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Mite fauna (Acari) associated with the poultry industry in different laying hen management systems in Southern Brazil: a species key

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ABSTRACT

This study is based on results from a large project on the mite diversity in commercial laying hen systems in Brazil. It aims to identify potential biocontrol agents amongst mites present in poultry farms, with a focus on one feather mite pest Megninia gingylmura. A secondary goal is to provide an operational identification tool to help the development of biological control in poultry farms. Sampling was conducted from August 2013 to August 2014, with 43 sampling events, in three different laying hen management systems. We used traps, laying hen feathers, and abandoned wild bird nests to collect the mites. A total of 38,862 mites belonging to 23 families and 39 species were found, including 17 species exclusively found in traps, six in wild bird nests, and one in feathers. The most abundant and frequent ectoparasitic species was M. gingylmura (76.3%; observed in all management systems). Amongst other mites, Tydeidae showed the highest richness with five species (Brachytydeus argentinensis (Baker, 1970), Brachytydeus australensis (Baker, 1970), Brachytydeus obnoxia (Kuznetsov and Zapletina, 1972), Brachytydeus oregonensis (Baker, 1970), and Brachytydeus tuttlei (Baker, 1965)), followed by Cheyletidae with four species (Chelacheles bipanus Summers and Price, 1970, Cheyletus eruditus (Schrank, 1781), Cheyletus malaccensis (Oudemans, 1903), and Cheletomimus (Hemicheyletia) wellsi (Baker, 1949)). Potential predatory species for biological control were C. malaccensis (9.4%), Typhlodromus transvaalensis (Nesbitt, 1951) (0.8%), Blattisocius keegani (Fox, 1947) (0.7%), and Blattisocius dentriticus (Berlese, 1918) (0.4%). A dichotomous key is provided to identify 48 species dwelling in Brazilian layer farms.

Keywords Aviculture; Ectoparasite, Megninia gingylmura, Tuccioglyphus setosus

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Introduction

The diversity of mites in poultry farms is wide and revealed different life habits as parasitic, predatory, detritivorous mites (Brady 1970). However, only a few species present economic or sanitary importance as the hematophagous mites Ornithonyssus bursa (Berlese, 1888), Ornithonyssus sylviarum (Canestrini; Fanzango, 1877) ( Macronyssidae) and Dermanyssus gallinae (De Geer, 1778) (Dermanyssidae) (Faccini 1987) or the feather mite Megninia gingylmura (Mégnin, 1877). Others may act as potential predatory mites.
The repeated use of acaricides at high concentrations to control infestations could lead firstly to the development of acaricide-resistant and more importantly to the accumulation of acaricides in chickens’ organs and also in eggs. Various synthetic chemical pesticides, for example carbaryl and permethrin, can accumulate in different levels in organs/tissues, skin, fat and muscle (Marangi et al. 2012).

Alternative controls, which replace the use of chemical pesticides, are important to increase the quality of the products, of the environment, of workers’ health, and of rural animal welfare. Biological control using Strongyloipsa mathurinii (Ribeiro, 1931) (Dermaptera: Labiidae) has been successful in controlling D. gallinae in the poultry industry of the state of São Paulo (Guimarães et al. 1992). Lesna et al. (2009) investigated potential predators for the biological control of D. gallinae among predatory mites, and found two genuine predators: Gaeolaelaps aculeifer (Canestrini, 1883) (Laelapidae) and Androlaelaps casalis (Berlese, 1887) (Laelapidae); they also highlighted Cheyletus eruditus (Schrank, 1781) (Cheyletidae), Zeronopsis remiger (Kramer, 1876) (Ascidae), and Blattisocicusskeegani (Fox, 1947) (Blattisocidae), which may act as predators. In another investigation, they observed that A. casalis and Stratiolaelaps scimitus (Womersley, 1956) (Laelapidae) were capable of feeding and reproducing on D. gallinae (Lesna et al. 2012). Toldi et al. (2014) studied the biology of Cheyletus malaccensis (Oudemans, 1903) (Cheyletidae) feeding on D. gallinae under laboratory conditions. This predatory mite showed no preference for any prey phase, feeding on all stages, and was considered by these authors as a potential natural enemy of D. gallinae.

The biological control of M. ginglymura was poorly investigated and needs further studies. Blattisocicuss dentriticus (Berlese, 1918) (Blattisocidae) feeding on M. ginglymura under laboratory conditions showed lower values of life-table parameters than Tyrophagus putrescentiae (Schrank, 1781) (Acaridae) (Silva et al. 2016a). These two prey species were also tested as food for the predator C. malaccensis, and M. ginglymura was considered the best food item as it achieved better life-table results ($R_0 = 135.6; T = 41.6; \lambda = 1.13; rm = 0.12$) than T. putrescentiae (Granich et al. 2016).

This study, which complements the study by Horn et al. (2016), provides additional data aiming to identify the most promising biocontrol agent species, with a focus on the feather mite M. ginglymura, and to provide a key to species derived from poultry farms in the South of Brazil.

Materials and methods

This study was conducted in different commercial laying hen systems between August 2013 and August 2014, in Lajeado County, Vale do Taquari, state of Rio Grande do Sul, Brazil. Six poultry houses were sampled with their characteristics as reported in Horn et al. (2016).

Two additional methods of sampling mites associated to poultry farms were proposed in this study as complementary to trap data by Horn et al. (2016): laying hen feathers and wild bird nests. For feather mites evaluations, ten laying hens were evaluated for each laying hen house. Five feathers per laying hen were collected, totaling 50 feathers per sample in each laying hen house. The feathers were placed individually in a plastic container with 70% alcohol during a minimum of 24 hours before the screening. The plastic containers were taken to the laboratory in paper box with styrofoam inside. The screening was performed by filtering the alcohol in qualitative filter paper of diameter 12.5 cm and weight of 80 g/m². This method primarily checks actual health and economic mite species. In addition, potential predatory mites captured in the feathers may indicate a possible predation relationship due to foraging for food.

