite of the nonexistence of the two species of *Ctenocephalides* in the same municipality or region. This review focuses on the characteristics used for interspecific diagnosis and intraspecific variations found between the species. Data on distribution, hosts, prevalence and parasitological action are also presented as an auxiliary means for recognizing the species.

Keywords: *Ctenocephalides felis felis*, *Ctenocephalides canis*, Siphonaptera, fleas, taxonomy, morphological variation.

Resumo

Ctenocephalides felis felis é um dos mais importantes ectoparasitos de cães e gatos no mundo inteiro, em virtude de sua distribuição geográfica, dupla ação parasitológica como agente infestante e vetor de doenças, perdas econômicas e resistência adquirida contra inseticidas comuns. No Brasil, ela sobrepuja *Ctenocephalides canis* em distribuição, número de espécies de hospedeiros infestadas, prevalência e importância epidemiológica. Todavia, em alguns estudos, as espécies têm sido incorretamente identificadas pelos caracteres morfológicos incluídos em chaves taxonômicas. As variações morfológicas de quetotaxia, especialmente aquelas da margem dorsal da tibia posterior e área metanotal lateral (LMA) encontradas em certos exemplares, algumas vezes têm sido erroneamente consideradas como híbridas, a despeito da inexistência das duas espécies em um mesmo município ou região. Esta revisão aborda as características utilizadas para o diagnóstico interespecífico e variações intra-específicas encontradas entre as espécies. Dados sobre distribuição, hospedeiros, prevalência e atuação parasitológica são também apresentados como um meio auxiliar para o reconhecimento das espécies.

Palavras-chave: *Ctenocephalides felis felis*, *Ctenocephalides canis*, Siphonaptera, pulgas, taxonomia, variações morfológicas.

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Introduction

Within the family Pulicidae of the order Siphonaptera, the genus *Ctenocephalides* Stiles & Collins, 1930, includes 13 species and subspecies (BEAUCOURNU; MÉNIER, 1998), but only two, respectively the dog flea *Ctenocephalides canis* (Curtis, 1826) and the cat flea *Ctenocephalides felis felis* (Bouché, 1835), are cosmopolitans that have been recorded in South America. *C. felis felis* is more adaptable than *C. canis*, since it infests more host species and has therefore become established in more extensive areas (HOPKINS et al., 1953). According to KOUTINAS et al. (1995), the distribution of these species is related to environmental factors that influence their survival, development and reproduction.

Although the two species of *Ctenocephalides* can occur in the same Brazilian geographical region and infest the same host species, *C. felis felis* is more important in disease transmission. Moreover, *C. felis felis* has also already shown resistance to common insecticides for two decades (EL-GAZZAR et al., 1986). For this reason, correct species identification is essential for control measures and genetic inferences.

The two species are usually separated according to the shape of the head, length of the first spine of the genal comb, number of bristles on the lateral metanotal area (LMA) (Figures 1, 2) and the number of short stout bristles in the interval between the postmedian and apical long bristles of the dorsal margin of the hind tibia (HOPKINS et al., 1953; JOHNSON, 1957; AMIN, 1976; MÉNIER; BEAUCOURNU, 1998; BEAUCOURNU; MÉNIER, 1998; LINARDI; GUIMARÃES, 2000) (Figures 3, 4; Table 1). Males can be further identified by the shape of the manubrium of the clasper (HOLLAND, 1949) (Figures 5, 6) and the size of the hamulus on the aedeagus (Figures 2 and 3 of MÉNIER; BEAUCOURNU, 1998). However, in spite of these differences, some variations in the chaetotaxy and the number of spines in the genal comb have been found (AMIN, 1976; AMIN et al., 1974). Some misidentifications have also been noticed: in the Afrotropical zone, *C. felis strongylus* has often been identified incorrectly as

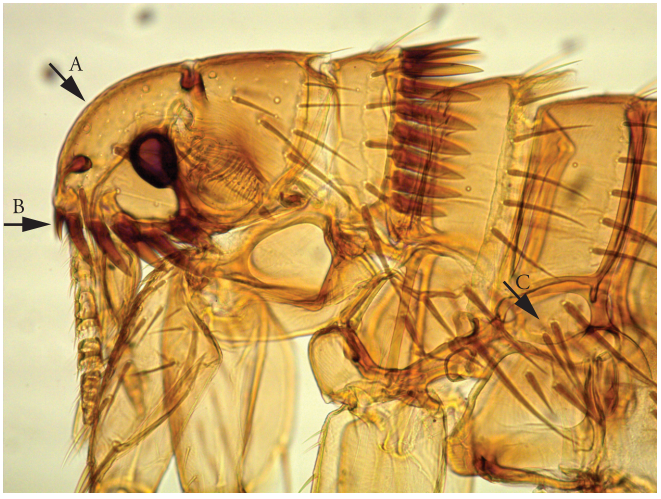

Figure 1. Female of *C. canis*. A. shape of the head; B. length of the first spine of the genal comb; C. number of bristles on the lateral metanotal area (LMA).

