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BIOECOLOGIA DE ÁCAROS (ACARI) ASSOCIADOS A AVES DE POSTURA DE OVOS COMERCIAIS NO VALE DO TAQUARI, RIO GRANDE DO SUL, BRASIL

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Tese apresentada ao programa de Pós-graduação em Ambiente e Desenvolvimento, do Centro Universitário UNIVATES, como parte da exigência para obtenção do grau de Doutora em Ambiente e Desenvolvimento na Linha de Pesquisa em Tecnologia e Ambiente.

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RESUMO

BIOECOLOGIA DE ÁCAROS (ACARI) ASSOCIADOS A AVES DE POSTURA DE OVOS COMERCIAIS NO VALE DO TAQUARI, RIO GRANDE DO SUL, BRASIL.

A produção intensiva de aves de postura em confinamento além de prejudicar o bem-estar das aves, aumenta o risco de epidemias. As ectoparasitoses podem levar a baixa produtividade e diminuição da qualidade dos ovos, destacando-se ácaros hematófagos e os ácaros das penas. Espécies do gênero *Megninia* spp. causam danos por acarretar reações alérgicas com prurido, propiciando contaminações secundárias por bactérias e fungos. Este estudo objetivou avaliar a diversidade de ácaros associados a aves de postura em empresa avícola do estado do Rio Grande do Sul; identificar ao nível específico os espécimes encontrados e descrever as espécies desconhecidas pela ciência; construir uma chave dicotômica para identificação dos ácaros associados a aves de posturas no Rio Grande do Sul; conhecer as interações ecológicas da acarofauna; conhecer a biologia de *Cheyletus malaccensis* (Oudemans) alimentando-se de *Megninia ginglymura* (Mégnin) e *Tyrophagus putrescentiae* (Schrank); e, avaliar a preferência de *M. ginglymura* por diferentes regiões do corpo de galinhas poedeiras e sua dinâmica populacional. Para avaliação da diversidade foram amostrados aviários automatizados, semiautomatizados e com aves mantidas livres (“caipira”). Os ácaros foram coletados em penas, ninhos de aves silvestres abandonados e com o uso de armadilhas de cano de PVC entre agosto de 2013 e agosto de 2014. Em laboratório, os ácaros foram montados em lâminas em meio de *Hoyer* e identificados com auxílio de chaves dicotômicas. Uma espécie nova da família Pyroglyphidae foi descrita e uma chave dicotômica com a acarofauna associada a aves de postura do Rio Grande do Sul foi elaborada. As interações ecológicas de espécies entre si e com fatores climáticos foram estabelecidas a partir da correlação de Spearman (p<0.001). A biologia de *C. malaccensis* foi iniciada com 60 ovos isolados em unidades experimentais sendo 30 alimentados com *M. ginglymura* e 30 com *T. putrescentiae*. Os dados utilizados na construção de tabelas de vida de fertilidade. A preferência de *M. ginglymura* pelas diferentes regiões do corpo de galinhas poedeiras foi calculada através da abundância e prevalência. Um total de 38.862 ácaros pertencentes a 23 famílias e 39 espécies foram encontradas sendo a abundância e riqueza maiores nos sistemas semiautomatizados, caipira e por último nos automatizados. A chave dicotômica é a primeira que contempla as espécies relatadas no Rio Grande do Sul. *Megninia ginglymura* foi a espécie de importância sanitária sendo suas populações influenciadas pela temperatura. A região do dorso, cloaca, abdômen apresentaram maior abundância e prevalência e no pescoço e parte interna das asas. A espécie **n. gen. *et* n. sp.** foi descrita. Os predadores mais importantes foram *C. malaccensis*, *Typhlodromus transvaalensis* (Nesbitt), *Blattisocius keegani* (Fox) e *B. dentriticus*. Em laboratório, *C. malaccensis* alimentando-se de *M. ginglymura* resultou em maior taxa de fertilidade do que quando *T. putrescentiae* foi a presa testada. *Cheyletus malaccensis* foi considerado um inimigo natural de *M. ginglymura*.

Palavras-chave: Ectoparasitas. Avicultura poedeira. Controle biológico. *Cheyletus malaccensis*. *Megninia ginglymura*. *Blattisocius dentriticus.*

ABSTRACT

BIOECOLOGY OF MITES (ACARI) ASSOCIATED TO COMMERCIAL LAYING HEN IN VALE DO TAQUARI, RIO GRANDE DO SUL, BRAZIL.

Intensive production of confined laying hens affects their welfare and increases the risk of epidemics. Ectoparasites as hematophagous and feather mites cause low productivity and decreased egg quality. Species of the genus *Megninia* spp. can cause allergic reaction with pruritus, causing secondary bacterial infections, which may lead to lower production. This study aimed to assess the diversity of mites in laying hen houses in a commecial poultry farm in the state of Rio Grande do Sul; to identify the specimens at species level and to describe unknown species; to build an identification dichotomous key of mites associated to poultry farms from Rio Grande do Sul; to know the ecological interactions of the mitefauna; to know *Cheyletus malaccensis* (Oudemans) biology feeding on *Megninia ginglymura* (Mégnin) and *Tyrophagus putrescentiae* (Schrank); and, to evaluate the preference of *M. ginglymura* for different body region of laying hen and its population dynamics. To evaluate the mite diversity it were sampled automated, semi-automated and free-range laying hen houses. The mites were taken from feathers, abandoned wild bird's nests and PVC traps between August 2013 and August 2014. In laboratory, mites were mounted in slides using Hoyer medium and identified with help of dichotomous key. A new species of the family Pyroglyphidae was described a dichotomous key of mitefauna associated to poultry farms in Rio Grande do Sul was provided. The ecological interactions of the species and with environmental conditions were evaluated with Spearman's correlation (p<0.001). Biology of *C. malaccensis* was initiated with 60 eggs where 30 feeding on *M. ginglymura* and 30 on *T. putrescentiae*. The data generated was used to build fertility life tables. The preference of *M. ginglymura* for different body region of the host and its population dynamics were calculated as abundance and prevalence. A total of 38,862 mites from 23 families and 39 species were found and the abundance and richness were higher in the semi-automated and free-range than automated systems. A dichotomous key is the first that includes the species from Rio Grande do Sul. *Megninia ginglymura* was the sanitary species and its populations seems to be influenced by temperature. Dorsum, cloaca and abdomen regions presents higher abundance and prevalence than neck and inner wings. A new species **n. gen. *et* n. sp.** was described. The most important predators were *C. malaccensis*, *Typhlodromus transvaalensis* (Nesbitt), *Blattisocius keegani* (Fox) and *B. dentriticus*. In laboratory, *C. malaccensis* feeding on *M. ginglymura* resulted in a higher fertility rate than when *T. putrescentiae* was the prey. *Cheyletus malaccensis* was considered a natural enemy of *M. ginglymura*.

Key words: Ectoparasites. Poultry industry. Biological control. *Cheyletus malaccensis*. *Megninia ginglymura*. *Blattisocius dentriticus.*

APRESENTAÇÃO

A cadeia produtiva de ovos no Brasil caracteriza-se pela produção de ovos para consumo *in natura* e industrializados. A produção inicia-se com a cria e recria das pintainhas e posteriormente, as aves são transferidas para galpões especializados, destinados à produção de ovos. A produção brasileira no ano de 2014 foi de 37,2 bilhões de ovos. Contudo, o consumo brasileiro *per capita* em 2014 foi de 182 unidades/ano (UBABEF, 2015). O estado do Rio Grande do Sul produz apenas 5,9% da produção nacional de ovos, porém é o segundo estado com as maiores exportações de ovos (38,4%), atrás de Minas Gerais (54,1%). As exportações atingiram sendo 12,2 mil toneladas, sendo 89,5% dos ovos exportados *in natura* (UBABEF, 2015).

As aves de postura são criadas em regime intensivo, fornecendo ao consumidor a contínua disponibilidade de ovos em qualquer época do ano. Em detrimento disso, tem-se uma elevada densidade populacional, com cerca de 550 cm^2/ave nos sistemas de gaiolas convencionais, 750 cm^2/ave em gaiolas enriquecidas e em torno de nove aves/m^2 em sistemas de piso, ou seja, de 1.110cm^2/ave (GUIMARÃES; LEFFER, 2009). A produção intensiva além de prejudicar o bem-estar das aves, aumenta o risco de epidemias. As aves de postura podem ser acometidas por várias complicações como a doença de "Newcastle", bronquites infecciosas, salmoneloses, micoplasmas, aspergilose, verminoses e ectoparasitoses (BERCHIERI Jr., *et al.*, 2009). A proliferação de ectoparasitas pode levar a baixa produtividade e diminuição da qualidade do produto. Dentre os ectoparasitas destacam-se os ácaros hematófagos e os ácaros das penas.

No Brasil, três espécies de ácaros hematófagos associados a aves de postura são conhecidas: *Ornithonyssus bursa* (Berlese, 1888), *O. sylviarum* (Canestrini; Fanzango,

1877) (Macronyssidae) e *Dermanyssus gallinae* (De Geer, 1778) (Dermanyssidae) (TUCCI, 2004). *Ornithonyssus bursa* (ácaro tropical ou piolho de galinha) parasita aves domésticas e silvestres (MASCARENHAS *et al.*, 2009), não ocorrendo na avicultura industrial (SOARES *et al.*, 2008). *Ornithonyssus sylviarum* (ácaro da pena) é uma espécie exótica e forma colônias no ventre e nas penas da região da cloaca (BACK, 2004) permanecendo continuamente sobre o corpo das aves (TUCCI, 2004; SOARES *et al.*, 2008). Infestam aves domésticas em confinamento, pombos e animais silvestres (GUIMARÃES; LEFFER, 2009). *Dermanyssus gallinae* (ácaro vermelho das aves) representa um problema sanitário e econômico na avicultura de postura comercial, sendo um dos mais importantes ácaros praga deste ramo no Brasil. As lesões provocadas durante o seu repasto sanguíneo podem ser identificadas no peito e nas pernas das aves (TUCCI; GUIMARÃES, 1998).

Em relação aos ácaros associados às penas ocasionam reação alérgica com prurido (TUCCI *et al.*, 2005), propiciando contaminações bacterianas secundárias, podendo levar ao decréscimo de produção. *Megninia ginglymura* (Mégnin, 1877) ataca penas do dorso, peito e uropígio deixando-as roídas, bárbulas cortadas ou rarefeitas, folículos inchados e vermelhos e o canhão recoberto de detritos, no ponto em que começa a haste (REIS; NÓBREGA, 1956). Reis (1939) reportou *Megninia cubitalis* (Mégnin, 1877) (Analgidae) e *M. ginglymura* pela primeira vez para o Brasil. Recentemente, *Allopsoroptoides galli* (Mironov) (Psoroptoididae) foi descrita parasitando aves domésticas no Brasil, causando dermatite e provocando perdas severas na produção de ovos (MIRONOV, 2013).

Para a erradicação ou ao menos o controle dos ectoparasitas são comumente usados pesticidas químicos sintéticos. Entretanto, as espécies ectoparasitas vêm se tornando cada vez mais resistentes (MARANGI *et al.*, 2009; ROY *et al.*, 2009) sendo necessário encontrar meios mais eficientes e econômicos para controlar a saúde animal, a fim de obter produtos saudáveis, a serem oferecidos ao consumidor final (BORNE; COMTE, 2003) e garantir o bem-estar das aves.

O uso de ácaros predadores para o controle de pragas agrícolas é bastante documentado (PARRA *et al.*, 2002). A família Cheyletidae possui espécies predadoras de grande importância (EZEQUIEL *et al.*, 2008) tais como *Cheyletus malaccensis* (Oudemans, 1903) (Cheyletidae) que é um importante agente de controle de

Glycyphagus destructor (Schrank, 1781) (Glycyphagidae) e *Tyrophagus putrescentiae* (Schrank, 1781) (Acaridae) e *Cheyletus eruditus* (Schrank, 1781) (Cheyletidae) com importância no controle de ácaros de produtos armazenados.

Estudos sobre a bioecologia de ácaros com ênfase na dinâmica populacional e técnicas eficientes para o controle de ácaros hematófagos são escassos na avicultura brasileira. Assim, há necessidade de aprimorar determinados métodos de controle de ectoparasitas dentro do sistema produtivo de postura de ovos comerciais.