The wild bird nests abandoned were found in the lateral roof side of the laying hens houses were also evaluated for the presence of mites. The species birds identified were Columbina picui (Temminck, 1813), C. talpacoti (Temminck, 1810) (Columbidae), Turdus sp. (Turdidae) and Zenaida auriculata (Des Murs, 1847) (Columbidae). The bird nests were stored in individual
plastic bags and in laboratory, they were exposed in Berlese funnel for five to seven days and mites stored in plastic container with 70% alcohol. This sampling method can highlight a possible migration relationship between acarofauna of wild birds and confined laying hens as well as help identify potential predators for biological control (Lesna et al. 2009).

All mites were collected with a fine-tipped paintbrush and mounted with Hoyer’s medium on microscope slides (Walter and Krantz 2009). The slides were kept for up to 10 days at 50-60 °C to dry the medium, to extend the legs and for diaphanization of the specimens.

**Identification**

The identification of specimens to the species level was done using a phase contrast light microscope and identifications keys. Voucher specimens were stored at the reference Collection of the Natural Sciences Museum of the UNIVATES University Center (ZAUMCN), Lajeado, Rio Grande do Sul, Brazil.

**Results**

A total of 38,862 mites belonging to 23 families and 39 species were found. Most mites were collected from feathers (73.1%), followed by traps (25.7%) and bird nests (1.2%). The family with the highest richness was Tydeidae, with five species (*Brachytydeus argentinensis* (Baker, 1970), *Brachytydeus australensis* (Baker, 1970), *Brachytydeus obnoxia* (Kuznetsov and Zapletina, 1972), *Brachytydeus oreognensis* (Baker, 1970), and *Brachytydeus tuttlei* (Baker, 1965)), followed by Cheyletidae with four species (*Chelacheles bipanus* Summers and Price, 1970, *C. eruditus*, *C. malaccensis*, and *Cheletomimus* (*Hemicheyletia*) *welshii* (Baker, 1949)), and Acaridae with three species (*Aleuroglyphus ovatus* (Troupeau, 1878), *Thyreophagus entomophagus* (Laboulbéne, 1852), and *T. putrescentiae*) (Figure 1). However, *M. ginglymura* had the highest abundance, with 76.3% of the total number of mites. This species was observed on laying hens of all systems evaluated; it was recorded both in traps (13.3% of the total) and feathers (99.7% of the total). The second most abundant species was *C. malaccensis* (9.4%) and the third one was *Tucciglyphus setosus* Horn and Klimov, 2017 (8.6%), both found on laying hens of all systems evaluated and in all sampling methods. *Cheyletus malaccensis* and *T. setosus* represent 35.1% and 32.7% of the total number of mites associated to traps, respectively. Aside from these species, *B. dentriticus*, *B. keegani*, *C. (Hemicheyletia) welshii*, *Tetranychus sp.*, *Typhlodromus transvaalensis* (Nesbitt, 1951) (Phytoseiidae), and *T. putrescentiae* were present in bird nests, feathers, and traps (Figure 1).

*Brachytydeus oreognensis*, *Raphignathus* sp., and *Tarsonemus granarius* Lindquist, 1972 (Taronemidae) were associated to traps and bird nests. *M. ginglymura*, *A. ovatus*, *Macrocheles muscaedomesticae* (Scopoli, 1772) (Macrochelidae), and *Rubroscirus nidorum* (Ferla and Rocha, 2012) (Cunaxidae) were present in feathers and traps.

Seventeen species were exclusively found in traps and a single species exclusively found on feathers, *Dermatophagoides farinae* (Hughes, 1961) (Pyroglyphidae). In bird nests, six exclusively species were found and three of them belong to the genus *Brachytydeus* (*B. argentinensis*, *B. australensis* and *B. obnoxia*). Furthermore, *A. casalis* and Oribatid mites were collected from bird nests. Also in abandoned bird nests, the most representative species were *C. malaccensis* (30.1%), *B. keegani* (19%), and *B. dentriticus* (11.7%). *Androlaelaps casalis* and *O. bursa* were only recorded using this sampling method. In feathers, there was a high dominance of *M. ginglymura* (99.7%) and all other species occurred in low numbers. The most representative species in traps were *C. malaccensis* (35.1%), *T. setosus* (32.7%), and *M. ginglymura* (13.3%).

Mite species and the laying hen systems where they were collected from are listed in Appendix, along with sampling month and year and comments on their known habits and habitats. The number of recorded specimens is shown in parentheses.
**Key to genera and species (excluding Orbatida) present in poultry farms in Rio Grande do Sul, Brazil**

1. With 1-4 pairs of dorsolateral or ventrolateral stigmata posterior to coxae II; coxae of legs free, usually movable; tarsi of legs II-IV with peripodomic fissure associated with slit organs; tarsus of leg I with dense dorsal cluster of solenidiform setae subdistally ............
   
   — Without visible stigmata posterior to coxae II; coxae I-IV fused to podosomatic body wall so that the first completely free leg segment is the trochanter; ; tarsi of legs II-IV without fissure and slit organs; tarsus of leg I with sparse pairings of dorsal setae distally and subdistally .

2. Gnathosoma usually narrow and elongate such that the hypostomal and subcapitular setae are aligned in a more or less longitudinal row; idiosoma tortoise-shape, usually oval in outline; pedofossae present; epigynial shield without setae .

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**Figure 1** Mite fauna and their relative abundances (%) (parentheses) in bird nests (BN), feathers (F) and traps (T) between August 2013 and August 2014, in Lajeado County, Rio Grande do Sul, Brazil.
Gnathosoma with another shape; second subcapitular setae (hypostomal seta h2) usually lateral of setae h3 and not in a linear arrangement with other subcapitular setae; idiosoma without tortoise-shape; pedofossae absent; epigynial shield usually with at least one pair of setae. 