Figure 2. Female of *C. f. felis*. A'. shape of the head; B'. length of the first spine of the genal comb; C'. number of bristles on the lateral metanotal area (LMA).

Table 1. Morphological differences between *C. felis felis* and *C. canis*.

Characteristics	*C. felis felis*	*C. canis*
Shape of the head	Length generally greater than twice the height (Figure 2A')	Length is not twice the height (Figure 1A)
Spine 1 and 2 of the genal comb	First two spines are approximately equal in length (Figure 2B')	First spine is half as long as second spine (Figure 1B)
Number of bristles on the LMA*	One or two (Figure 2C')	Three (Figure 1C)
Number of notches on tibiae	Tibiae of all 6 legs have 5 to 6 notches (Figure 4)	Tibiae of all 6 legs have 7 to 8 notches (Figure 3)
Number of stout bristles on dorsal margin of the hind tibia	One in the interval between postmedian and apical long bristles (Figure 4)	Two in the interval between postmedian and apical long bristles (Figure 3)
Metatibial formula of chaetotaxy	2-2-2-2-1-3 (Figure 4)	2-2-2-2-2-1-1-3 (Figure 3)
Male: shape of the manubrium of the clasper	Not expanded apically (Figure 6)	Expanded apically (Figure 5)
Male: aedeagus	Hamulus small, longer than width (~2.5 times) (according to Figure 3 of MÉNIER; BEAUCOURNU, 1998)	Hamulus: length and width approximately the same (according to Figure 2 of MÉNIER; BEAUCOURNU, 1998)

*Lateral metanotal area.

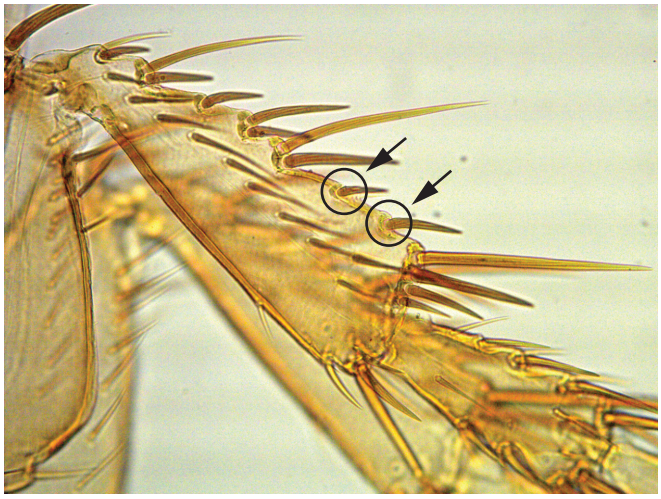

Figure 3. Female of *C. canis*. Two short stout bristles in the interval between the postmedian and apical long bristles of the dorsal margin of the hind tibia.

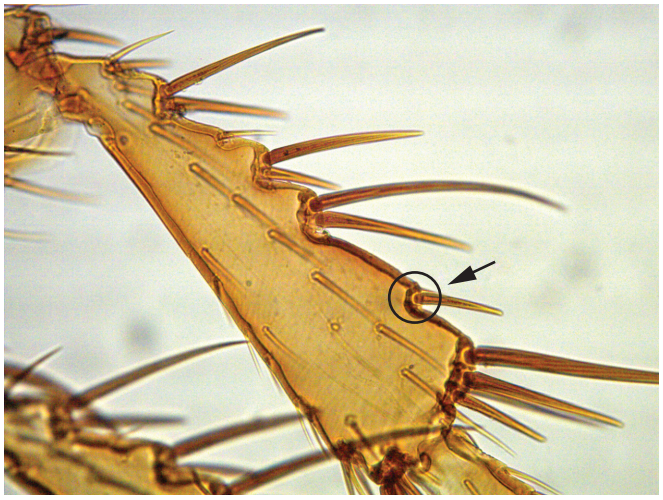

Figure 4. Female of *C. f. felis*. One short stout bristle in the interval between the postmedian and apical long bristles of the dorsal margin of the hind tibia.