Com o objetivo de auxiliar a preencher as lacunas existentes no conhecimento biológico e ecológico dos ácaros associados a aves de postura no Rio Grande do Sul e fazer uma proposta de manejo de controle de ácaros de importância sanitária, seis artigos foram produzidos:

Artigo 1: Mite fauna (Acari) associated to poultry industry in different management systems of laying hen in Southern Brazil: key to species. A ser submetido para o periódico "Systematic and Applied Acarology".

Artigo 2: **n. gen. *et* n. sp.** (Acari: Pyroglyphidae), a new genus and species of mites associated with commercial laying hen from Brazil. Submetido para o periódico "Zootaxa".

Artigo 3: Influence of laying hen systems on the mite fauna (Acari) community of commercial poultry farms in southern Brazil. Artigo publicado no periódico "Parasitology Research".

Artigo 4: Population fluctuation of predators and sanitary importance mites (Acari) in commercial laying hen: ecological interactions. A ser submetido para o periódico "Acarologia".

Artigo 5: Ectoparasitism of commercial laying hen by *Megninia ginglymura* (Mégnin) (Acari): population dynamic and distribution on the body regions. Artigo submetido para o periódico "Experimental and Applied Acarology" (em revisão).

Artigo 6: Development of *Cheyletus malaccensis* (Acari: Cheyletidae) feeding on mite species found in poultry systems: *Megninia ginglymura* (Acari: Analgidae) and

Tyrophagus putrescentiae (Acari: Acaridae). Artigo publicado no periódico “Systematic and Applies Acarology”.

ARTIGO 1

Horn, TB., Granich, J., Körbes, J.H., Ferla, J.J., Silva, G.L., Ferla, N.J. Mite fauna (Acari) associated to poultry industry in different management systems of laying hen in Southern Brazil: key to species. A ser submetido ao periódico "Systematic and Applied Acarology".

Mite fauna (Acari) associated to poultry industry in different management systems of laying hen in Southern Brazil: key to species

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Abstract

This study shows the result of a large project that aimed to recognize the mite fauna associated with different commercial laying hens systems in Lajeado, Rio Grande do Sul, Southern of Brazil and provide a key of species. Samplings were conducted from August 2013 to August 2014 totaling 43 sampling events. Three different management systems of laying hen were evaluated: I) Automated (A_1, A_2 and A_3); II) Semi-automated (S_1 and S_2); III) Free range (*FR*). To collect the mites were used traps, laying hen feathers and abandoned wild bird's nests. A total of 38,862 mites belonging to 23 families and 39 species were found, including 17 exclusive species of traps, six of wild bird's nests and one of feathers. Tydeidae showed the highest richness with five species (*Brachytydeus argentinensis* (Baker, 1970), *Brachytydeus australensis* (Baker, 1970), *Brachytydeus obnoxia* (Kuznetzov & Zapletina, 1972), *Brachytydeus oregonensis*

(Baker, 1970) and *Brachytydeus tuttlei* (Baker, 1965)), followed by Cheyletidae with four species (*Chelacheles bipanus* Summers & Price, 1970, *Cheyletus eruditus* (Schrank, 1781), *Cheyletus malaccensis* (Oudemans, 1903) and *Cheletomimus (Hemicheyletia*) *wellsi* (Baker, 1949). Among the feather mites, *Megninia ginglymura* (Mégnin, 1877) was the most abundant species (76.3%) observed in all management systems. The predators potential 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%).

Key words: Aviculture; Ectoparasite, *Megninia ginglymura*, *Cheyletus malaccensis,* n. gen. *et* n. nov.

Introduction

Laying hens, free and wild birds may carry pathogenic organisms and ectoparasites to the farms linked to commercial aviculture. The integral control of people and objects, flux and ectoparasites is essential for the maintenance biosecurity. The absence of these controls increases the diseases risk (Borne & Comte 2003). The proliferation of ectoparasites, especially hematophagous and feather mites can lead to a decrease in egg production, fragility of the eggshell, laying hens becoming anemic, restless and aggressive towards each other (Sparagano 2009).

Three species of hematophagous mites are known to be associated with laying hens in Brazil: *Ornithonyssus bursa* (Berlese, 1888), *Ornithonyssus sylviarum* (Canestrini; Fanzango, 1877) (Macronyssidae) and *Dermanyssus gallinae* (De Geer, 1778) (Dermanyssidae) (Tucci & Guimarães 1998). *Ornithonyssus bursa* (tropical fowl mite) is a parasite of domestic and wild birds (Mascarenhas *et al.* 2009) but poultry industry it seems to have been replaced by *O. sylviarum* over time in Brazilian poultry industry and bit currently being reported (Soares *et al.* 2008). *Ornithonyssus sylviarum* (northern fowl mite) 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 & Guimarães 1998; Soares *et al.* 2008). It infests laying hens in confinement, pigeons and wild animals (Guimarães & Leffer 2009). *Dermanyssus gallinae* (poultry red mite) is a sanitation and economic problem in commercial laying hens, where it is one of the most important pest mites of this production system in Brazil. The skin lesions caused during the blood feeding can be identified in breast and legs of hens (Tucci & Guimarães 1998). This cosmopolitan species is found in laying hen farms, where its causes stress, injury due to bites, anemia, decreased egg production, and it can also be a vector of pathogenic microorganisms (Back 2004; Guimarães & Leffer 2009). Evaluated commercial poultry houses and abandoned nests of wild birds in the same region of this work showed that this species was the most abundant (Silva *et al.* 2013).

Feather mites cause allergic reaction with pruritus (Tucci *et al.* 2005) causing secondary bacterial infections, which may lead to lower production. *Megninia ginglymura* (Mégnin, 1877) (Analgidae) is an ectoparasite found in bird feathers (Flechtmann 1985). Their saliva causes allergic reactions, stress and the itching leads to the development of petechiae hemorrhagic, vesicles and the crust formation on the site providing secondary bacterial infections and pyorderma (Tucci *et al.* 2005). Tucci *et al.* (2005) reported concomitant presence of *M. ginglymura* and *Megninia cubitalis* (Mégnin, 1877) (Analgidae) in parasitic infestations in laying hens causing injuries on poultry industry reaching 20% drop in egg production. *Megninia ginglymura* was associated with nests and laying hen feathers in the Teutônia municipality, Vale do Taquari, State of Rio Grande do Sul (Silva *et al.* 2013; Faleiro *et al.* 2015). *Allopsoroptoides galli* (Mironov, 2013) (Psoroptoididae) was described parasiting laying hen in Brazil, causing dermatitis and severe losses in egg production (Mironov 2013; Tucci *et al.* 2014). Hens parasitized by this species show intense itching, desquamation and a marked drop in egg production (approximately 30%) (Tucci *et al.* 2014).

Alternative control which replace the use of chemical pesticides are important to increase the quality of the products, environment, worker health and rural animal welfare. Biological control using *Strongylopsalis mathurinii* (Moreira) (Dermaptera: Labiidae) were successful to control *D. gallinae* in poultry industry in the state of São Paulo (Guimarães *et al.* 1992). Between the predators mites, Lesna *et al.* (2009) investigated candidate of predators for biological control of *D. gallinae* and found two genuine predators: *Gaeolaelaps aculeifer* (Canestrini, 1883) (Laelapidae) and *Androlaelaps casalis* (Berlese, 1887) (Laelapidae) and remark *Cheyletus eruditus* (Schrank, 1781) (Cheyletidae), *Zerconopsis remiger* (Kramer, 1876) (Ascidae) and *Blattisocius keegani* (Fox, 1947) (Blattisocidae) that may act as predators. In another investigation observed *A. casalis* and *Stratiolaelaps scimitus* (Womersley, 1956) (Laelapidae) as capable of feeding and reproducing on a diet of *D. gallinae* as prey (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 phase of prey, feeding on all the stages, and was considered by these authors a potential natural enemy of *D. gallinae*.

Investigations into biological control of *M. ginglymura* are scarce and need further study. *Blattisocius dentriticus* (Berlese, 1918) (Blattisocidae) feeding on *M. ginglymura,* in laboratory conditions, showed lower values of the life-table parameters than *Tyrophagus putrescentiae* (Schrank, 1781) (Acaridae) (Silva *et al.* 2016a). These two species of prey were also tested as food for the predator *C. malaccensis* being *M.*

ginglymura considered the best food since achieved the best results of life table (*Ro* = 135.6; *T* = 41.6; λ = 1.13; *rm* = 0.12) than *T. putrescentiae* (Artigo 6).

This study investigates the mite fauna associated to commercial laying hens in South Brazil in order to know the real problems of health interest as well as subsidize posterior studies applied to potential predators for the alternative control of ectoparasites mites. Besides, it is provided a key of species from poultry industry in South of Brazil including the mite fauna presents in Silva *et al.* (2013).

Materials and Methods

This study was conducted in different commercial laying hen systems between August 2013 and August 2014 in Lajeado municipality, Vale do Taquari, state of Rio Grande do Sul, Brazil.

Six poultry houses were sampled, where in three of them the laying hen system consisted of an automated or semi-automated vertical battery cages. In automated systems ($A_{1,2,3}$), the laying hen were confined in metal cages on six floors with an area of approximately 450 cm^2/hen (nine hens/cage) and the cages were placed one top of the other in stacks of four. Hen feed was provided in a metal structure and water in nipple-type drinker, and eggs were collected on an automatic treadmill. In addition, feces were collected at least three times per week by treadmills at the bottom of the floor of cages. In this laying hen system, there are screens throughout the laying hen house to prevent wild bird access.

Among the A_1 laying hens, 39,000 white laying hens of the Bovans breeds were maintained and two batches were evaluated: the first, 45 weeks old at the beginning of sampling and 94 weeks old in July 2014, when it was replaced by a new batch at 16 weeks old and evaluated up to 20 weeks old in August 2014, giving a total of 20 samples. In A_2, there were 60,000 laying hens, 50% Bovans breed and 50% Isa Brown breed. The batch was 68 weeks old at the beginning of sampling and 98 weeks old in March 2014. A new batch was introduced in April 2014 at 17 weeks old and evaluated up to 37 weeks old in August 2014, resulting in 18 samples. In A_1 and A_2, Topline® (fipronil 1%) was added to the feed in September 2013 was it routine maintenance targeting parasites. In A_3, there were 35,000 red Isa Brown laying hens, evaluation beginning with a batch of 99 weeks old evaluated up to 109 weeks old in October 2013. A new batch of 19 weeks old was introduced in December 2014 and evaluated up to 54 weeks old in August 2014, giving a total of 16 samples. In this system, Couro Limpo® (15% cypermethrin, 25% chlorpyrifos and 1% citronellal) was applied twice in April 2014.

In the semi-automated laying hen system ($S_{1,2}$), the cages were arranged in the form of stair steps with two stacks of cages in each poultry house. Feed and water were provided in an automated manner and eggs collected manually. The S_1 system was a wood structure in the style of a "California house," and S_2 was a "wide-span model" (Axtell 1986). S_1 did not receive any type of pesticide application during the evaluation period and was considered the semi-automated control. S_1 housed 7,750 red DeKalb laying hens, with 45 weeks old at the beginning of sampling and 88 weeks old in July 2014 when the batch was removed, totaling 18 samples. S_2 housed 10,400 red Isa Brown laying hens, 41 weeks old at the beginning of sampling and 95 weeks old in August 2014, totaling 21 samples. This system received Topline® in the feed in September 2013 and May 2014. S_1 and S_2 allowed the entry of wild birds.

The other laying hen house evaluated was raised free under a sawdust bed arranged over ground, popularly known as free range (*FR*). In Brazil, this system is popularly known as "caipira". In *FR*, 3,500 red Isa Brown laying hens were housed, they were 44 weeks old and evaluated up to 88 weeks old in July 2014, when they were removed, totaling 19 samples. Feed and water were provided in an automated way and egg collecting was manual. The nests were packed in a wooden structure with sawdust inside for maintenance of eggs. The laying hens were released in the day to sunbathe, if pecking and flapping. The nests were treated with Bolfo® (propoxur 1%) powder in December 2013 and January and April 2014. Cars' access from other hen houses has been denied throughout the study.

Mites samplings

Three methods of sampling mites associated to poultry farms were used: laying hen feathers, traps and wild bird's 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 containing 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/m^2.

In each laying hen house were placed 16 traps of 27-cm PVC pipe (50 mm diameter) with 13 holes of 0.8 mm with the ends closed with caps (PVC cap) in each laying hen house (Tucci *et al.* 1989) attached to the cage with a rubber band distributed evenly along the length. Three lightly crushed paper towel sheets were placed inside the traps, to provide shelter. Attracting substances were not used. Throughout the evaluation period, the traps were maintained at the same point, where they were replaced every 15 days. At each evaluation, the paper towel was collected, packed individually in plastic bags, labeled and taken to the laboratory, where it was kept in a freezer (0°C) for at least 24 hours. For each evaluation, the collected paper towel was placed in Petri plates and observed under a stereomicroscope.