Dermanyssiae 

3. Peritremes looped proximally, joining the stigma posteriorly. 

MACROCHELIDAE ........................................... Macrocheles muscaedomesticae (Scopoli, 1772)

4. Deutonymphs and adults with less than 20 pairs of dorsal shield setae. 

PHYTOSEIIDAE .............................................

5. Podonotal region of dorsal shield with four pairs of lateral setae (j3, z2, z4 and s4) 

PHYTOSEIIDAE .............................................

6. Female sternal shield with one or typically two pairs of setae (sternal setae 1-2); corniculi often divided distally or entire; Femur II with 10 setae, including 4 dorsals. 

AMEROSEIIDAE .............................................

7. Female with epigynial shield truncate or weakly convex posteriorly and either narrowly separated from or abutting a ventrianal shield or widely separated from an anal shield that is round or oval but usually not inversely subtriangular. 

8. Female with epigynial shield gently rounded posteriorly and usually with an oval or elliptical anal shield bearing only the 3 anal setae (or rarely expanded to capture the nearest pair of opisthogastric setae); fixed cheliceral digit with pilus dentilis modified to a hyaline flap. 

MELICHARIDAE .............................................

9. Peritreme extending as far forward as coxae I; both digits of the chelicerae equally well-developed. 

BLATTISOCIDAE .............................................

10. Peritreme reaching to about the posterior margin of coxae II; fixed digit of the chelicerae very short, without teeth; the movable digit has three teeth. 

11. Chelicerae of female whip-like, styliform; corniculi membranous, indistinct. 

DERMANYSSIDAE .............................................

— Chelicerae variously produced but not styliform; corniculi variously developed ........ 12

12. Chelicerae elongate, edentate; corniculi membranous, usually lobate; palptrochanter often with a raised medioventral keel; with a large anterior nonsetigerous spur on leg coxae II; genu IV typically with two ventral setae .......................................................................................................................... MACRONYSSIDAE ........ Ornithonyssus bursa (Berlese, 1888)
— Chelicerae various, dentate or edentate; corniculi strongly sclerotized or membranous, horn-like, barbed or lobate; palptrochanter without raised medioventral keel; generally with more than one large nonsetigerous coxal spur; genu IV typically with one ventral setae .......... .............................................................. LAELAPIDAE ........ 13

13. Sternal shield of female broader than long; digits of male chelicerae edentate; pilus dentilis long and slender .................................. Androlaelaps casalis (Berlese, 1887)
— Sternal shield of female usually longer than broad; digits of male chelicerae dentate; pilus dentilis short and setiform .................................................................................................................. 14

14. Genital shield of female large; pre-endopodal plates well-defined and connected by narrow strip; tectum with a smooth anterior margin .......................................................... Hypoaspis lubrica Voigts and Oudemans, 1904
— Genital shield of female small; pre-endopodal plates indistinct; tectum with a denticulate margin ................................................................. Gaeolaelaps aculeifer (Canestrini, 1883)

15. Chelicerae rarely chelate, fixed digit often regressed and movable digit usually a hook, knife, needle or stylet-like structure; cheliceral bases sometimes fused medially; palpi simple or modified into a thumb-claw process, sometimes reduced; subcapitulum without rutella; ambulacral of at least legs II and III usually with 2 lateral claws and with or rarely without a median empdion that may be padlike or rayed and often armed with tenent hairs, or occasionally claw- or sucker-like; opisthosoma lacking paired lateral glands; opisthosomatic setal row c usually with 2 pairs of setae (c1-c2), rarely with 3 pairs or hypertrichous; tracheal system with 1 pair of stigmata opening between bases of chelicerae or on anterior prodorsum usually present and sometimes associated with peritremes dorsally on the cheliceral bases or on the anterior margin of prodorsum .............................................................. Suborder Prostigmata ................ 16
— Chelicerae typically chelate, usually dentate, rarely attenuate or stylet-like; cheliceral bases always separated; palpi simple, never with thumb-claw process; subcapitulum usually with rutella or pseudorutella; ambulacral of legs I-IV usually with 1 or 3 claws, bidactyl condition rare, empodium clawlike or sucker-like, never pad-like, rarely rayed; opisthosoma usually with pair of lateral glands (these are absent in more primitive taxa); opisthosomatic setal row c usually with 3-4 pairs of setae or hypertrichous; tracheal system absent or, when present, arising from bases of legs or as brachytracheae (relatively short tubes) on various parts of the legs or idiosoma; stigmata and peritremes never present between cheliceral bases or on prodorsum .......... .............................................................. Suborder Astigmata .......... 36

16. Pretarsal empodium of legs II and III membranous, nude; adult females with anterolateral prodorsal stigmata openings ............................................ TARSONEMIDAE .. 17
— Pretarsal empodium of legs II and III claw-like, split distally, pad-like, rayed; juveniles and adults with stigmata openings at base of gnathosoma, on gnathosoma or absent .......... 18

17. Female with sejugal apodeme not emarginated; pharynx short, resembling a horse shoes; setae c1 and c2 with similar lengths ................. Tarsenemus granarius Lindquist, 1972
— Female with sejugal apodeme emarginated symmetrically in the middle region; pharynx elongated, similar to bowling bottles; setae c2 longer than c1 ................................................................. Tarsenemus confusus Ewing, 1939
18. With 1-2 pairs of variously shaped prodorsal trichobothria ........................................... 19
   — Without prodorsal trichobothria .............................................................. 25

19. Leg trichobothria absent .................................................................................. 20
   — Trichobothria present on at least tibia leg IV, tibia I or tarsus leg I ......................... 21
      ....................................................... CUNAXIDAE.............. Rubroscirus nidorum Ferla and Rocha, 2012

20. Pretarsus leg I with vestigial claws or without any claws or with apotele I absent ............ 22
   — Pretarsus leg I with paired claws and/or apotele I present ................................. IOLINIDAE.......Parapronematus sp.