C. canis based on the sole criterion of the cephalic profile; and likewise, *C. orientis* in Asia (BEAUCOURNU; KOCK, 1990). *Ctenocephalides* collected from epidemiological investigations, particularly in relation to plague in the Palaearctic and Nearctic regions, were often named according to their hosts, although urban dogs are much more infested with *C. felis felis* than with *C. canis* (BEAUCOURNU, 1973). On the other hand, some characteristics have been improperly interpreted when using certain taxonomic keys.

Hosts of *Ctenocephalides*

Ctenocephalides species infest carnivores, edentates, lagomorphs, marsupials, primates, rodents and ungulates, and can also be found in the nests, burrows, trails and tracks of their hosts, as well as indoors, where they colonize profusely (LINARDI; GUIMARÃES, 2000). Brazilian host species recorded for species of *Ctenocephalides* include seven orders and 41 species of mammals, as well as one species of bird infested by *C. felis felis* (Table 2). Although carnivores can be considered to be the true or primary hosts, infestations on Brazilian carnivores and rodents represent respectively 26.8% and 43.9% of the findings. The cat flea is commonly collected on opossums because of the varied habitats that they use (LINARDI, 2006). On the contrary, *C. canis* is only seen on domestic carnivores.

Figure 5. Male of *C. canis*. Shape of the manubrium of the clasper.

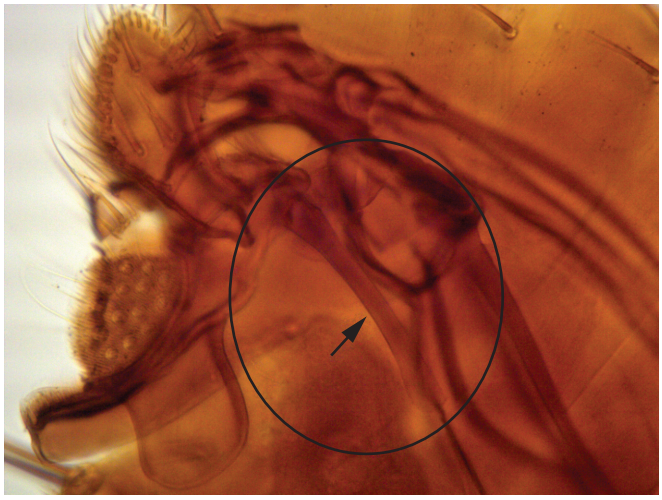

Figure 6. Male of *C. f. felis*. Shape of the manubrium of the clasper.

Ctenocephalides Species as Vectors of Diseases

Amongst the arthropods, *C. felis felis* is the most important ectoparasite of dogs and cats throughout the world, causing annoyance to the animals and acting as a vector of diseases (RUST; DRYDEN 1997). It causes allergic dermatitis (HALLIWELL, 1979) and in heavy infestations can also cause iron deficiency anemia in young animals (HARVEY et al., 1982). More than twenty different

types of endosymbionts or pathogens have been found to be associated with species of *Ctenocephalides* as biological vectors or intermediate hosts, including bacteria, protozoa and helminths, thus representing a potential health risk for humans (JELLISON, 1959; JENKINS, 1964; BEARD et al., 1990; KRÄMER; MENCKE, 2001; LINARDI; GUIMARÃES, 2000; LINARDI, 2001). The cat flea also lodges other monoxenic organisms, such as gregarines, microsporidians and trypanosomatids. The endosymbionts or pathogens found in *Ctenocephalides* species in Brazil are shown in Table 3. According to De Avelar et al. (2007, 2008), these endosymbionts might be useful for biological control of *C. felis felis* in environments exhibiting high levels of infestation. Also using molecular techniques, Coutinho and Linardi (2007) and Ferreira et al. (2009a) recognized DNA of *Leishmania chagasi* in *C. felis felis*, thus opening new perspectives for mechanical transmission of canine visceral leishmaniasis.