The wild bird’s 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’s 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.

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

Identifications

The identification of specimens to the species level was done using a phase contrast light microscope and identifications of the species was according to Fain 1965, Hughes 1976, Fain & Yan 1997, Oconnor 1982, Gaud *et al.* 1985, Zhang *et al.* 1999, Fain *et al.* 2002, Colloff 2009, Krantz & Walter 2009, Ferla & Rocha 2012 and Silva *et al.* 2016b. Voucher specimens were stored at the reference Collection of the Natural Sciences Museum of the Centro Universitário UNIVATES (ZAUMCN), Lajeado, Rio Grande do Sul, Brazil.

Results

A total of 38,862 mites belonging to 23 families and 39 species were found. Most of the mites were collected from feathers (73.1%) followed by traps (25.7%) and bird's nests (1.2%). The most richness family was Tydeidae, with five species (*Brachytydeus argentinensis* (Baker, 1970), *Brachytydeus australensis* (Baker, 1970), *Brachytydeus obnoxia* (Kuznetzov & Zapletina, 1972), *Brachytydeus oregonensis* (Baker, 1970) and *Brachytydeus tuttlei* (Baker, 1965)), followed by Cheyletidae with four species (*Chelacheles bipanus* Summers & Price 1970, *C. eruditus*, *C. malaccensis* and *Cheletomimus (Hemicheyletia*) *wellsi* (Baker, 1949)) and Acaridae with three (*Aleuroglyphus ovatus* (Troupeau, 1878), *Thyreophagus entomophagus* (Laboulbéne, 1852) and *T. putrescentiae*) (Figure 1). However, higher abundance of *M. ginglymura* with 76.3% of the total number of mites. This species was observed in all the systems evaluated laying hen, being recorded in feathers (99.7% of total) and traps (13.3% of total). The second more abundant species was *C. malaccensis* (9.4%) and the third n. gen. *et* n. nov. (8.6%), both were found in all laying hen systems evaluated and in all methods of sampling mites. *Cheyletus malaccencis* represents 35.1% and n. gen. *et* n. nov. 32.7% of the total number of mites associated to traps. Besides these species, *B. dentriticus*, *B. keegani*, *C.* (*Hemicheyletia*) *wellsi*, *Tetranychus* sp., *Typhlodromus transvaalensis* (Nesbitt, 1951) (Phytoseiidae) and *T. putrescentiae* were present in bird's nests, feathers and traps (Figure 1).

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

In traps, were found exclusively 17 species that can highlight the first register of *Paraneognathus wangae* Fan & Li 1995 (Caligonellidae) in Brazil and made in this area (Silva et al. 2015) and a new species of the genus *Ctenoglyphus* sp. nov.. In the feathers, just one exclusively species was found, *Dermatophagoides farinae* (Hughes, 1961) (Pyroglyphidae). In bird's nests, six exclusively species were present and three of them belong to the genus *Brachytydeus* (*B. argentinensis*, *B. australensis*, *B. obnoxia*), furthermore *A. casalis* and Oribatida mites were collected from bird's nest. Also in abandoned bird's 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 in this method of collecting mites. In feathers, there was there was a great dominance of the species *M. ginglymura* (99.7%) and all other species were in low numbers. In traps, the species most representative were *C. malaccensis* (35.1%), n. gen. *et* n. nov. (32.7%) and *M. ginglymura* (13.3%).

The mite species and the laying hen systems where found collected are presented below, along with month and year of collection. Specimens' numbers are showed in parentheses.

Suborder Astigmata

Acaridae Ewing & Nesbitt, 1954

Aleuroglyphus ovatus (Troupeau, 1878)

Tyroglyphus ovatus Troupeau, 1878

Locality of the specimens examined: **Feather:** S_2: VI-2014(1); *FR*: VII-2014(1). **Trap:** A_2: V-2014(2), VI-2014(1); S_1: IV-2014(1), V-2014(2), VI-2014(5); *FR*: VI-2014(2).

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

Thyreophagus entomophagus (Laboulbéne, 1852)

Acarus entomophagus Laboulbéne, 1852

Locality of the specimens examined: **Trap:** A_1: X-2013(2), XI-2013(2), VII-2014(2), VIII-2014(44); A_2: X-2013(1); A_3: IX-2013(1); S_1: IX-2013(2).

Comments: It is a storage mite usually sited in farms Franz *et al.* (1997), but not in house dust of households Fernandez-Caldas *et al.* (1990). Sensitization to mite species might produce occupational respiratory disorders in farmers. However, it is unusual to live in urban houses or to produce symptoms by ingestion but Inglesis-Souto *et al.* (2009) reported a child suffering anaphylaxis produced by ingestion of contaminated flour with *T. entomophagus*.

Tyrophagus putrescentiae (Schrank, 1781)

Acarus putrescentiae Schrank, 1781:552.

Locality of the specimens examined: **Feather:** A_1: VII-2014(1); A_2: X-2013(1); A_3: I-2014(2), VI-2014(1), VII-2014(5); S_1: IX-2013(2), X-2013(2), XI-2013(1), III-2014(1), V-2014(1); S_2: X-2013(1), XI-2013(1); *FR*: II-2014(2), V-2014(1), VI-2014(1). **Trap**: A_1: I-2013(1), VII-2014(5), VIII-2014(2); A_2: IX-2013(3), III-2014(2), VII-2014(1); A_3: IX-2013(4), V-2014(4), VI-2014(28); S_1: IX-2013(1), I-2014(1), VI-2014(4); S_2: IX-2013(1), X-2013(1), XI-2013(4). **Birds nest**: *Columbina picui*: XI-2014(3).

Comments: *Tyrophagus putrescentiae* is commonly associated with stored foods with high grease content and protein such as flour, wheat, soy, cheese, rye bread, milk powder, various seeds and 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 hens nests, feathers and abandoned bird's nests.

Analgidae Trouessart, 1915

Megninia ginglymura (Mégnin, 1877)

Analges ginglymura Mégnin 1877:1-193.

Locality of the specimens examined: **Feather:** *A_1:* XI-2013(3), XII-2013(63), I-2014(80), II-2014(80), III-2014(11), V-2014(1); *A_2:* IX-2013(1), X-2013(21), XI-2013(69), XII-2013(117), I-2014(387), II-2014(1050), III-2014(386), IV-2014(17), V-2014(40), VI-2014(2), VII-2014(46), VIII-2014(75); *A_3*: IX-2013(1), X-2013(1), II-2014(16), III-2014(543), IV-2014(834), V-2014(108), VI-2014(41), VII-2014(68), VIII-2014(15); *S_1*: VIII-2013(317), IX-2013(340), X-2013(982), XI-2013(895), XII-2013(1080), I-2014(638), II-2014(1169), III-2014(1222), IV-2014(1151), V-2014(979), VI-2014(461); *S_2*: VIII-2013(154), IX-2013(226), X-2013(493), XI-2013(494), XII-2013(905), I-2014(637), II-2014(972), III-2014(1177), IV-2014(1175), V-2014(955), VI-2014(297), VII-2014(939), VIII-2014(697); *FR*: VIII-2013(537), IX-2013(539), X-2013(1046), XI-2013(573), XII-2013(149), I-2014(27), II-2014(331), III-2014(608), IV-2014(673), V-2014(597), VI-2014(291), VII-2014(502). **Trap:** *A_1*: XI-2013(1), XII-2013(1), I-2014(23), II-2014(41), III-2014(12), IV-2014(2), VI-2014(5), VII-2014(1); *A_2*: XI-2013(2), I-2014(10), II-2014(50), III-2014(6), VI-2014(8), VII-2014(1), VIII-2014(4); *A_3*: IX-2013(1), II-2014(7), III-2014(9), IV-2014(14), V-2014(17), VI-2014(2), VIII-2014(1); *S_1*: IX-2013(33), X-2013(54), XI-2013(88), XII-2013(56), I-2014(72), II-2014(78), III-2014(65), V-2014(119), VI-2014(95); *S_2*: IX-2013(10), X-2013(7), XI-2013(7), XI-2013(10), XII-2013(3), I-2014(2), II-2014(43), III-2014(56), IV-2014(12), V-2014(6), VI-2014(16), VII-2014(4), VIII-2014(12); *FR*: IX-2013(51), X-2013(77), XI-2013(15), XII-2013(1), I-2014(1), II-2014(4), III-2014(23), IV-2014(3), V-2014(6), VI-2014(61), VI-2014(27).

Comments: *Megninia ginglymura* feeds the feathers of birds and hen infested. The mite's saliva causes an allergic reaction, stress, and intense itching, which leads to the formation of crusts, facilitating secondary bacterial infections and pyoderma. The itching may cause petechiae and hemorrhagic blisters on the skin of the bird parasitized (Tucci *et al.* 2005). Monteiro (2005) noted the decrease of 20% in egg production in laying hens infested with *Megninia* spp.. Silva *et al.* (2013) observed this species in laying hen's nests, feathers and traps in poultry houses.

Carpoglyphidae Oudemans, 1923

Carpoglyphus lactis (Linnaeu, 1767)

Acarus lactis Linnaeu, 1767:1024.

Locality of the specimens examined: **Trap**: A_1: VIII-2014(1).

Comments: Species from *Carpoglyphus* genus are reported as stored food mites. *Carpoglyphus lactis* was observed in dried fruits, honeycombs, pollen in bee hives rotting, potatoes, cheese, old flour, cocoa beans and groundnuts (Hughes 1976).

Chortoglyphidae Berlese, 1897

Chortoglyphus arcuatus (Troupeau, 1879)

Tyroglyphus arcuatus Troupeau, 1879

Locality of the specimens examined: **Trap**: S_2: VIII-2014(1); *FR*: X-2013(2), I-2014(6), II-2014(2), III-2014(3), IV-2014(1), V-2014(12), VI-2014(22), VII-2014(42).

Comments: *Chortoglyphus arcuatus* is a mite identified in dust samples mattress, 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 frequently found in flour and heaps of old straw (Hughes

1976). Silva *et al.* (2013) observed this species in laying hen's nests, feathers and abandoned bird's nests in poultry houses.

Epidermoptidae Trouessart, 1892

Locality of the specimens examined: **Trap:** *S_1*: XII-2013(1), I-2013(2).

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

Glycyphagidae Cunliffe, 1958

Ctenoglyphus sp. nov.

Locality of the specimens examined: **Trap**: *FR*: I-2014(12), III-2014(1), VI-2014(1).

Comments: *Ctenoglyphus plumiger* (Koch, 1836) occurs in barns, wheat, oats and barley, grass seed, and sometimes appears in large populations, in the hay. It has been found in fish meal and honeycombs (Hughes 1976).

Glycyphagus destructor (Schrank, 1781)

Acarus destructor Schrank, 1781:552.

Locality of the specimens examined: **Trap**: *A_1*: VI-2014(1), *S_2*: VIII-2014(1); *FR*: X-2013(1), V-2014(1), VI-2014(51), VII-2014(67).

Comments: *Glycyphagus destructor* is common in stored food and is frequently found in association with *Acarus siro* L. (1758) and *C. eruditus* or *C. malaccensis* (Hughes 1976). Silva *et al.* (2013) observed this species in laying hen's nests and traps in poultry houses.

Pyroglyphidae Cunliffe, 1958

Dermatophagoides farinae (Hughes, 1961)

Dermatophagoides farinae Hughes, 1961:1-287.

Locality of the specimens examined: **Feather:** A_2: VIII-2014(1).