21. Cheliceral styles distinctly shorter than palpaltarsus ................................................. 23
   — Cheliceral styles not shorter than palpaltarsus .................................................. 24

22. Empodial hooks (om) present .............................................................................. 25
   — Empodial hooks (om) absent ............................................................................ 26

23. Body elongated; ventral striae between metasternal setae lying longitudinally; dorsal setae slender and relatively long: setae f1 distinctly longer than $\frac{1}{2}$ distance f1-h1; bothridial setae (bo) slightly serrate; solenidion o1 long: not shorter than the width of tarsus I ............... 27
   — Body broadened; ventral striae between metasternal setae lying transversely; dorsal setae lanceolate, short: setae f1 about as long as $\frac{1}{2}$ section f1-h1; bothridial setae (bo) smooth; solenidion o1 short: shorter than $\frac{1}{2}$ width of tarsus I .................................................. Brachytydeus oregonensis (Baker, 1970)

24. Stilettos as long as palpaltarsus .............................................................................. 28
   — Stilettos distinctly longer than palpaltarsus ..................................................... 29
      ....................................................... Brachytydeus australensis (Baker, 1970)

25. Pretarsal claws well developed or reduced but always with tenant hairs ....................... 30
   — Pretarsal claws lacking tenant hairs .................................................................. 31

26. Tarsi I-II without peg-shaped or bulbous solenidia and with 1-2 long, slender, tapered solenidia usually closely associated with a short or minute seta to form duplex sets ......................... 32
   — Tarsi I-II with distal, peg-shaped or bulbous solenidia and with no solenidia closely associated with a seta to form duplex sets ....................................................... TETRANYCHYDAE.............. Tetranychus sp.

27. Palptarsus with 1 or 2 comb-like setae; stylophore fused to subcapitulum; base of movable digit contained within the stylophore capsule .................................................. CHEYLETIDAE.............. 33
   — Palptarsus without comb-like setae; cheliceral bases variously fused to each other, never completely fused to subcapitulum; base of movable digit located at the tip of the cheliceral base, not within stylophore ....................................................... 34

28. Eyes absent ........................................................................................................... 35
   — One pair of prodorsal eyes present .................................................................. 36

29. Dorsal idiosomal setae short and fanshaped .................................................. Eucheyletia reticulata Cunliffe, 1962
   — Dorsal idiosomal setae slender to narrowly-spatulate, never fanshaped ............... 37

30. Omega in tarsus I distinctly swollen basally; usually with one tooth at the basis of pedipalpal claw; femur IV with 1 seta ......................................................... Cheyletus malaccensis (Oudemans, 1903)
— Omega on tarsus I narrows very gradually without swelling; usually with more than one tooth at the basis of pedipalpal claw; femur IV with 2 setae ................................................................. Cheyletus eruditus (Schrank, 1781)

31. Body fusiform; coxal fields II and III separated by about body width ........................................ Cheletachles bipanus Summers and Price, 1970
— Body ovoid; coxal field II and III separated by less than body width ........................................ 32

32. Dorsum with two sclerites .................. Cheletomorpha lepidopterorum (Shaw, 1794)
— Dorsum with three sclerites ........ Cheletominimus (Hemicheyleta) wellsi (Baker, 1949)

33. Peritremes and stigma absent STIGMAEIDAE ........ Storchia pacificus (Summers, 1964)
— Peritremes associated with cheliceral bases or on anterior margin of prodorsum ........ 34

34. Peritremes at anterior margin of prodorsum .................. Raphignathus sp.
— Peritremes on dorsal surface of stylophore ........................................ 35

35. Peritremes emerging anteriorly, posteriorly to cheliceral condyle; peritremes arising medially on stylophores ................................................ Molothrognathus sp.
— Peritremes confined in W-shaped; stylophore elongated and tapered .................. Paraneognathus wangi Fan and Li, 1995

36. Body cuticle usually at least partially striated; pretarsi often enlarged, with ambulacral stalk and disk well developed, empodial claws usually reduced or incorporated into ambulacral disk as central sclerites ................................................................. 45
— Body cuticle smooth or striated; pretarsi variously formed, sometimes enlarged; empodial claws variously formed or absent ........................................ 37

37. Prodorsum with lamellar (le) setae absent; pretarsi with long, thin condylophores or fused or absent; dorsal setae may be elongate, but never heavily barbed .................................. CARPOGLYPHIDAE ........ Carpoglyphus lactis (Linnaeu, 1767)
— Prodorsum with lamellae (le) setae present, or if absent, then pretarsi with short condylophores or dorsal setae long and heavily barbed ........................................ 38

38. Ventral subcapitulum with a prominent pattern of external transverse and oblique ridges ................ GLYCYPHAGIDAE ........ 39
— Ventral subcapitulum without external ridges ........................................ 40

39. Tibia I-II with 1 ventral setae; dorsal body setae often strongly modified (flattened and pectinate, bipectinate or foliate) ........................................ Diamesoglyphus sp.*
— Tibia I-II with 2 ventral setae; dorsal body setae densely pectinate ........................................ Glycyphagus destructor (Schrank, 1781)

40. Discrete coxal apodemes III and sometimes IV absent; discrete propodosomal sclerites absent .......... CHORTOGLYPHIDAE ........ Chortoglyphus arcuatus (Troupeau, 1879)
— Discrete coxal apodemes III and IV present, projecting obliquely from bases of trochanters; propodosomal sclerites usually present ........................................ 41

41. Tarsi with both tectal setae filiform, similar in length ........................................ SUIDASIIDAE ........ Suidasia pontifica Oudemans, 1905
— Tarsi with tectal setae asymmetrical ........................................ ACARIDAE ........ 42
42. External vertical setae ve arising the anterior angles of the dorsal propodosomal shield at the same level as vi or slightly posterior .................................................................43
— Seta ve rudimentary or absent or when present arising near the middle of the lateral edge of the propodosomal shield .................................................................44