De Avelar et al. (2011) raised the possibility that *Leptomonas* of fleas may be pathogenic to humans and dogs because some people crush dog fleas between their fingers and carry them to their mouths. Besides, dogs are likely to ingest flea gut contents or entire fleas when crushing the insects between their teeth or licking their own fur or that of other dogs. According to Garin et al. (2001), it is possible that the numbers of human cases of infection with lower trypanosomatids is underestimated because of the morphological similarity to and cross-reactivity with *Leishmania infantum chagasi*.

In addition to the role as a transmitter of diseases, *C. felis felis* provokes allergic dermatitis and has been reported to produce anemia in dogs, cats, goats, cattle and sheep (OBASAJU; OTESILE, 1980; YERUHAM et al., 1989).

Geographical Distribution

C. felis felis was most prevalent species in studies on companion animals in Argentina (LOMBARDDERO; SANTA-CRUZ, 1986), Australia (CORNACK; O'ROURKE, 1991), Denmark (KRISTENSEN et al., 1978), Egypt (AMIN, 1966), Germany (LIEBISCH et al., 1985), Puerto Rico (FOX, 1952), South Africa (HORAK, 1982), United Kingdom (BERESFORD-JONES, 1981; COWARD, 1991; CHESNEY, 1995) and USA (AMIN, 1976; MUNSEE, 1985; HARMAN et al., 1987). Otherwise, *C. canis* was the commonest species found on dogs in Austria (RESSL, 1963), Greece (KOUTINAS et al., 1995), Ireland (BAKER; HATCH, 1972), New Zealand (GUZMAN, 1984) and Poland (PIOTROWSKI; POLOMSKA, 1975).

In Brazil, *C. felis felis* is also the most common flea of Canidae and has been found in 17 states: Alagoas, Amazonas, Bahia, Ceará, Espírito Santo, Goiás, Mato Grosso, Minas Gerais, Paraíba, Paraná, Pernambuco (including the territory of Fernando de Noronha), Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Roraima, Santa Catarina and São Paulo. On the other

Table 2. Species of hosts for *Ctenocephalides* spp. recorded in Brazil.

Host Orders	*C. canis*	*C. felis felis*
Artiodactyla	-	*Bos taurus*
Carnivora	*Canis familiaris, Felis catus*	*Canis familiaris, Cerdocyon thous, Chrysocyon brachyurus, Eira barbara, Felis catus, Leopardus pardalis, Leopardus tigrinus, Lycalopex vetulus, Nasua nasua, Panthera onca, Procyon cancrivorus*
Didelphimorphia	-	*Didelphis albiventris, D. aurita, D. marsupialis, Lutreolina crassicaudata, Monodelphis domestica*
Lagomorpha	-	*Sylvilagus brasiliensis brasiliensis*
Primates	-	*Allouatta seniculus, Cebus* sp., *Homo sapiens*
Rodentia	-	*Akodon serrensis, Cavia porcellus, Euryzygomatomys spinosus, Galea spixii spixii, Hydrochoerus hydrochoeris, Mus musculus, Necromys lasiurus, Oligoryzomys eliurus, O. nigripes, Oryzomys subflavus, Oxymycterus angularis, O. roberti, Rattus norvegicus, R. rattus, Rhipidomys mastacalis, Sciurus aestuans, Thrichomys apereoides, Trinomys albispinus,*
Xenarthra	-	*Dasypus novemcinctus, Tamandua tetradactyla*
Aves	-	*Bubo crassirostris*

Table 3. Endosymbionts of *Ctenocephalides* species encountered in natural and experimental infections in Brazil.

Endosymbionts	*C. canis*	*C. f. felis*	Infection	Reference
Rickettsia felis	+	+	natural	Oliveira et al. (2002), Horta et al. (2006, 2007)
Mixomae molitor	-	+	experimental	Aragão (1920)
Yersinia pestis	+	+	natural	Brasil et al. (1989)
Nosema ctenocephali	-	+	natural	De Avelar et al. (2007)
Steinina sp.	-	+	natural	De Avelar et al. (2007)
Leptomonas ctenocephali	-	+	natural	De Avelar et al. (2007)
Dipylidium caninum	-	+	natural	De Avelar et al. (2011)
Dipetalonema reconditum	-	+	natural	Linardi (2002)

hand, *C. canis* occurs less frequently, mainly in areas with high or low temperatures (LINARDI; NAGEM, 1973). Up until now, infestations by *C. canis* on companion animals have been recorded only in nine states: Amazonas, Bahia, Maranhão, Minas Gerais, Paraná, Pernambuco, Rio Grande do Sul, Santa Catarina and São Paulo. In relation to the state of Paraná, out of the 2,676 fleas recovered by Unti (1935) on several dogs in the municipalities of Curitiba, Araucária, Marechal Mallét, Pirahy, Mafra, Rio Negro, Ponta Grossa, Paranaguá and Colombo, 53.5% were *C. canis* and 40.6% *C. felis felis*. Also in Florianópolis, state of Santa Catarina, *C. canis* and *C. felis felis* were found in respectively, 54% and 38% of the samples. The data concerning the prevalence of these two species on Brazilian domestic carnivores are shown in Table 4.