Comments: *Dermatophagoides farinae* were isolated from poultry and pig-rearing meal. Also observed as house dust and appears to be more plentiful in house and mattress dust than *D. pteronyssinus* (Trouessart, 1897) (Hughes 1976).

n. gen. *et* n. sp. Horn & Ferla

Locality of the specimens examined: **Feather:** A_1: XII-2013(2), V-2014(2), VI-2014(1); A_2: XI-2013(1), XII-2013(1), IV-2013(4); A_3: III-2014(2), IV-2014(1), VI-2014(2), VII-2014(7), VIII-2014(1); S_2: VI-2014(1), VII-2014(4), VIII-2014(2). **Trap**: A_1: IX-2013(7), X-2013(29), XI-2013(13), XII-2013(39), I-2014(196), II-2014(48), III-2014(14), IV-2014(3), V-2014(10), VI-2014(26), VII-2014(39), VIII-2014(57); A_2: IX-2013(6), X-2013(59), XI-2013(63), XII-2013(19), I-2014(22), II-2014(12), III-2014(2), V-2014(19), VI-2014(237), VII-2014(154), VIII-2014(680); A_3: IX-2013(6), X-2013(9), I-2014(1), II-2014(72), III-2014(53), IV-2014(19), V-2014(48), VI-2014(41), VII-2014(11), VIII-2014(48); S_1: IX-2013(14), X-2013(42), XI-2013(20), XII-2013(14), I-2014(17), II-2014(11), III-2014(9), IV-2014(6), V-2014(17), VI-2014(34); S_2: IX-2013(53), X-2013(89), XI-2013(23), XII-2013(5), I-2014(3), II-2014(3), III-2014(51), IV-2014(41), V-2014(51), VI-2014(110), VII-2014(153), VIII-2014(350); *FR*: IX-2013(1), VI-2013(6), XII-2013(2), I-2014(4), III-2014(1), VI-2014(1), VII-2014(1). **Bird's nest**: *Columbina picui*: XI-2014(37); *Columbina taupacoti*: XI-2014(1); *Zenaida auriculata*: XI-2014(8).

Comments: this species was described from specimens collected in this study site (Artigo 2). **n. gen. *et* n. sp.** seems to be influenced by temperature and the relative humidity of air in laying hen houses and its populations had relationship with the predators mites *C. malaccensis* and *B. dentriticus* (Artigo 4). Silva *et al.* (2013) and Horn *et al.* (2016) misidentified as *Pyroglyphus* sp..

Suidasiidae Hughes, 1948

Suidasia pontifica Oudemans, 1905

Suidasia pontifica Oudemans, 1905:209.

Locality of the specimens examined: **Trap:** S_1: II-204(3).

Comments: *Suidasia nesbitti* Hughes, 1948 is associated with wheat pollards and bran, Rice, on birds skin, milking machinery, flour mill. Its has been recorded as giving rise to dermatitis in humans (Hughes 1976; Kilpio & Pirila 1952).

Suborder Mesostigmata

Melicharidae Hirschmann, 1962

Proctolaelaps pomorum (Oudemans, 1929)

Typhlodromus pomorum Oudemans, 1929:11-20.

Locality of the specimens examined: **Trap**: A_3: IX-2013(1).

Comments: this genus are versatile in feeding habits. It has been reared on fungal cultures and it will also feed on *Tetranychus urticae* (Koch, 1836), devouring its prey entirely, rather than sucking it dry. *Proctolaelaps pomorum* (Oudemans, 1929) was associated to *A. siro* from a house and also found on home-grown oats with *A. siro* and on bales of mouldy Algerian esparto grass heavily infested with *A. siro* and *Tyrophagus* sp. (Hughes 1976).

Blattisocidae Garman, 1948

Blattisocius dentriticus (Berlese, 1918)

Lasioseius (L.) *dentriticus* Berlese, 1918:7-16.

Locality of the specimens examined: **Feather:** A_1: XII-2013(1). **Trap**: A_1: XI-2013(1), XII-2013(3), VI-2014(1), VIII-2014(3); A_2: IX-2013(2), X-2013(3), III-2014(1), V-2014(1) A_3: IX-2013(1), X-2013(1), I-2014(1), III-2014(1), V-2014(2), VI-2014(3); S_1: IX-2013(6), X-2013(22), XI-2013(19), XII-2013(6), I-2014(1), V-2014(2); S_2: IX-2013(1), XI-2013(4), XII-2013(1), VIII-2014(5); *FR*: XI-2013(2). **Bird's nest**: *Columbia picui*: XI-2014(5); *Zenaida auriculata*: XI-2014(51).

Comments: *Blattisocius dentriticus* feeds *T. putrescentiae* is associated with imported food in the United States (Hughes 1976). This species is a predator that competes with *C. eruditus* (Collins 2012). *Rhizoglyphus robini* (Claparédè, 1869) proved to be the most favorable food (Mohamed 2013). *Blattisocius dentriticus* was tested feeding on *M. ginglymura* and showed lower values in the life table than when the prey was *T. putrescentiae* (Silva *et al.* 2016a) and no relationship with *M. ginglymura* populations (Artigo 4).

Blattisocius keegani (Fox, 1947)

Melichares (B.) *keegani* Fox, 1947: 598-603

Locality of the specimens examined: **Feather:** A_2: IV-2014(1); A_3: IV-2014(1); S_2: XII-2013(1), IV-2014(1), VIII-2014(1). **Trap**: A_1: IX-2013(8), X-2013(1), XI-2013(5), I-2014(4), II-2014(2), III-2014(13), IV-2014(1), VI-2014(10), VII-2014(2), VIII-2014(8);

A$_2$: IX-2013(2), X-2013(3), III-2014(1), V-2014(1); *A*$_3$: IX-2013(7), X-2013(5), III-2014(2), V-2014(1), VII-2014(2), VIII-2014(28); *S*$_1$: I-2014(1), IV-2014(61); *S*$_2$: XI-2013(1), I-2014(1), VIII-2014 (8). **Bird's nest**: *Columbina picui*: XI-2014(20); *Columbina taupacoti*: XI-2014(7); *Zenaida auriculata*: XI-2014(64).

Comments: *Blattisocius keegani* was reported from stored rice (Flechtmann 1968), dried fishes (Flechtmann & Castelo 1982) and *Araucaria angustifolia* (Bertol.) (Araucariaceae) (Fenilli & Flechtmann 1990). Silva *et al.* (2013) observed this species in laying hen's nests and traps in poultry houses. The populations of *B. keegani* showed a relationship with *M. ginglymura* in a free range laying hen house and this predator was not influenced by n. gen. *et* n. nov. (Artigo 4).

Laelapidae Berlese, 1892

Androlaelaps casalis (Berlese, 1887)

Iphis casalis Berlese, 1887: 8

Locality of the specimens examined: **Bird's nest**: *Zenaida auriculata*: XI-2014(3).

Comments: *Androlaelaps casalis* is a generalist mite predator of *T. putrescentiae*, *Glycyphagus domesticus* (De Geer, 1778), *B. keegani* and immature of *D. gallinae* (Hughes 1976; Lesna *et al.* 2009). It has been collected from bodies and also the nests of mammals and species of birds. Silva *et al.* (2013) observed this species in laying hen's nests and abandoned bird's nests in poultry houses.

Hypoaspis lubrica Voigts and Oudemans, 1904

Hypoaspis smithii Hughes, 1948:654.

Locality of the specimens examined: **Trap:** *S*$_1$: IX-2013(1).

Comments: *Hypoaspis lubrica* is found in association with acarid mites on grain debris, rotting oats, nests of small mammals and swallow's nests. It is also has been found in the deep litter of broiler houses (Hughes 1976).

Macrochelidae Vitzhum, 1930

Macrocheles muscaedomesticae (Scopoli, 1772)

Acarus muscaedomesticae Scopoli, 1772:1-128.

Locality of the specimens examined: **Feather:** S_1: X-2013(1). **Trap**: *FR:* IX-2013(7), V-2014(1).

Comments: *Macrocheles muscaedomesticae* is a predator (Lesna *et al.* 2009) of house fly and related species. It is found in manure, including poultry manure, habitat conducive to the development of flies. Larvae and adults feed on the eggs of flies. It is common to find female *M. muscaedomesticae* in stored food or in any other place where have flies (Zhang 1963). Silva et al. (2013) observed this species in laying hen's nests and abandoned bird's nests in poultry houses.

Macronyssidae Oudemans, 1936

Ornithonyssus bursa (Berlese, 1888)

Leiognathus bursa Berlese, 1888:143.

Locality of the specimens examined: **Bird's nest**: *Columbina picui*: XI-2014(5); *Zenaida auriculata*: XI-2014(1).

Comments: 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 & Guimarães 1998; Soares *et al.* 2008). This species can parasitize humans (Oliveira *et al.* 2012).

Phytoseiidae Berlese, 1913

Typhlodromus transvaalensis (Nesbitt, 1951)

Kampimodromus transvaalensis Nesbitt, 1951:55.

Locality of the specimens examined: **Feather:** A_1: VIII-2014(3); S_1: III-2014(1); S_2: XI-2013(1). **Trap**: A_1: IX-2013(4), X-2013(18), XI-2013(23), XII-2013(6), II-2014(1), III-2014(3), IV-2014(3), V-2014(1), VI-2014(20), VII-2014(2), VIII-2014(8); A_2: X-2014(4), I-2014(1), VI-2014(4), VIII-2014(2); A_3: IX-2013(1), X-2013(1), I-2014(5), II-2014(1), III-2014(1), V-2014(1), VI-2014(31), VII-2014(37), VIII-2014(55); S_1: X-2013(1), XI-2013(1), I-2014(2), V-2014(1); S_2: IX-2013(2), X-2013(11), XI-2013(19), XII-2013(16), I-2014(9), IV-2014(1), VII-2014(1), VIII-2014(6); *FR*: VII-2014(1). **Bird's nest**: *Columbina picui*: XI-2014(3); *Zenaida auriculata*: XI-2014(1).

Comments: This species was collected from native vegetation and vines in the state of Rio Grande do Sul (Ferla & Moraes 2002; Ferla *et al.* 2011). Silva *et al.* (2013) observed this species in laying hen's nests and traps in poultry houses.

Uropodidae Kramer, 1881

Fuscuropoda sp.

Locality of the specimens examined: **Trap:** A_1: VI-2014(1); S_1: 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, attack soft-bodied animals such as nematodes and immature stages of mites (Hughes 1976). These mites are phoretic, attach to the surface of their prey. There are studies reporting that some uropodina's are carnivores (Gerson & Smiley 1990).

Suborder Prostigmata

Caligonellidae Grandjean, 1944

Molotrognathus sp.

Locality of the specimens examined: **Trap**: S_1: I-2014(1); S_2: XI-2013(1).

Comments: Some species were cited feeding on eggs of spider mites (Summers & Schlinger 1955; Dosse 1967).

Paraneognathus wangae Fan & Li, 1995

Paraneognathus wangae Fan & Li, 1995: 323-327.

Locality of the specimens examined: **Trap:** *FR*: VII-2014(1); S_1: II-2014(3), V-2014(1); S_2: VI-2014(1).

Comments: the first observation of this species in Brazil was registered in the area of the present research (Silva *et al.* 2015).

Raphignathidae Kramer, 1877

Raphignathus sp.

Locality of the specimens examined: **Traps:** *FR*: I-2014(1); VI-2014(1); **Bird's nest**: *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 birds' nests (Dönel & Doğan, 2011).

Cheyletidae Leach, 1815

Chelacheles bipanus Summers and Price, 1970

Chelacheles bipanus Summers and Price, 1970:79.

Locality of the specimens examined: **Trap**: S_2: XI-2013(1).

Comments: reported in willow bark and twigs (Summers & Price 1970).

Cheletomimus (Hemicheyletia) wellsi (Baker, 1949)

Cheyletia wellsi Baker, 1949a: 300-301.

Locality of the specimens examined: **Feather:** S_2: XI-2013(1), XII-2013(1). **Trap:** S_1: X-2013(5), XI-2013(22), XII-2013(23), I-2014(66), II-2014(22), III-2014(9), IV-2014(6), V-2014(10), VI-2014(6); S_2: XI-2013(3), XII-2013(5), I-2014(8), II-2014(8), III-2014(7), IV-2014(4), V-2014(4). **Bird's nest**: *Columbina picui*: XI-2014(16); *Zenaida auriculata*: XI-2014(10).

Comments: species reported in soil, grape leaves and grass (Summers & Price 1970), citrus leaves and fruits were *Phyllocoptruta oleivora* (Ashmead, 1879) is present (Chiavegato 1980) and in rubber tree in São Paulo State (Feres 2000).

Cheyletus eruditus (Schrank, 1781)

Acarus eruditus Schrank, 1781:1-24.

Locality of the specimens examined: **Trap**: *FR*: IX-2013(11), X-2013(6), XI-2013(1).

Comments: *Cheyletus eruditus* has been observed feeding on young forms of *D. gallinae* (Maurer & Hertzberg 2001) in poultry houses. This species practice cannibalism in the absence of food, or when kept with food with low nutritional value. There are reports of stored grains containing only *C. eruditus* without any prey (Cebolla *et al.* 2009). Apart from grain stores and farms detritus, it is also a regular inhabitant of birds and mammals nests. Silva *et al.* (2013) observed this species in laying hen's nests and traps in poultry houses.