43. Genu I with solenidion σ” no more than three times longer than σ”; ventral apex of tarsi with proral (p, q) and unguinal (u, v) setae usually in the form of short, stout spines, occasionally one or both pairs strongly reduced or absent; male without modifications of leg I ...........
— Genu I with solenidion σ” at least three times longer than σ”; ventral apex of tarsi with proral (p, q) and unguinal (u, v) setae thin, not short, stout spines; male with leg I enlarged and bearing a ventral apophysis on femur .................. Tyrophagus putrescentiae (Schrank, 1781)

44. Tarsi I-II with setae ft` (ba) absent or if present on tarsus I, then filiform ....................
— Tarsi I-II with setae ft` (ba) in the form of a spine directly adjacent to solenidion ω1 .............. Rhyzoglyphus callae Oudemans, 1924

45. Genu III with solenidion σ absent ................................................ EPIDERMOMPTIDAE
— Genu III with solenidion σ present ................................................46

46. Vertical setae (vi) absent; tarsus I with solenidion ω1 inserted subcapically, very near solenidion ω3. House dust mites. Nests of rodents and birds .................................................. PYROGLYPHIDAE............47
— Vertical setae (vi) present; tarsus I with solenidion ω1 inserted basally. Ectoparasites of avian orders; feather mites ...... ANALGIDAE........ Megninia ginglymura (Mégnin, 1877)

47. Setae si and se equal or subequal. Setae se distinctly shorter than ½ of body width ........
— Setae si and se unequal. Setae se longer than ½ of body width ........................................... Dermatophagoides farinae Hughes, 1961

Discussion

Commercial egg production is an important economic activity in Vale do Taquari and in the state of Rio Grande do Sul. In this context, improving the efficiency and sustainability of pest control practices is a major challenge. The development of biological control against pest mites might be of help and requires to know all associated mites, their frequency, damages caused by them (Silva et al. 2013) and possible natural enemies. Among food habits of mites, the huge diversity can be emphasized: there are detritivorous, predatory (Horn et al. 2016), parasitic, hematophagous and omnivorous mites, not to mention feather mites (which are more detritivorous-microbivorous, but live as parasites on birds’ body). This study provides the first dichotomous key that helps to identify the main species associated with poultry farms in Southern Brazil. It includes all food habits and might assist acarologists as well as farm technicians (agronomists, agricultural technicians, veterinarians, and zoo-technicians) to better understand pest problems and contribute to improve control. It includes species with health and economic importance such as feather mites, hematophagous mites and stored food mites as well as potential predatory mites.

The biological control of mite pests by natural predators can help reduce high infestations, preventing ectoparasites from becoming a health and economic problem, and is essential to knowing which laying hens and wild birds are carriers of the pest mites into poultry houses.
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(Horn et al. 2018). *Megninia ginglymura* stood out as a sanitary species associated with all environments and managements evaluated. Currently used synthetic acaricides have limitations, such as unfeasible eradication and presence of residues in eggs (Lesna et al. 2009). The biological control of *M. ginglymura* by the predators *C. malaccensis* (Granich et al. 2016) and *B. dentriticus* (Silva et al. 2016a) under laboratory conditions showed higher values of life-table parameters when *C. malaccensis* was evaluated as natural enemy of *M. ginglymura* ($R_0 = 135.6; T = 41.6; \lambda = 1.13; rm = 0.12$). No *M. ginglymura* specimen was recorded in abandoned bird nests in this study, thus corroborating the findings of Silva et al. (2013). This absence of *M. ginglymura* from any of the abandoned wild bird nests under test might be considered a very important piece of information in elucidating the relationship between wild birds in this region and mite fauna of laying hen houses. However, this information must be considered with caution as this mite species feeds on the body of the host, and nests should be evaluated soon after abandonment so that *M. ginglymura* could be captured. *Ornithonyssus bursa* was recorded only in abandoned bird nests and no specimens were recorded inside laying hen houses. However, several predators and other mites belonged to the same species as those collected in laying hen houses (feathers and traps) and abandoned bird nests, which leads us to conclude that there may be a transit of mite fauna in commercial poultry farms, corroborating the results obtained by Silva et al. 2013.

Among the recorded mite fauna, eight species were captured with all three methods for sampling mites: five of which were considered as having predatory habits (*B. dentriticus*, *B. keegani*, *C. (Hemicheyletia) wellsi*, *C. malaccensis* and *T. transvaalensis*), two were generalists (*T. setosus* and *T. putrescentiae*) and the presence of *Tetranychus* sp. in laying hen houses is yet to be elucidated due to the fact that this genus is largely known as a phytophagous genus (Bolland et al. 1998).

Predatory mite strategies to control feather mites are different from other economic pests as *D. gallinae* can remain outside the host and be captured by them over this period. For *M. ginglymura* to be effectively controlled by predatory mites, these must be able to have foraging activity directly on the bird-host body. Moreover, requirement is related to physical constraints: the predatory mite must survive to hight temperature of the body of the host. The fact that predatory mites were captured in feathers might suggest that they were able to live in the host and endure the average body temperature of laying hens (41.5 – 42.5°C). The presence of several predatory mite species on feathers strongly suggests that they are not able to forage on host, which makes biological control against *M. ginglymura* promising.

Predatory species associated with feathers were observed at very low relative densities (Figure 1). It is worth noting that some of Cheyletids developed parasitic habits throughout evolution (some *Cheyletiella* spp.). This suggests that this group (which comprises mostly predatory mites) is intrinsically more adapted to on-bird life than other predatory mites such as soil/litter mites, and therefore, represents a promising candidate to control of *M. ginglymura*.

The predator *Raphignathus* sp. and the generalists *B. oregonensis* and *T. granarius* were concomitant in abandoned bird nests and traps. *Brachydeles oregonensis* was misidentified as *Lorria* sp. and observed in hen nests (Silva et al. 2013).