Morphological Variations

In *Ctenocephalides* spp., the most frequent morphological variations are observed in the combs and chaetotaxies of LMA (erroneously referred to as the metepisternum by some authors) and in hind tibia (AMIN et al., 1974; AMIN, 1976). In Canada, Holland (1949) found certain nontypical specimens, usually females, which were difficult to identify with certainty. Because of this, the two species were treated collectively in those localities where they were collected.

Alterations in chaetotaxy on the LMA and metatibia might suggest hybridization between the two species, as previously proposed by Holland (1949), Fox (1952), Amin et al. (1974) and Amin (1976). According to Benton (1998), hybrids depend upon occurrence of two closely related species in close association, such as in fleas of the genus *Ceratophyllus* Curtis, 1832, which share the same bird nests in North America. However, the hypothesis of hybridization between *C. felis felis* and *C. canis* must be rejected because good species do not cross with each other, as reinforced by Beaucournu and Guiller (2006).

In Brazil, altered chaetotaxies on the LMA or hind tibia of *Ctenocephalides* spp. were also observed by Nagem (1977) when examining fleas from dogs in the municipality of São João d'El Rei, state of Minas Gerais, and by Fernandes et al. (1996) in fleas from dogs and cats in the municipality of Rio de Janeiro, state of Rio de Janeiro. However, in these surveys, they were named *C. felis felis*. Other variations concerning the chaetotaxy of these species were unduly designated hybrids in some studies (RODRIGUES et al., 2008; SANTOS, 2008; STALLIVIERE et al., 2009).

In a sample of 87 fleas collected from 33 dogs in the rural zone of the municipality of Jaboticatubas, around Serra do Cipó National Park (19° 30' S and 43° 44' W), state of Minas Gerais, Brazil, Santos (2008) found that all the dogs were infested by *C. f. felis*, and 18 of them (54.5%) by specimens presenting variations in the number of bristles on the LMA and/or metatibia. Out of the 87 specimens of *C. f. felis* examined, 27 (31.0%) presented variations both on the LMA and hind tibia (Table 5). Separately by sex, the variations represented 40.7% in females and

Table 4. Prevalence of *C. f. felis* and *C. canis* on companion animals raised in different regions of Brazil.

Location, state	Host	Nº	Prevalence (%)		Reference
			C. f. felis	*C. canis*	
Manaus, AM	dog	50	-	22.00	Gordon and Young (1922)
Manaus, AM	dog	73	38.30	-	Castro and Rafael (2006)
	cat	11	72.70	-	
Imperatriz, MA	dog	72	-	1.40	Santos et al. (2011)
Mossoró, RN	dog	293	3.75	-	Ferreira et al. (2009b)
	cat	62	11.30	-	
Apodi, RN	dog	110	17.80	-	Ferreira et al. (2010a)
João Pessoa, PB	cat	432	27.30	-	Ferreira et al. (2010b)
Recife, PE	dog	325	8.93	2.77	Torres et al. (2004)
Salvador, BA	dog	10	30.00	100	Menezes (1954)
Goiânia, GO	dog	40	45.00	-	Lustosa et al. (1973)
Belo Horizonte, MG	dog	100	52.00	-	Costa et al. (1962)
MG: Belo Horizonte and neighboring municipalities	dog	287	87.20	3.20	Linardi and Nagem (1973)
Jaboticatubas, MG	dog	33	100	-	Santos (2008)
Uberlândia, MG	dog	182	26.80	-	Raszl et al. (1999)
	cat	21	26.67	-	
Juiz de Fora, MG	cat	213	83.09	-	Teixeira and Silva (1975)
Juiz de Fora, MG	dog	104	76.90	-	Rodrigues et al. (2001)
Juiz de Fora, MG	dog	101	64.35	-	Rodrigues et al. (2008)
Vitória, ES	dog	61	54.00	-	Costa et al. (1990)
RJ: Rio de Janeiro and neighboring municipalities	dog	267	50.90	-	Fernandes et al. (1996)
	cat	32	68.80	-	
Lages, SC	dog	143	12.20	4.70	Stalliviere et al. (2009)
Porto Alegre, RS	dog	77	79.20	9.10	Corrêa (1947)
Porto Alegre, RS	dog	129	39.33	60.25	Oliveira and Ribeiro (1982,1983)

Nº - number; % - percentage.