Cheyletus malaccensis (Oudemans, 1903)

Cheyletus malaccensis Oudemans, 1903:84.

Locality of the specimens examined: **Feather:** A_2: IV-2014(2); A_3: V-2014(1); S_1: V-2014(1); S_2: III-2014(3); *FR*: I-2014(1). **Trap**: A_1: IX-2013(39), X-2013(63), XI-2013(104), XII-2013(41), I-2014(36), II-2014(96), III-2014(125), IV-2014(46), V-2014(32), VI-2014(95), VII-2014(10), VIII-2014(81); A_2: IX-2013(38), X-2013(45), XI-2013(73), XII-2013(10), I-2014(139), II-2014(371), III-2014(325), V-2014(16), VI-2014(37), VII-2014(20), VIII-2014(21); A_3: IX-2013(15), X-2013(6), I-2014(9), II-2014(30), III-2014(72), IV-2014(33), V-2014(78), VI-2014(96), VII-2014(78), VIII-2014(193); S_1: XII-2013(9), I-2014(27), II-2014(1), III-2014(6), V-2014(1), VI-2014(4); S_2: X-2013(2), XI-2013(59), XII-2013(72), I-2014(128), II-2014(60), III-2014(75), IV-2014(32), V-2014(17), VI-2014(13), VII-2014(6), VIII-2014(22); *FR*: IX-2013(46), X-2013(96), XI-2013(59), XII-2013(7), I-2014(20), II-2014(35), III-2014(56), IV-2014(26), V-2014(57), VI-2014(29), VII-2014(65). **Bird's nest**: *Columbina picui*: XI-2014(40); *Columbina taupacoti*: XI-2014(10); *Zenaida auriculata*: XI-2014(94).

Comments: *Cheyletus malaccensis* is related to biological control of prey and has proved very effective in controlling *G. destructor* and *T. putrescentiae*. This mite also practiced cannibalism in the absence of food, or when kept with food with low nutritional value (Cebolla *et al.* 2009). Silva *et al.* (2013) observed this species in laying hen's nests and traps in poultry houses. The biology of *C. malaccensis* feeding on *D. gallinae* showed no preference for any phase of prey, feeding on all the stages (Toldi *et al.* 2014). *C. malaccensis* seem to be the most common predator when the decrease in populations of *M. ginglymura* (Artigo 4).

Cunaxidae Thor, 1902

Rubroscirus nidorum Ferla; Rocha, 2012

Rubroscirus nidorum Ferla; Rocha, 2012: 435-440

Locality of the specimens examined: **Feather:** *S_1*: V-2014(9); *S_2*: V-2014(2). **Trap**: *S_1*: XI-2013, XII-2013(12), I-2014(8), II-2014(4), III-2014(7), IV-2014(4), V-2014(23), VI-2014(4); *S_2*: I-2014(1), II-2014(1), V-2014(3), VII-2014(2), VIII-2014(4); *S_2*: III-2014(3), IV-2014(3), VII-2014(1); *FR*: IX-2013(1), X-2013(1), XI-2013(2).

Comments: Cunaxidae are fast runners and appear feeding on various small arthropods that occur in different cultures (Gerson & Smiley 1990). The cunaxids are cited by Gerson *et al.* (2003) as predators of mites tenuipalpids, eriophyids and especially nematodes. This species is reported in hen's nests from poultry industry in the same region as this research (Silva *et al.* 2013).

Stigmaeidae Oudemans, 1931

Storchia pacificus (Summers, 1964)

Apostigmaeus pacificus Summers, 1964: 184-186.

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

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

Tarsonemidae Kramer, 1877

Tarsonemus granarius Lindquist, 1972

Tarsonemus granarius Lindquist, 1972: 1699 - 1708.

Locality of the specimens examined: **Trap**: A_3: III-2014(1). **Bird's nest**: *Columbina picui*: XI-2014(40); *Columbina taupacoti*: XI-2014(1); *Zenaida auriculata*: XI-2014(4).

Comments: *Tarsonemus granarius* is associated with fungi species which are likely to develop in stored grain (Sinha *et al.* 1969a, b).

Tenuipalpidae Berlese, 1913

Brevipalpus phoenicis (Geijskes, 1939)

Tenuipalpus phoenicis Geijskes 1939:23.

Locality of the specimens examined: **Trap:** S_1: IX-2013(1).

Comments: *Brevipalpus phoenicis* is a plant mite and it is the vector of the leprosis virus that causes the pathogenesis in citrus (Chiavegato 1980).

Tetranychidae Donnadieu, 1975

Tetranychus sp.

Locality of the specimens examined: **Feather:** A_2: IV-2014(3); S_2: X-2013(1).**Trap:** *FR:* X-2013(2); S_1: IX-2013(1); S_2: X-2013(1). **Bird's nest**: *Zenaida auriculata*: XI-2014(1).

Comments: *Tetranychus* is one of the most economically important genus of spider mites, due to its high potential to destroy agriculture (Bolland *et al.* 1998).

Tydeidae Kramer, 1877

Brachytydeus argentinensis (Baker, 1970)

Tydeus argentinensis Baker, 1970: 167.

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

Comments: This species description was made from specimens collected in the soil (Baker 1970).

Brachytydeus australensis (Baker, 1970)

Tydeus australensis 1979: 168.

Locality of the specimens examined: **Birds nest**: *Columbina picui*: XI-2014(37); *Zenaida auriculata*: XI-2014(2).

Comments: It was described from celery leaves, in Australia (Baker 1970).

Brachytydeus obnoxia (Kuznetzov & Zapletina, 1972)

Tydeus obnoxius Kuznetzov & Zapletina, 1972: 1579.

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

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

Brachytydeus oregonensis (Baker, 1970)

Tydeus oregonensis Baker 1970: 171.

Locality of the specimens examined: **Trap**: A_1: IX-2013(1), I-2014(1), II-2014(4), III-2014(4), IV-2014(11), V-2014(15), VI-2014(21), VII-2014(2); A_2: I-2014(1), II-2014(3), III-2014(1), V-2014(12); A_3: I-2014(1); S_1: X-2013(1), II-2014(5), III-2014(9), V-2014(4), VI-2014(4); S_2: II-2014(4), III-2014(5), IV-2014(2), V-2014(3), VI-2014(6), VII-2014(3), VIII-2014(2); *FR*: IX-2013(10), X-2013(15), I-2014(2), VII-2014(2). **Birds nest**: *Zenaida auriculata*: XI-2014(5).

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

Brachytydeus tuttlei (Baker, 1965)

Tydeus tuttlei Baker, 1965:100.

Locality of the specimens examined: **Trap**: A_1: XI-2013(2), I-2014(3), VIII-2014(37); A_2: X-2013(2), XII-2013(1), I-2014(9), II-2014(8), III-2014(8), V-2014(8), VI-2014(3), VII-2014(1); A_3: X-2013(2), I-2014(8), II-2014(3), III-2014(6), IV-2014(1), V-2014(5), VI-2014(1), VIII-2014(2); S_1: IX-2013(1), X-2013(6), XI-2013(92), XII-2013(16), I-2014(24), II-2014(30), III-2014(20), IV-2014(5), V-2014(13), VI-2014(5); S_2: XI-2013(1), XII-2013(3), I-2014(9), II-2014(17), III-2014(43), IV-2014(8), V-2014(5), VI-2014(10), VII-2014(1), VIII-2014(10); *FR*: II-2014(2), IV-2014(1), V-2014(11), VI-2014(1), VII-2014(2).

Comments: *Brachytydeus tuttlei* was reported in *Serjanea* sp. associated to soybean agroecosystem in Brazil (Reichert *et al.* 2014).

Suborder Oribatida

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

Comments: Oribatids mites are common in the soil. They feed on fungi and fallen plants, are important in decomposition and soil formation. There are few species that live in the aerial parts of plants, but still has economic importance because they are known as plant pests (Zhang 1963).

Key to genera and species (excluding Oribatida) presents in poultry farms in Rio Grande do Sul, Brazil[*]

* the species mentioned in Silva *et al.* (2013) and Faleiro *et al.* (2015) were included in the key (these authors misidentified: *Diamesoglyphus* sp. as *Ctenoglyphus* sp.; **n. gen. *et* n. sp.** as *Pyroglyphus* sp.).

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 peripodomeric fissure associated with slit organs; tarsus of leg I with dense dorsal cluster of solenidiform setae sub distally (these may be further elaborated into receptor organ complexes) …………………..**Superorder Parasitiformes**……………..2

- 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 sub distally…..…… **Superorder Acariformes**…....…15

2. Gnathossoma usually narrow and elongate such that the hypostomal and subcapitular setae are aligned in a more or less longitudinal row; epigynial shield without setae ………………..Uropodiae………………**UROPODIDAE** ………………………………………………………….….*Fuscuropoda* sp.

- Gnathossoma with another shape; second subcapitular setae (hypostomal seta *h2*) usually laterad of setae *h3* and not in a linear arrangement with other subcapitular setae; epigynial shield usually with at least one pair of setae ………………………………..….Dermanyssiae…….……………………….………3

3. Peritremes looped proximally, joining the stigma posteriorly…….**MACROCHELIDAE**……….*Macrocheles muscaedomesticae*

- Peritremes not looped ……………………………………………..4

4. Deutonymphs and adults with less than 20 pairs of dorsal shield setae……………........…**PHYTOSEIIDAE**………………………………... 5
- Deutonymphs and adults with more than 20 pairs of dorsal shield setae……….6

5. Podonotal region of dorsal shield with four pairs of lateral setae (*j3*, *z2*, *z4* and s4) ……………………………………….………… *Amblyseius herbicolus*
- Podonotal region of dorsal shield (anterior to *R1*) with five or six pairs of lateral setae (*j3*, *z2*, *z4* and *s4* present; *z3* and/or *s6* present)...*Typhlodromus transvaalensis*

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** …………. *Kleemannia plumigera*
- Female with zero to typically three sterna setae on the sternal shield; corniculi usually entire, rarely divided distally; Femur II with 10-11 setae, including 5 dorsals …………………………………………………………..……… 7

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 broadly or narrowly rounded posteriorly, usually widely separated from inversely subtriangular anal shield or epigynial shield expanded into a genitoventral or genitoventrianal shield ….………………..… 11

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** ……………..…*Proctolaelaps pomorum*

- Female with epigynial shield usually truncate posteriorly and usually with a ventrianal shield bearing 2-7 of the opisthogastric setae in addition to the anal setae; ……….................. **BLATTISOCIDAE**……………………………….. 9

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

- Peritreme is very short, not extending beyond coxae II; fixed digit of the chelicerae considerably shorter than the movable ……………………………..10

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 …...……………………………………………………….…... *Blattisocius tarsalis*

- Peritreme short, barely reaching the middle of coxae III; fixed digit of chelicerae with minute teeth and about two-thirds the length of the movable digit; the movable digit has one or two teeth ………………………… *Blattisocius keegani*

11. Chelicerae of female whip-like, styliform; cheliceral digits minute, chelate; corniculi membranous, indistinct …………………………….…………… …………………**DERMANYSSIDAE……………...**…. *Dermanyssus gallinae*

- Chelicerae variously produced but styliform; corniculi variously developed ... 12

12. Chelicerae elongate, edentate; corniculi membranous, usually lobate; palpotrochanter 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*

- Chelicerae various, dentate or edentate; corniculi strongly sclerotized or membranous, horn-like, barbed or lobate; palpotrochanter 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*

- 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*

- Genital shield of female small; pre-endopodal plates indistinct; tectum with a denticulate margin………………………………………….. *Hypoaspis aculeifer*

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 empodium 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 *(cl-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; opisthosomata 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, resemble a horse shoes; pharynx short, resemble a horse shoes; setae *c1* and *c2* with similar lengths …………………………………...…………… *Tarsonemus granarius*

- Female with sejugal apodeme emarginated symmetrically in the middle region; pharynx elongated, similar to bowling bottles; setae *c2* longer than *c1* ……………………………………………………….. *Tarsonemus confusus*

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 ……………………..……**CUNAXIDAE**………………… *Rubroscirus nidorum*

20. Pretarsus leg I with vestigial claws or with no claws or apotele I absent …………………………... **IOLINIDAE** …………………. *Parapronematus* sp.