Inside hen houses, *A. ovatus*, *M. muscaedomesticae*, *M. ginglymura*, and *R. nidorum* were common (species present in feathers and traps). Most predatory species were associated to hen nests and traps; *B. dentriticus*, *B. keegani*, *C. eruditus*, *C. malaccensis*, *Cheletomorpha lepidopterorum* (Shaw, 1794) (Cheyletidae), and *T. transvaalensis* (Silva et al. 2013; Faleiro et al. 2015). A total of 17 species were captured exclusively in traps, with the most recurrent species being *B. tuttlei*, *G. destructor*, and *C. arcuatus*. Species exclusively found in abandoned bird nests were *A. casalis*, *B. argentimensis*, *B. australensis*, *B. obnoxia*, *O. bursa* and the soil-mite group Oribatida. *Androlaelaps casalis* is a generalist predator that is capable of feeding and reproducing on *D. gallinae* (Lesna et al. 2012). This provides a valuable overview of mite species present in poultry farm buildings, and thus a basis for subsequent studies dedicated to improve biocontrol in such contexts. The next step is choosing the natural enemies’ candidates amongst present predatory mites, in order to initiate the development of a pest management
method without pesticides to control ectoparasites. Preliminary studies at laboratory level indicate potential for biological control of *M. ginglymura* by natural enemies in poultry systems. New investigative stage should be the application of this knowledge to the practical level in poultry farms.

References


Appendix: Mite species and collection data and information on the known habits and habitats. The number of recorded specimens is shown in parentheses.

Suborder Astigmata

Acaridae Ewing and Nesbitt, 1954

Aclepyroglyphus ovatus (Troupeau, 1878)

Tyrophagus ovatus Troupeau, 1878

Locality of the specimens examined: **Feather**: S2: VI-2014(1); FR: VII-2014(1). **Trap**: A2: V-2014(2), VI-2014(1); S1: IV-2014(1), V-2014(2), VI-2014(5); FR: VI-2014(2).

Comments: Species from the genus *Aclepyroglyphus* are reported as stored food mites. *Aclepyroglyphus ovatus* are common in bran, wheat, chicken meal, dried fish products, flour, and pollards, where it can multiply to form large colonies. It has also been found in laying hen houses (Hughes 1976).

Thyreophagus entomophagus (Laboulbène, 1852)

Acarus entomophagus Laboulbène, 1852

Locality of the specimens examined: **Trap**: A1: X-2013(2), XI-2013(2), VII-2014(2), VIII-2014(44); A2: X-2013(1); A3: IX-2013(1); S1: IX-2013(2).

Comments: It is a storage mite usually reported in farms (Franz et al. 1990). Sensitivity to mite species might cause occupational respiratory disorders in farmers. However, it does not inhabit urban houses often nor it causes symptoms by ingestion, although Iglesias-Souto et al. (2009) reported a child suffering from anaphylaxis caused by the ingestion of flour contaminated with T. entomophagus.

Tyrophagus putrescentiae (Schrank, 1781)

Acarus putrescentiae Schrank, 1781:1522


Comments: It is commonly associated with stored foods with high content of grease and protein such as flour, wheat, soy, cheese, rye bread, milk powder, various seeds, and as a cosmopolitan mite it is a pest of fungal cultures. High infestations cause deterioration in the quality and hygiene of the product and can accelerate deterioration (Duek et al. 2001). Silva et al. (2013) observed this species in laying hen nests, feathers, and abandoned bird nests.

Analgidae Trouessart, 1915

Megninia gingylumura (Mégnin, 1877)


Comments: It feeds on the feathers of infested birds and hens. This mite’s saliva causes allergic reaction, stress, and intense itching, which leads to the formation of crusts, facilitating secondary bacterial infections and pyoderma. Itching may cause petechiae and hemorrhagic blisters on the skin of the host (Tucci et al. 2005). Silva et al. (2013) observed this species in laying hen nests, feathers, and traps in poultry houses.

Carpoglyphidae Oudemans, 1923

Carpoglyphus lactis (Linnaeus, 1767)

Acarus lactis Linnaeus, 1767:1024.

Locality of the specimens examined: **Trap**: A1: VIII-2014(1).
Comments: *Carpoglyphus* species are reported as stored food mites. *Carpoglyphus lactis* is a cosmopolitan species observed in dried fruits, honeycombs, pollen in rotting bee hives, potatoes, cheese, old flour, cocoa beans, and groundnuts (Hughes 1976).

**Chortoglyphidae** Berlese, 1897

*Chortoglyphus arceatus* (Troupeau, 1879)

*Tyroglyphus arceatus* Troupeau, 1879


Comments: It has been identified in dust samples mattress, and is commonly found in rural areas of Central Europe, being responsible for allergies in farmers (Schulz et al. 2004). It is common in the floor dust of barns, mills, stables, and granaries and is frequently found in flour and heaps of old straw (Hughes 1976). Silva et al. (2013) observed this species in laying hen nests, feathers, and abandoned bird nests in poultry houses.

**Chortoglyphidae** Berlese, 1897

*Chortoglyphus arcuatus* (Troupeau, 1879)

*Tyroglyphus arcuatus* Troupeau, 1879


Comments: It has been identified in dust samples mattress, and is commonly found in rural areas of Central Europe, being responsible for allergies in farmers (Schulz et al. 2004). It is common in the floor dust of barns, mills, stables, and granaries and is frequently found in flour and heaps of old straw (Hughes 1976). Silva et al. (2013) observed this species in laying hen nests, feathers, and abandoned bird nests in poultry houses.

**Epidermoptidae** Trouessart, 1892

Locality of the specimens examined: **Trap**: S1: XII-2013(1), I-2013(2).

Comments: Parasitic of feather follicles or skin lesions of numerous avian orders. Some species of Epidermoptidae are unusual as they have developed hyperparasitic relationships with parasitic flies of the Hippoboscidae family. Adult females of *Myialges* and *Promyialges* attach to the abdomen of the dipteran host (Krantz and Walter 2009).

**Glycyphagidae** Cunliffe, 1958

*Ctenoglyphus* sp. nov.