15.1% in males, with a significant difference between them when compared using the chi-square test ($\chi^2 = 6.26$; $p < 0.05$). Also in this sample, 15 specimens (17.2%) presented variations only on one side (asymmetrical), while in four (4.6%) the alterations were observed on both sides of the thorax (symmetrical) (Table 6). About 21.8% of the alterations from the standard numbers consisted of an increase of at least one bristle. Alterations occurred significantly more frequently in females (33.3%) than in males (6.1%) ($\chi^2 = 7.1$; $p < 0.01$). Figure 7 shows the variation of the number of bristles on the left side of the LMA. The variations of chaetotaxy of the hind tibia among the sampled specimens of *C. f. felis* are indicated in Table 7; 12.7% of the specimens examined presented such variations. Figure 8 illustrates one of these variations. Contrary to the characteristics of the LMA, the chaetotaxy of the hind tibia was approximately equally variable in both sexes. Asymmetrical variations (9.2%) were more frequent than symmetrical ones (3.4%). Likewise, variations involving increased numbers of bristles were more frequently found (9.2%) than ones relating to decreased numbers (3.4%) (Table 7).

Although the total numbers of variations (Table 5) and the ones concerning the LMA (Table 6) in the present study were more significant in females, and a great number of females were collected (62.1%), Amin (1976) found similar results when studying dog and cat fleas from Wisconsin, USA. Interestingly, both variations of bristles on the LMA (Table 6) and hind tibia (Table 7) were more significant in relation to increased numbers of bristles, rather than decreased numbers.

Table 5. Variations in the number (Nº) of bristles on the lateral metanotal area (LMA) and hind tibia of *C. f. felis* from dogs in the vicinity of Serra do Cipó National Park, state of Minas Gerais.

Specimens	Variations	Nº		Total	(%)		Total
		Females	Males		Females	Males	
Standard chaetotaxy		32	28	60	59.3	84.8	69.0
	LMA	15	1	16	27.7	3.0	18.4
Altered chaetotaxy	Tibia	5	3	8	9.3	9.1	9.2
	Tibia/LMA	2	1	3	3.7	3.0	3.4
Total		54	33	87	100	99.9	100

% - percentage.

Table 6. Number (Nº) of bristles on the lateral metanotal area (LMA) in 87 specimens of *C. f. felis* from dogs in the vicinity of Serra do Cipó National Park, state of Minas Gerais.

Nº of bristles on LMA (R/L*)	Nº		Total	(%)		Total
	Females	Males		Females	Males	
2/2	36	31	67	41.4	35.6	77.0
2/1	1	0	1	1.1	-	1.1
2/3	13	2	15	14.9	2.3	17.2
3/3	4	0	4	4.6	-	4.6

% - percentage; *Right and left LMA.