- Pretarsus leg I with paired claws and/or apotele I ….. **TYDEIDAE** ………… 21

21. Cheliceral stilettos distinctly shorter than palpal tarsus.................................... 22

- Cheliceral stilettos not shorter than palpal tarsus... 24

22. Empodial hooks (*om*) occur……………………………......*Brachytydeus tuttllei*

- Lack of empodial hooks (*om*) …………………………..………………… 23

23. Body elongated; ventral striae between metasternal setae lie longitudinally; dorsal setae slender and relatively long: setae *f1* distinctly longer than 1/2 distance *f1-h1*; bothridial setae (*bo*) slightly serrate; solenidion *ωI* long: not shorter than the width of tarsus I..................................*Brachytydeus oregonensis*

- Body broadened; ventral striae between metasternal setae lie transversely; dorsal setae lanceolate, short: setae *f1* about as long as 1/2 section *f1-h1*; bothridial setae (*bo*) smooth; solenidion ωI short: shorter than 1/2 width of tarsus I………………………………...……..…………..….*Brachytydeus obnoxia*

24. Stilettos as long as palpal tarsus.................................. *Brachytydeus australensis*

- Stilettos distinctly longer than palpal tarsus .... *Brachytydeus argentinensis*

25. Pretarsal claws well developed or reduced but always with tenent hairs…...….26

- Pretarsal claws lacking tenent hairs…………………………………………… 27

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....................**TETRANYCHYDAE**…………………*Tetranychus* sp.

- Tarsi I-II with distal, peg-shaped or bulbous solenidia and with no solenidia closely associated with a seta to form duplex sets……………………**TENUIPALPIDAE**.…………….*Brevipalpus phoenicis*

27. Palptarsus with 1 or 2 comb-like setae; stylophore fused to subcapitulum; base of moveable digit contained within the stylophore capsule ………………………..**CHEYLETIDAE**…………………………………….28

- 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 ……..…........................... 33

28. Without eyes ……..……29
- With one pair of prodorsal eyes ………..31

29. Peritreme usually with three short transverse links; lateral dorsal setae fan-like ……………………………………………………...….. *Eucheyletia reticulata*
- Peritreme M-shaped or forming an inverted U; lateral dorsal setae slender to narrowly-spatulate …………………………………………………………..30

30. Omega in tarsus I distinctly expanded towards its base; usually with on tooth at base of pedipalpal claw...*Cheyletus malaccensis*
- Omega on tarsus I tapering gradually towards its distal end; usually with more than one tooth at base of pedipalpal claw.................................*Cheyletus eruditus*

31. Body fusiform; coxal fields II and III separated by about body width ………………………………………………………….... *Chelacheles bipanus*
- Body ovoid; coxal field II and III separated by less than body width …..……. 32

32. Dorsum with two sclerites…………………..…. *Cheletomorpha lepidopterorum*
- Dorsum with three sclerites ..……………..….…*Cheletomimus (Hemicheyletia) wellsi*

33. Peritremes and stigma absent ….…**STIGMAEIDAE**..……… *Storchia pacificus*

- 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 emmerging anteriorly, posterior of cheliceral condyle; peritemes arising medially on stylophores………………………………*Molothrognathus* sp.
- Peritremes confined in W-shaped; stylophore elongated and tapered..…….*Paraneognathus wangae*

36. Body cuticle usually at least partially striate; 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 striate; 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*
- 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 proeminent 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*

40. Discrete coxal apodemes III and sometimes IV absent; discrete propodosomal sclerites absent .... **CHORTOGLYPHIDAE** ……...*Chortoglyphus arcuatus*

- 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*

- 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 … ……………………...…..*Aleuroglyphus ovatus*

- 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*

44. Tarsi I-II with setae ft' (*ba*) absent or if present on tarsus I, then filiform ………………………………...………………...*Thyreophagus entomophagus*

- Tarsi I-II with setae ft' (*ba*) in the form of a spine directly adjacent to solenidion ω1 …………………………………………………….….*Rhyzoglyphus callae*

45. Genu III with solenidion σ absent …………………...…**EPIDERMOPTIDAE**

- 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*

47. Setae *se* long, longer than ½ of body wibth …………*Dermatophagoides farinae*

- Setae *se* distinctly shorter than ½ of body width …….……..…. n. gen. *et* n. nov.

Discussion

The commercial laying hen is an important economic activity of Vale do Taquari and state of Rio Grande do Sul and it is necessary to know the associated mites, their frequency and damages caused by them (Silva *et al.* 2013). This study proposes the first dichotomous key that helps to identify the main species associated with the poultry farms in southern Brazil.

The biological control of mite pests by natural predators can help reduce high infestations, preventing the ectoparasites becoming a health and economic problem and is essential to know what laying hens and wild birds are carriers of the pest mites for poultry houses (Silva *et al.* 2013). *Megninia ginglymura* was the sanitary importance species associated with all environments and management's evaluated. The synthetic acaricides currently used has limitations as well as infeasibility eradication and residues presence in eggs (Lesna *et al.* 2009). Horn *et al.* (Artigo 4) report that the populations of *M. ginglymura* demonstrating a tendency to resistance to the pesticides applied or this products are not efficient to its control. It is possible to emphasize that no *M. ginglymura* specimen was recorded in abandoned bird's nests in this study corroborating records of Silva *et al.* (2013). Thus, according to the studies conducted so far, it can be said that wild birds are not vectors of this ectoparasite in southern Brazil. Besides this, *O. bursa* was recorded only in abandoned bird's nests and no specimens was recorded within the laying hen houses. However, several predators and other mites were similar to those collected in laying hen houses (feathers and traps) and abandoned bird's nests concluding que exist a transit of mitefauna of the environment natural for commercial poultry farms corroborating the results obtained by Silva *et al.* 2013.

Between the registered mitefauna, eight species were concomitant to the methods of sampling mites used and five of these were considered with predatory habit

(*B. dendriticus*, *B. keegani*, *C. (Hemicheyletia) wellsi* and *C. malaccensis*), two generalists (n. gen. *et* n. nov. and *T. putrescentiae*) and *Tetranychus* sp. that its role in laying hen houses still need to be elucidated due to this genus is largely related to phytophagous species (Bolland *et al.* 1998). **n. gen. *et* n. sp.** was misidentified as *Pyroglyphus* sp. and registered only in the feathers (Silva *et al.* 2013; Faleiro *et al*. 2015). This species presents negative and significative correlation with temperature in automated and semi-automated laying hen house and positive with the relative humidity of air in semi-automated. Also was negative and significative correlated to *C. malaccensis* in automated and semi-automated and *B. dentriticus* in semi-automated laying hen houses (Artigo 4). *Dermanyssus gallinae* was not recorded in the laying hen houses. This species was common to all management of laying hen houses (Silva *et al.* 2013; Faleiro *et al.* 2015).

The predator *Raphignathus* sp. and the generalists *B. oregonensis* and *T. granarius* were concomitant in the abandoned bird's nests and traps. *Brachytydeus oregonensis* was misidentified as *Lorryia* sp. and observed in hen's nests (Silva *et al.* 2013).

Inside the hen houses (species presents in feathers and traps) were common *A. ovatus*, *M. muscaedomesticae*, *M. ginglymura* and *R. nidorum*. Most predatory species were associated to hen's 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). In our evaluations, 17 species were captured exclusively in traps. It can highlight *B. tuttlei*, *G. destructor* and *C. arcuatus*. Species exclusively found in abandoned bird's nests were *A. casalis*, *B. argentinensis*, *B. australensis*, *B. obnoxia*, *O. bursa* and Oribatida. *Androlaelaps casalis* is a generalist predator that is able to feed and reproduce on a diet of *D. gallinae* as prey (Lesna *et al.* 2012). *Dermatophagoides farinae* was an exclusive mite of feathers.

These data help to clarify some questions in poultry farms: the presence of ectoparasites mites in wild birds can not be the main source of contamination in these environments. Differently from that shown by Silva *et al.* (2013) that wild birds have often similar mitefauna of the natural environment for commercial poultry farms: 1. the hens were infected with *M. ginglymura* and this species was not registered on abandoned bird's nests and 2. *O. bursa* was associated in abandoned bird's nests and this species was not registered within the hen houses.

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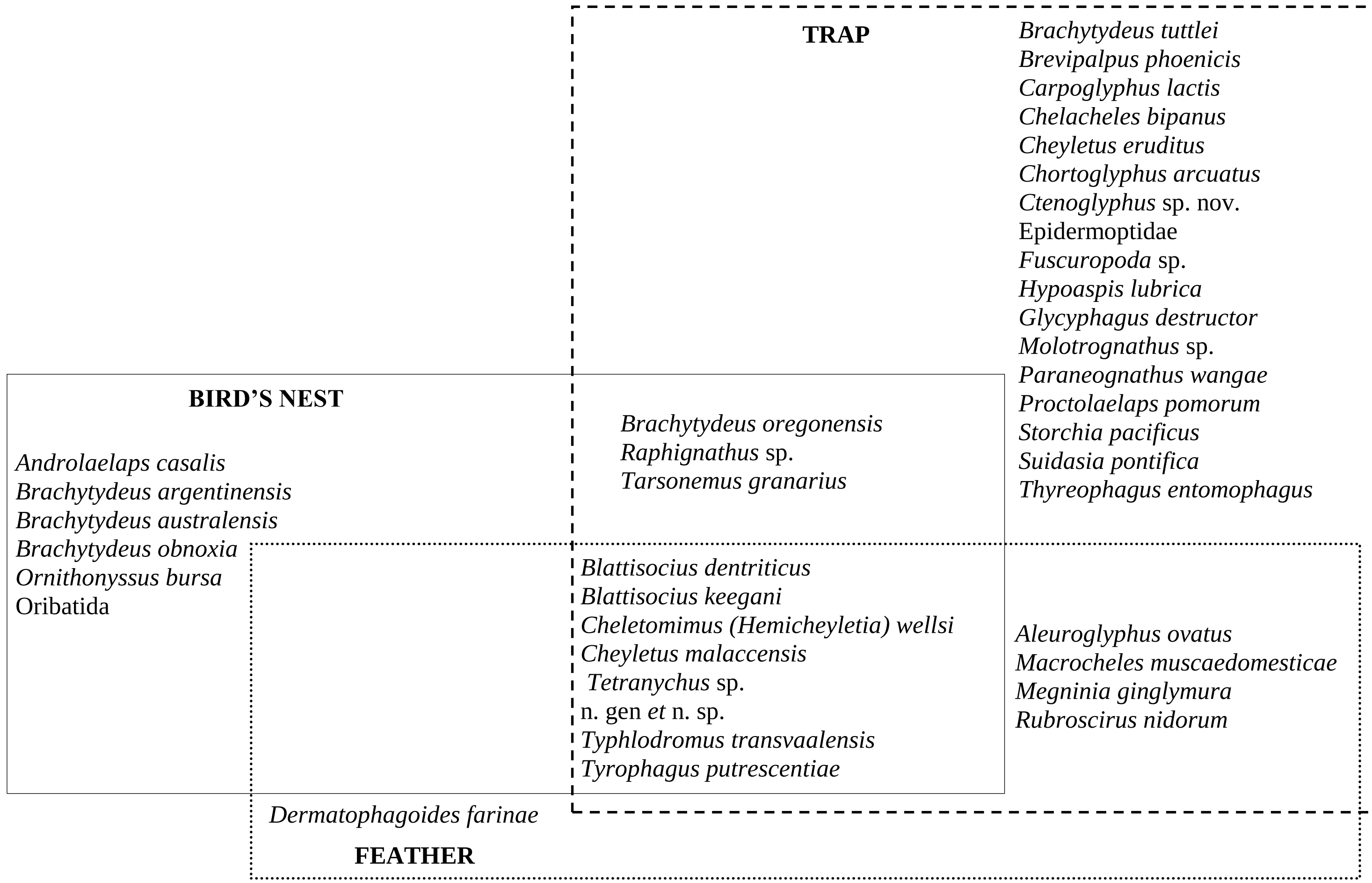
Legends to figure:

FIGURE 1: Mites found in bird’s nests, feathers and traps between August 2013 to August 2014, in Lajeado County, Rio Grande do Sul, Brazil.