Comments: *Ctenoglyphus plumiger* (Koch, 1836) occurs in barns, wheat, oats and barley, grass seed, fishmeal, and it sometimes appears in large populations in hay (Hughes 1976). *Ctenoglyphus strinii* (Armanelli, 1887) is associated with the dust of stables and haylofts and *Ctenoglyphus palmifer* (Fumouze and Robin, 1868) has been found in chaff, stable dust, and oat mill. Our species differs from others of the genus by having body setae pectinate and ribbon-shaped.

**Glycyphagus destructor** (Schrank, 1781)

*Acarus destructor* Schrank, 1781:552.


Comments: It is common in stored food and is frequently found in association with *Acarus siro* L. (1758) and *C. eruditus* or *C. malaccensis* (Hughes 1976). It is also associated to soil in agricultural zones. Silva et al. (2013) observed this species in laying hen nests and traps in poultry houses.

**Tuccioglyphus setosus** Horn and Klimov, 2017

Locality of the specimens examined: **Feather**: A2: VIII-2014(1).

Comments: This species was described based on specimens collected in our study area (Horn et al. 2018).

**Suidasiidae** Hughes, 1948

*Suidasis pontica* Oudemans, 1905

*Suidasis pontica* Oudemans, 1905:209.

Locality of the specimens examined: **Trap**: S1: II-204(3).

Comments: It has been found in the quills of the remiges of *Aramus* sp. from tropical America.
Suborder Mesostigmata

Melicharidae Hirschmann, 1962

Proctoelaclips pomorum (Oudemans, 1929)
Typhlodromus pomorum Oudemans, 1929; 11-20.
Locality of the specimens examined: Trap: A3: IX-2013(1).
Comments: This species was associated to *A. siro* from a household and was also found on home-grown oats with *A. siro* and on bales of mouldy esparto grass heavily infested with *A. siro* and *Tyrophagus* sp. (Hughes 1976).

Blattissocidae Garman, 1948

Blattisocius dentriticus (Berlese, 1918)
Lastoseius (L.) dentriticus Berlese, 1918; 7-16.
Bird nests: *Columba picata*: XI-2014(5); *Zenaida auriculata*: XI-2014(5).
Comments: This species is a predator that competes with *C. eruditus* (Collins 2012). It feeds on *T. putrescentiae* and is associated with imported food in the United States (Hughes 1976). *Blattisocius dentriticus* was tested feeding on *M. ginglymura* and showed lower life-table values than when feeding on *T. putrescentiae* (Silva et al. 2016a).

Blattisocius keegani (Fox, 1947)
Melichares (B.) keegani Fox, 1948; 598-603
Comments: It was reported in stored rice (Flechtmann 1968), dried fishes (Flechtmann and Castelo 1982), and *Araucaria angustifolia* (Berol.) (Araucariaceae) (Fenilli and Flechtmann 1990). Silva et al. (2013) observed this species in laying hen nests and traps in poultry houses.

Laelapidae Berlese, 1892

Androlaelaps casalisi (Berlese, 1887)
Iphis casalisi Berlese, 1887; 8
Locality of the specimens examined: Bird nest: *Zenaida auriculata*: XI-2014(3).
Comments: It is a generalist predatory mite of *T. putrescentiae*, *Glycyphagus domesticus* (De Geer, 1778), *B. keegani*, and of immature stages of *D. gallinae* (Hughes 1976; Lesna et al. 2009). It has been collected from bodies and also from the nests of mammals and bird species. Silva et al. (2013) observed this species in laying hen nests and abandoned bird nests in poultry houses.

Hypoaspis lubrica Voiggs and Oudemans, 1904
Hypoaspis smithii Hughes, 1948; 654.
Locality of the specimens examined: Trap: S1: IX-2013(1).
Comments: It is found in association with acaridae mites in grain debris, rotting oats, nests of small mammals, and swallow nests. It has also been found in the dead litter of broiler houses (Hughes 1976).

Macrochelidae Vitzhum, 1930

Macrocheles muscaedomesticae (Scopoli, 1772)
Acarus muscaedomesticae Scopoli, 1772; 1-128.
Comments: It is a predator of house fly and related species (Lesna et al. 2009). It is found in manure, including poultry manure, which is a favorable habitat to the development of flies. Larvae and adults feed on fly eggs. Silva et al. (2013) observed this species in laying hen nests and abandoned bird nests in poultry houses.

Macronyssidae Oudemans, 1936

Ornithonyssus bursa (Berlese, 1888)
Leiognathus bursa Berlese, 1888; 143.
Locality of the specimens examined: Bird nest: *Columba picata*: XI-2014(5); *Zenaida auriculata*: XI-2014(1).
Comments: It is a cosmopolitan species and forms colonies in the cloaca and feathers of the cloacal region (Back 2004), remaining continuously on the hen’s body (Tucci and Guimarães 1998; Soares et al. 2008). This species can be parasitic of humans (Oliveira et al. 2012).
Phytoseiidae Berlese, 1913

Typhlodromus transvaalensis (Nesbitt, 1951)
Kampimodromus transvaalensis Nesbitt, 1951:55.

Uropodidae Kramer, 1881

Fuscuropoda sp.
Locality of the specimens examined: **Trap**: A1: VI-2014(1); S1: III-2014(2). Comments: They are mites that live in forests, fertile soil, and manure. They feed on bread, yeast, and immature stages of flies, fungal hyphae and spores, and they attack soft-bodied animals such as nematodes and immature stages of mites (Hughes 1976), and are phoretic mites that attach to the surface of their prey. Some studies have reported that some Uropodina are carnivores (Gerson and Smiley 1990).

Suborder Prostigmata

Caligonellidae Grandjean, 1944

Molotoognathus sp.
Locality of the specimens examined: **Trap**: S1: I-2014(1); S2: XI-2013(1). Comments: Some species have been reported as feeding on eggs of spider mites (Summers and Schlinger 1955; Dosse 1967).