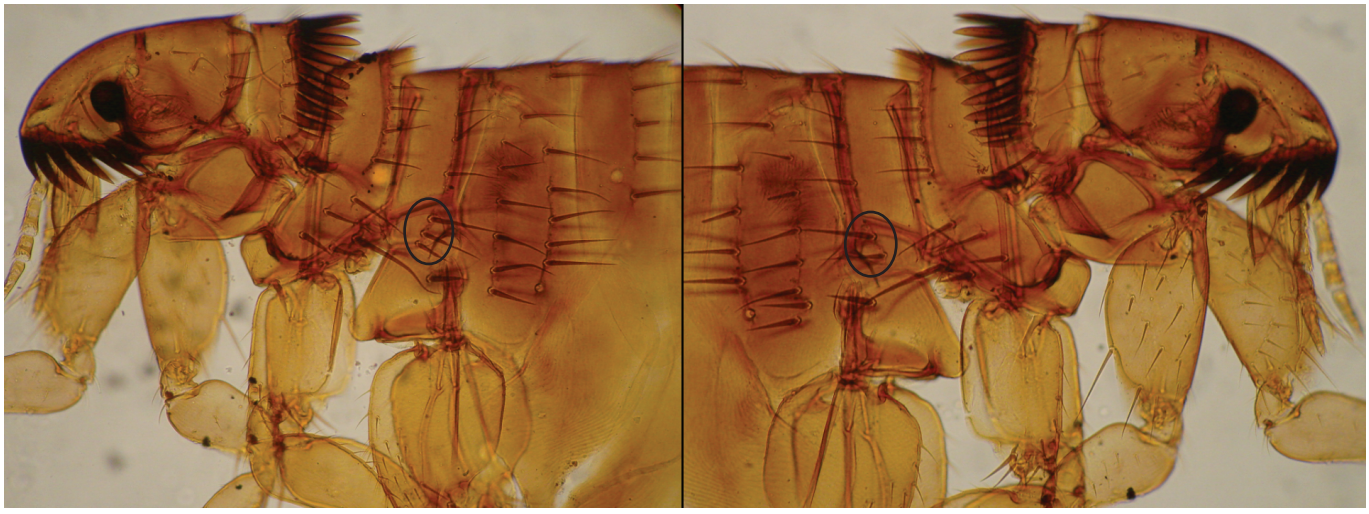

Figure 7. Female of *C. f. felis* presenting variations in the number of bristles on the lateral metanotal area (LMA): three on the left side, two on the right side.

Table 7. Chaetotaxy of the dorsal margin of the hind tibia in 87 specimens of *C. f. felis* from dogs in the vicinity of Serra do Cipó National Park, Minas Gerais State.

Chaetotaxy (R/L)*	Nº		Total	(%)		Total
Tibial formulae	Females	Males		Females	Males	
222213/222213	47	29	76	55.2	32.2	87.4
222213/222223	4	2	6	4.6	2.3	6.9
222223/222223	1	1	2	1.1	1.1	2.3
222213/222113	2	0	2	2.3	-	2.3
222113/222113	0	1	1	-	1.1	1.1

*Right and left hind tibiae; Nº - number; % - percentage.

Figure 8. Female of *C. f. felis*. Variation of the chaetotaxy of the hind tibia.

Final Remarks

Given the enormous epidemiological and economical importance of these fleas, correct identification of species is indispensable. Pet flea-related diseases account for over 50% of the dermatological cases reported to veterinarians (BEVIER-TOURNAY, 1989). Moreover, the annual expenditure by pet owners on flea control products in the United States exceeds $ 1 billion (CONNIFF, 1995). Besides the economical aspect, *C. felis felis* has been reported to have developed resistance to at least five different categories of insecticides, including carbamates, organophosphates, pyrethroids, pyrethrins and organochlorines (WHO, 1992).

In Brazil, *C. felis felis* is the most important flea species on pets because of its geographical distribution, number of other hosts parasitized and vector competence. It is more euryxenous than *C. canis*, having been recorded on 41 different host species (Table 2) and 17 states, as well as being found naturally infected by eight different species of endosymbionts (Table 3). The infestations are more prevalent in southeastern states (Table 4). In all states, cats exclusively harbored *C. felis felis.* Except for Manaus and Salvador, where only small numbers of few dogs were sampled, the prevalence of infestation by *C. canis* seems to increase from north to south. Interestingly, Castro and Rafael (2006) found no specimens of *C. canis* on dogs in Manaus, whereas previously Gordon and Young (1922) observed dogs infested only by this species. It remains unclear as to whether this finding was geographically isolated or whether, in fact, this species is truly decreasing in numbers towards extinction; or else, whether it was incorrectly identified.

It is important to stress that the head curvature is highly different between males and females of *C. felis felis*; however, this characteristic may be unclear for separating males of the two species. Consequently, in some studies, males of *C. felis felis* have been incorrectly diagnosed as *C. canis*.

Morphological variations among fleas do not always result from interbreeding between species (TIPTON; MACHADO-ALISSON, 1972; AMIN; SEWELL, 1977; AMIN et al., 1974; LINARDI, 1984), but they must be used carefully for taxonomic purposes. Since the chaetotaxies of the hind tibia and LMA showed significant intraspecific variations, these two characteristics must be cautiously used for interspecific diagnoses. Sometimes, specimens exhibiting variations have been improperly treated as hybrids, in spite of the nonexistence of the two species in the same municipality or region.

It is concluded that separation of the two species of *Ctenocephalides* must be done while considering all characteristics. Data on hosts, geographical distribution and prevalence of infestation may support identification of the species.

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