TRAP
Brachytydeus tuttlei
Brevipalpus phoenicis
Carpoglyphus lactis
Chelacheles bipanus
Cheyletus eruditus
Chortoglyphus arcuatus
Ctenoglyphus sp. nov.
Epidermoptidae
Fuscuropoda sp.
Hypoaspis lubrica
Glycyphagus destructor
Molotrognathus sp.
Paraneognathus wangae
Proctolaelaps pomorum
Storchia pacificus
Suidasia pontifica
Thyreophagus entomophagus
BIRD'S NEST
Androlaelaps casalis
Brachytydeus argentinensis
Brachytydeus australensis
Brachytydeus obnoxia
Ornithonyssus bursa
Oribatida
Brachytydeus oregonensis
Raphignathus sp.
Tarsonemus granarius
Blattisocius dentriticus
Blattisocius keegani
Cheletomimus (Hemicheyletia) wellsi
Cheyletus malaccensis
Tetranychus sp.
n. gen et n. sp.
Typhlodromus transvaalensis
Tyrophagus putrescentiae
Aleuroglyphus ovatus
Macrocheles muscaedomesticae
Megninia ginglymura
Rubroscirus nidorum
Dermatophagoides farinae
FEATHER

ARTIGO 2

Horn, T.B., Ferla, J.J., Körbes, J.H., Granich, J., Klimov, P., Ferla, N.J. **n. gen. *et* n. sp.** (Acari: Pyroglyphidae), a new genus and species of mites associated with commercial laying hen from Brazil. Submetido ao periódico "Zootaxa".

n. gen. *et* n. sp. (Acari: Pyroglyphidae), a new genus and species of mites associated with commercial laying hen from Brazil

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Abstract

n. gen. *et* n. sp. (Pyroglyphidae) is described morphologically based on females and males from Brazil. The new species primarily occurs in the litter of commercially reared laying hen, both in confined systems as well free range birds. It also was also found in nests of wild birds.

Key words: Taxonomy, poultry industry, *Gallus gallus*

Introduction

Pyroglyphid house dust mites include free-living species that are most known as human associates living in dust, upholstery, pillow and matrass stuffing, and causing allergies. Some species have economical importance as pests in stored food in warehouses and residential homes (Fain 1988; Vargas & Smiley 1994). Numerous species live in bird nests, and a few can be found in nests of rodents (Hughes 1976). The early-derivative subfamily Onychalginae includes permanent (full-time) parasites of birds (Bochkov *et al.* 2014; Klimov *et al.* 2016), while other pyroglyphids, notably of the genus *Dermatophagoides* Bogdanov, 1864, can be found dispersing on the birds' plumage (Klimov & OConnor 2013). Phylogenetically pyroglyphids originated within the core of Psoroptidia (bird and mammal mites) and secondarily abandoned the parasitic life style, breaking Dollos' law (Klimov & OConnor 2013). Pyroglyphids can be distinguished from many (but not all) psoroptidian mites by an apparently specialized character, the migration of solenidion *ω1* toward to tarsal apical region, being located very near solenidion and *ω3* near the tarsal apex. This character state also occurs in other families of Psoroptida; Paralgopsidae, Ptyssalgidae, some Psoroptoididae (bird mites), and Psoroptidae (mammal mites). The small number of derived character states makes it difficult to diagnose genera (Gaud & Atyeo 1996), and molecular evidence strongly suggests that the central pyroglyphid genus, *Dermatophagoides* is paraphyletic and needs to be re-defined (Klimov *et al.* 2016). Substantial taxonomic confusion exists in recognizing pyroglyphid subfamilies (reviewed Klimov *et al.* 2016). As an example, *Asiopyroglyphus* Fain & Atyeo 1990 had been placed in the subfamily Dermatophagoidinae (Fain & Atyeo 1990; Gaud & Atyeo 1996), despite the presence of a tegmen, a structure characteristic to another subfamily, Pyroglyphinae (Fain 1988).

We collected another species showing the presence of a small tegmen, but otherwise having diagnostic characters of Dermatophagoidinae. This species was associated with commercially laying hen in the southern Brazil. Here we describe the species based on females and males and propose a new genus.

Materials and methods

The material described here was collected from commercially laying hens in the State of Rio Grande do Sul, Brazil. The mites were collected from confined systems and free range laying hen with traps of PVC pipe (Tucci *et al.* 1989). To provide shelter, three lightly crushed paper towel sheets were placed inside the traps. We did not use any attracting chemicals. Egg-laying hen feathers (*Gallus gallus* L.) of the Bovans and Isa Brown breeds were sampled. The new species was also found in birds' nests of *Columbina picui* (Temminck), *C. talpacoti* (Temminck) and *Zenaida auriculata* (Des Murs) (Columbidae) built in the lateral roof side of the hen house.

All mite specimens were mounted on slides in Hoyer's medium according to the standard technique for small mites (Krantz & Walter 2009). General morphological terms, the leg chaetotaxy follow Gaud & Atyeo (1996) and Griffiths *et al.* (1990); idiosomal chaetotaxy also follows those references with the corrections proposed by Norton (1998). All measurements are in micrometers (µm), followed, in parentheses, by the minimum and the maximum.

Systematics

Family Pyroglyphidae Cunliffe 1958

Subfamily Dermatophagoidinae Fain 1963

n. gen.

Type species ***n. gen.*** *et* ***n. sp.***

Diagnosis. n. gen. ***et*** **n. sp.** differs from other genera of the subfamilies Dermatophagoidinae and Pyroglyphinae by the presence of long setae *si* (♀−47 (38−55), ♂ − 42 (33−50), which are distinctly than setae *se* (Fig. 1A−B).

FEMALE: Bursa opening in the median line, a little behind the anal slit. The internal orifice of the bursa is difficult to see and the external part of the bursa is straight, with the external rounded and sclerotized.

HETEROMORPHIC MALE: Legs III slightly longer than legs IV.

Remarks. n. gen. described here belongs to subfamily Dermatophagoidinae by the absence of the tegmen (tectum) covering part of the gnathosoma, the tegument has uniform and regular striation of the cuticle, setae *h2* e *h3* are long; many other idiosomal setae are much longer in comparison to these of other pyroglyphids. In Pyroglyphinae, the cuticle is more heavily sclerotized and irregularly striated, a two or three-pointed tegmen is present (Spieksma 1973). The new species differs from all other genera: setae *si* are distinctly longer than setae *se*. In the genus *Malayoglyphus* and many pyroglyphine genera, setae *se* and *si* short and subequal in length. Most other dermatophagine genera have setae *si* very short and *se* long. The epigynum is ∩-shaped and well sclerotised is similar to the genera *Dermatophagoides* sp.. In *Malayoglyphus* sp. the epigynum is short, transverse, poorly sclerotised.

Etymology. This name of the new genus is a composite of "____" as a tribute to the Brazilian researcher Dra. "____" (Instituto Biológico, State of São Paulo, Brazil) and *glyphus* (from the Greek verb γλύφω - to carve, cut out with a knife, engrave), which is commonly used to form compound names for Astigmata.

n. gen. et n. sp.

(Figs. 1−4)

Diagnosis. Females and males differ from other genera of Dermatophagoidinae and Pyroglyphinae by characters above.

Description. FEMALE (Figs. 1−3). (Based on holotype and 11 paratypes). *Dorsum* (Fig. 1A): Length of the idiosoma 250 (228−273), width of idiosoma 339 (315−360). Length of propodosomal shield 60 (48−78), width of propodosomal shield 94 (78−113), Setal lengths: *se* 25 (18−33) nearly twice as long as *si* 47 (38−55) and setae *se* separated to *si* by 20 (15−28), *c1* 55 (50−65), *c2* 45 (38−55), *d1* 54 (35−78), *d2* 46 (40−50), *e1* 52 (45−58), *e2* 48 (40−58), *f2* 19 (15−23) and *cp* 28 (25−30).

Venter (Fig. 1B): Ventral surface with four pairs of coxal setae: *1a* 23 (15−30), *3a* 14 (10−18), *4a* 26 (13−33) and *3b* 27 (20−38).

Genital region between legs III. Genital apodemes developed. Setae *g* 14 (10−18). Copulatory opening length 14 (7−21) and width 1 (1−1). Anal region with one pair of anal setae *ps3* 11 (8−13). Setal length: *c3* 14 (10−20), *h2* 214 (180−240), *h3* 13 (10−20), *ps1* 14 (8−18) and *ps2* 93 (108−125).

Gnathosoma (Fig. 2A−B): Chelicera chelate 23 (16−25), fixed digit 15 (10−23) with 3 or 4 teeth; movable digit with 3 or 4 teeth. Subcapitular setae (*subc*) 15 (10−18).

Legs (Fig. 3A−F): leg I 134 (120−150) long (Fig. 3A−B); tarsus I 30 (25−35). Lengths of solenidia: tarsus I: *ω3* 52 (25−78); tibia I: ϕ1 77 (68−88); genu I: σ" 10 (5−13), σ' 9 (9−9). Leg II 135 (125−143) long (Fig. 3C−D); tarsus II 39 (25−48). Lengths of solenidia: tibia II: *ω1* 22 (15−36); tibia II ϕ 97 (88−113); genu II σ 8 (6−10). Legs III and IV slender. Leg III 129 (122−143) long (Fig. 3E); tarsus III 37 (30−45). Lengths of solenidia: tibia III ϕ 73 (60−83); genu III σ 7 (4−9). Leg IV 132 (120−143) long (Fig. 3F); tarsus IV 41 (30−48). Lengths of solenidia: tibia IV ϕ 11 (9−17).

MALE (Fig. 4) (Based on 12 paratypes). *Dorsum*. Length of the idiosoma 241 (225−263), width of idiosoma 185 (170−208). Length of propodosomal shield 62 (50−75), width of propodosomal shield 82 (63−100). Propodosomal shield as in female. Setae *se* 31 (23−40), *si* 42 (33−50). Setae *se* separated to *si* by 16 (10−30). Setae *c1* 44 (30−53), *c2* 44 (33−50), *d1* 43 (35−55), *d2* 44 (33−53), *e1* 44 (38−53), *e2* 43 (33−55), *f2* 17 (10−20) and *cp* 30 (15−38).

Venter (Fig. 4): Genital region between legs III and IV. Sclerotized ring around anus 42 (30−50) long and 28 (20−38) wide. Anal region with one pair of anal setae *ps3* 10 (8−13). Adanal suckers present. Setal length: *c3* 18 (15−23), *cp* 30 (15−38), *h2* 190 (150−228) and *h3* 15 (8−23), *ps1* 13 (10−18), *ps2* 96 (80−113). Ventral surface with four pairs of coxal setae: *1a* 23 (18−30), *3a* 22 (10−33), *4a* 8 (5−13) and *3b* 15 (10−33).

Gnathosoma: Chelicera chelate 23 (15−28), fixed digit 14 (13−18) with 3 or 4 teeth; movable digit with 3 or 4 teeth. Subcapitular setae (*subc*) 15 (10−20) long.

Legs (Fig. 4): Leg I more robust than others legs (Fig. 4A−B). Femur I with stout spine. Leg I 159 (128−188) long; tarsus I 30 (28−35). Lengths of solenidia: *ω1* 22 (20−25), *ω3* 24 (20−30); tibia I ϕ 71 (63−85); genu I σ1 16 (10−23); σ2 9 (6−13). Leg II 135 (123−143) long (Fig. 4C); tarsus II 33 (25−43). Lengths of solenidia: *ω1* 8 (5−15); tibia II ϕ 84 (73−100); genu II σ 8 (5−10). Leg III longer than leg IV. Leg III 125 (120−128) (Fig. 4D); tarsus III 25 (20−28). Lengths of solenidia: tibia III ϕ 62 (45−70); genu III 9 (8−10) (Fig. 4D). Leg IV 97 (93−100); tarsus IV 24 (18−30). Lengths of solenidia: tibia IV ϕ 31 (28−35) (Fig. 4E).

Type material. The material was collected in traps and in feathers of commercial egg laying hen (Bovans and Isa Brown breeds). Also found in nests of *C. picui*, *C. talpacoti* and *Z. auriculata*. Holotype female and 11 female paratypes females; holotype male and 11 male paratypes. **BRAZIL:** Lajeado County (29º 41’ 87” S; 52º 01’ 35” W), state of Rio Grande do Sul, collected between September 2013 to July 2014.

Type deposition. Holotype female (ZAUMCN 1201), collected in traps in semi-automated laying hen system in 13 May 2016, coll. T.B. Horn and 1 paratype male (ZAUMCN 1202), collected in traps in automated system of laying hen in 17 October 2013, coll. M. Senter, both were registered in Lajeado municipality and were deposited at the Museu de Ciências Naturais (MCN), Centro Universitário Univates, Lajeado, Rio Grande do Sul, Brazil. Paratypes: 11 male and 11 female (2 ♀and 1 ♂ were deposited in the University of Michigan Museum of Zoology; 1 ♀and 1 ♂ were deposited to Universidade de São Paulo).