Paraneognathus wangae Fan and Li, 1995
Locality of the specimens examined: **Trap**: FR: VII-2014(1); S1: II-2014(3), V-2014(1); S2: VI-2014(1). Comments: The first observation of this species in Brazil was registered in our study area (Silva et al. 2015).

Raphignathidae Kramer, 1877

Raphignathus sp.
Locality of the specimens examined: **Traps**: FR: I-2014(1); VI-2014(1); **Bird nests**: Columbina picui: XI-2014(3); Zenaida auriculata: XI-2014(1). Comments: Raphignathid mites can be found underneath tree bark and in litter, moss, lichens, soil, stored products, house dust, and bird nests (Dönel and Doğan, 2011).

Cheyletidae Leach, 1815

Chelaches bipanus Summers and Price, 1970
Locality of the specimens examined: **Trap**: S2: XI-2013(1). Comments: They have been reported on willow bark and twigs in California, USA (Summers and Price 1970).

Cheyletinus (Hemichyletia) wellsi (Baker, 1949)
Cheyletinus wellsi Baker, 1949: 300-301.

Cheyletus eruditus (Schrank, 1781)
Locality of the specimens examined: **Trap**: FR: IX-2013(11), X-2013(6), XI-2013(1). Comments: It has been observed feeding on young forms of *D. gallinae* (Maurer and Hertzberg 2001) in poultry houses. This species practices cannibalism in the absence of food, or when food has low
nutritional value. There are reports of stored grains containing only C. eruditus without any prey (Cebolla et al. 2009). Apart from stored grains and farm detritus, it is also a regular inhabitant of bird and mammal nests. Silva et al. (2013) observed this species in laying hen nests and traps in poultry houses.

Cheyletus malaccensis (Oudemans, 1903)

Cheyletus malaccensis Oudemans, 1903:84.


Comments: This species is associated with fungi species which are likely to develop in stored grains (Sinha et al. 2013). Apart from stored grains and farm detritus, it is also a regular inhabitant of bird and mammal nests. Silva et al. (2013) observed this species in laying hen nests and traps in poultry houses. C. malaccensis feeding on D. gallinae. This predatory species did not show preference for any prey stage, feeding on all of them (Toldi et al. 2014).

Cunaxidinae Thor, 1902

Rubrosaurus nidorum Ferla; Rocha, 2012

Rubrosaurus nidorum Ferla; Rocha, 2012: 435-440


Comments: Cunaxids are mentioned by Gerson et al. (2003) as predators of tenuipalpids, eriophyids, and especially, nematodes. This species is reported in hen nests from the poultry industry in the same region as our study (Silva et al. 2013).

Stigmaeidae Oudemans, 1931

Storchia pacifica (Summers, 1964)


Locality of the specimens examined: **Trap:** FR: V-2014(1).

Comments: Species described based on specimens from Indonesia and the Philippines intercepted in Hawaii on Manihot esculenta Crantz (cassava or manioc) and Oryza sativa L. (rice) (Summers 1964). Silva et al. (2013) observed this species in laying hen nests in poultry houses.

Tarsonemidae Kramer, 1877

Tarsonemus granarius Lindquist, 1972


Locality of the specimens examined: **Trap:** A3: III-2014(1). **Bird nests:** Columbina picui: XI-2014(40); Columbina taupacoti: XI-2014(1); Zenaida auriculata: XI-2014(4).

Comments: This species is associated with fungi species which are likely to develop in stored grains (Sinha et al. 1969a, b) in Canada. In Japan, it has more often been found on granary floors than in stored wheat or rice.

Tenuipalpidae Berlese, 1913

Brevipalpus phoenicus (Geijskes, 1939)

Tenuipalpus phoenicus Geijskes 1939-23.

Locality of the specimens examined: **Trap:** S1: IX-2013(1).

Comments: It is a cosmopolitan plant mite and it is the vector of the citrus lepros virus (Chiavegato 1980).

Tetranychidae Donnadieu, 1975

Tetranychus sp.

Locality of the specimens examined: **Feather:** A2: IV-2014(3); S2: X-2013(1). **Trap:** FR: X-2013(2); S1: IX-2013(1); S2: X-2013(1). **Bird nest:** Zenaida auriculata: XI-2014(1).

Comments: Tetranychus is one of the most economically important genera of spider mites in agriculture, due to its high potential to damage crops (Bolland et al. 1998).

Tydeidae Kramer, 1877

Brachytydeus argentinensis (Baker, 1970)

Locality of the specimens examined: **Bird nest**: Columbina picui: XI-2014(4).

Comments: Originally described from females and males reported in North and South America in soil (Baker 1970).

*Brachytydeus australensis* (Baker, 1970)

*Tydeus australensis* 1979: 168.

Locality of the specimens examined: **Bird nest**: Columbina picui: XI-2014(2).

Comments: This species was described on celery leaves in Australia (Baker 1970).

*Brachytydeus obnoxia* (Kuznetzov and Zapletina, 1972)


Locality of the specimens examined: **Bird nest**: Zenaida auriculata: XI-2014(1).

Comments: Species related to nuts in Azerbaijan (Livshitz *et al.* 1972).

*Brachytydeus oregonensis* (Baker, 1970)


Comments: Described in the United States of America on oatmeal (Baker 1970). Silva *et al.* (2013) observed this species associated with laying hen facilities and misidentified it as *Lorryia* sp..

*Brachytydeus tuttlei* (Baker, 1965)


Comments: Described on *Cynodon dactylon* (L.) in United States of America. *Brachytydeus tuttlei* was reported in *Serjanea* sp. associated to the soybean agro-ecosystem in Brazil (Reichert *et al.* 2014).

**Suborder Oribatida**

Locality of the specimens examined: **Bird nest**: Zenaida auriculata: XI-2014(1).

Comments: Oribatid mites are very common soil mites. They feed on fungi and fallen plants, and play an important role in decomposition of organic matter and soil formation (Zhang 1963). Oribatids mites were collected in traps, hen’s nests and abandoned bird’s nest in poultry farms in the South of Brazil (Silva *et al.* 2013).