Etymology. The specific epithet "____" indicates the morphological characteristic of long dorsal setae in especially the setae *si*.

Acknowledgement

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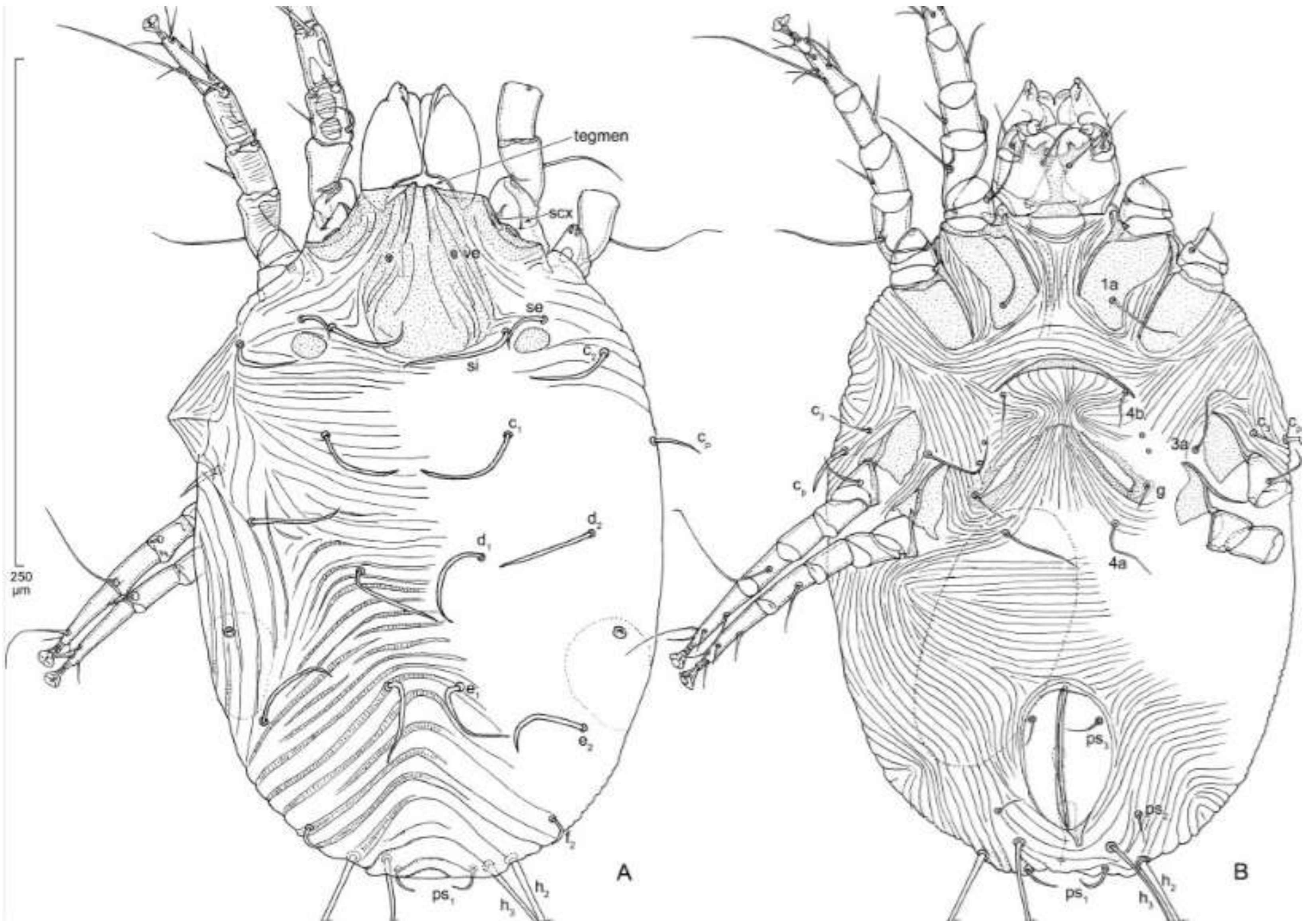
Legends to illustrations

FIGURE 1. n. gen. *et* n. sp. FEMALE. A. Dorsal view of idiosoma; B. Ventral view of idiosoma.

FIGURE 2. n. gen. *et* n. sp. FEMALE. A. Gnathosoma ventral view. B. Gnathosoma dorsal view. C. Chelicera. D. Genital region.

FIGURE 3. n. gen. *et* n. sp. FEMALE. A. Leg I. B. Tarsus I. C. Leg II. D. Tarsus II. E. Leg III. F. Leg IV.

FIGURE 4. n. gen. *et* n. sp. MALE. A. Tarsus and tibia of leg I: ventral view. B. Tarsus I: dorsal view. C. Tarsus and tibia of leg II. D. Tarsus and tiia of leg III. E. Tarsus and tibia of leg IV. F. Anal region.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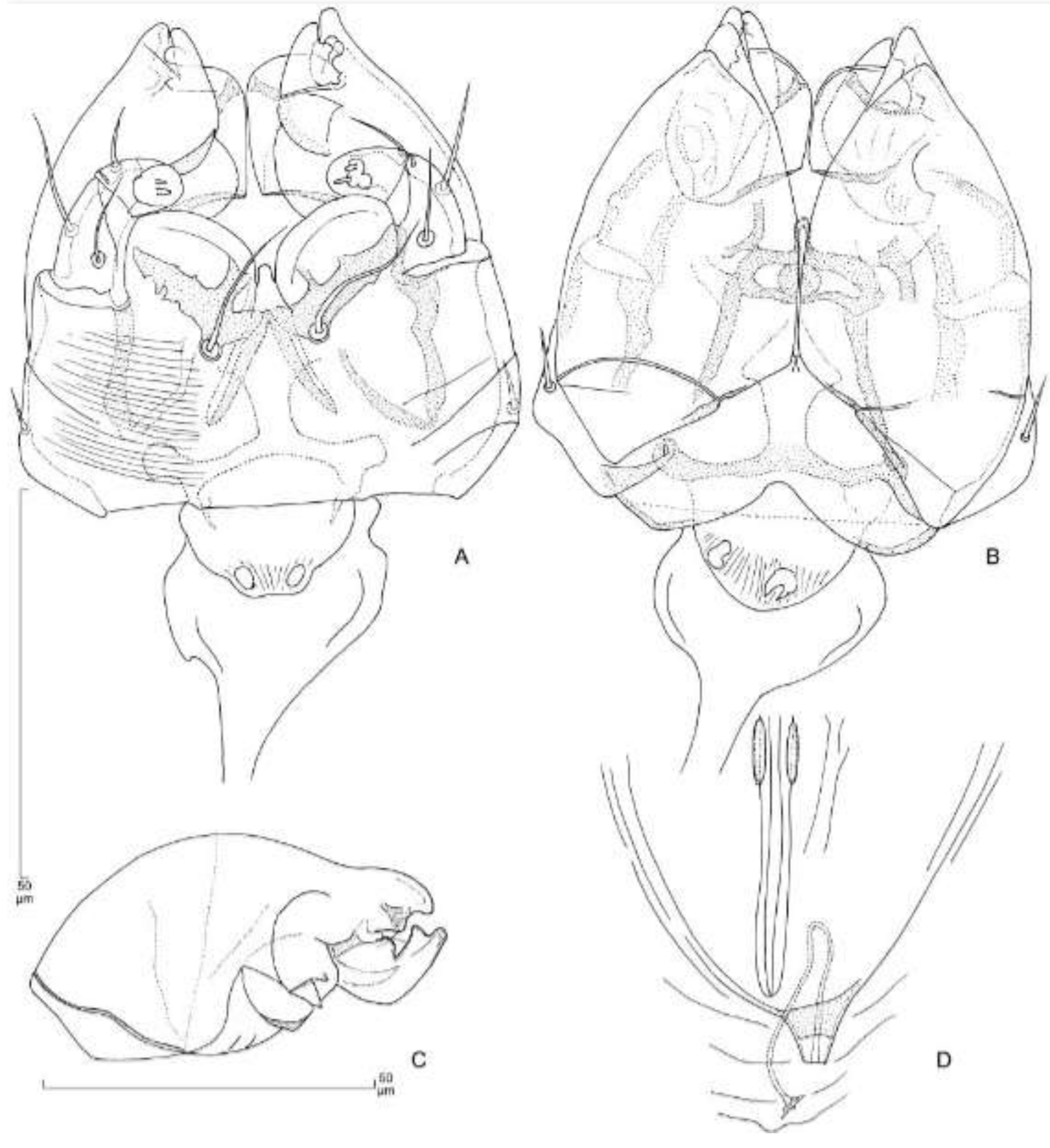
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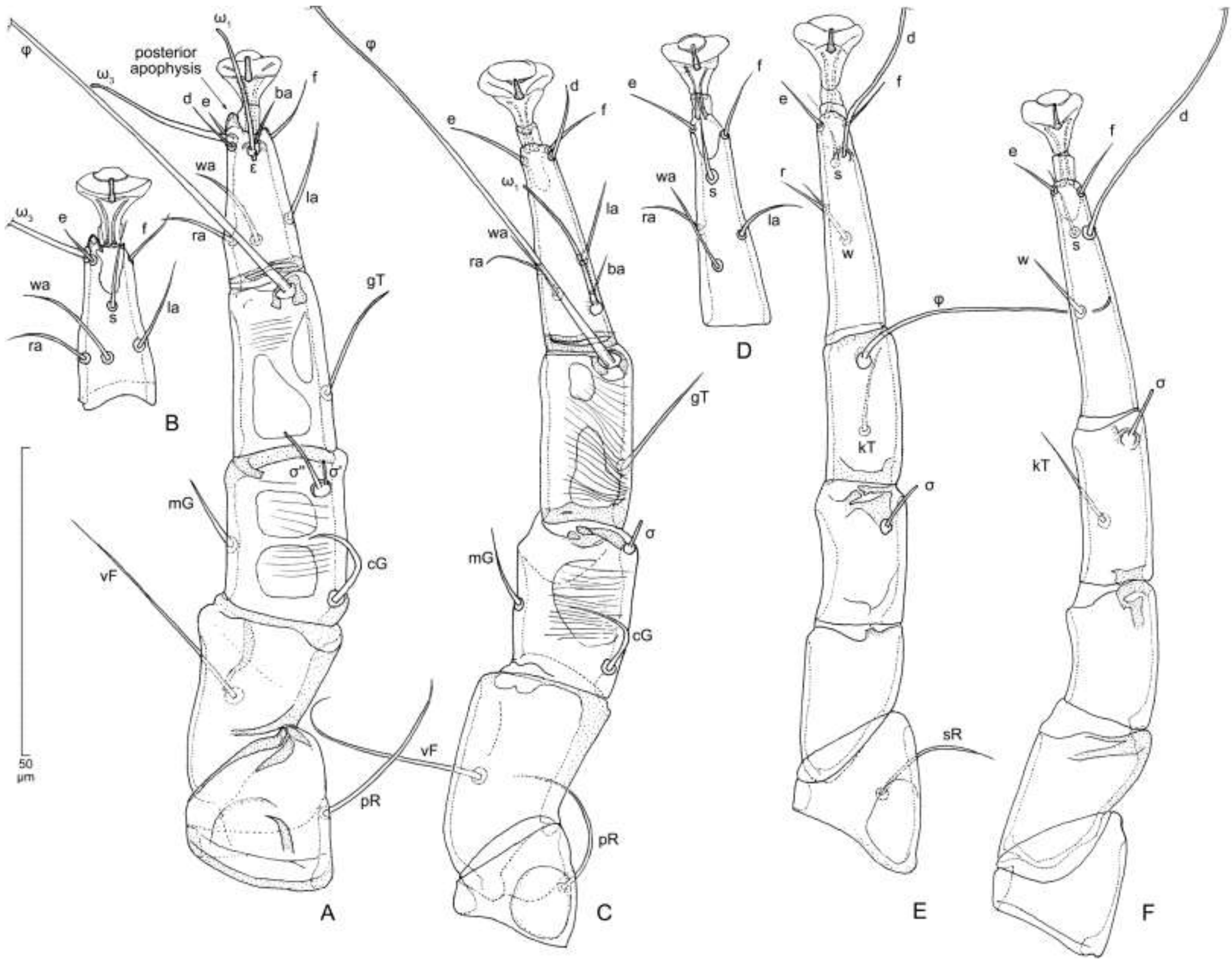
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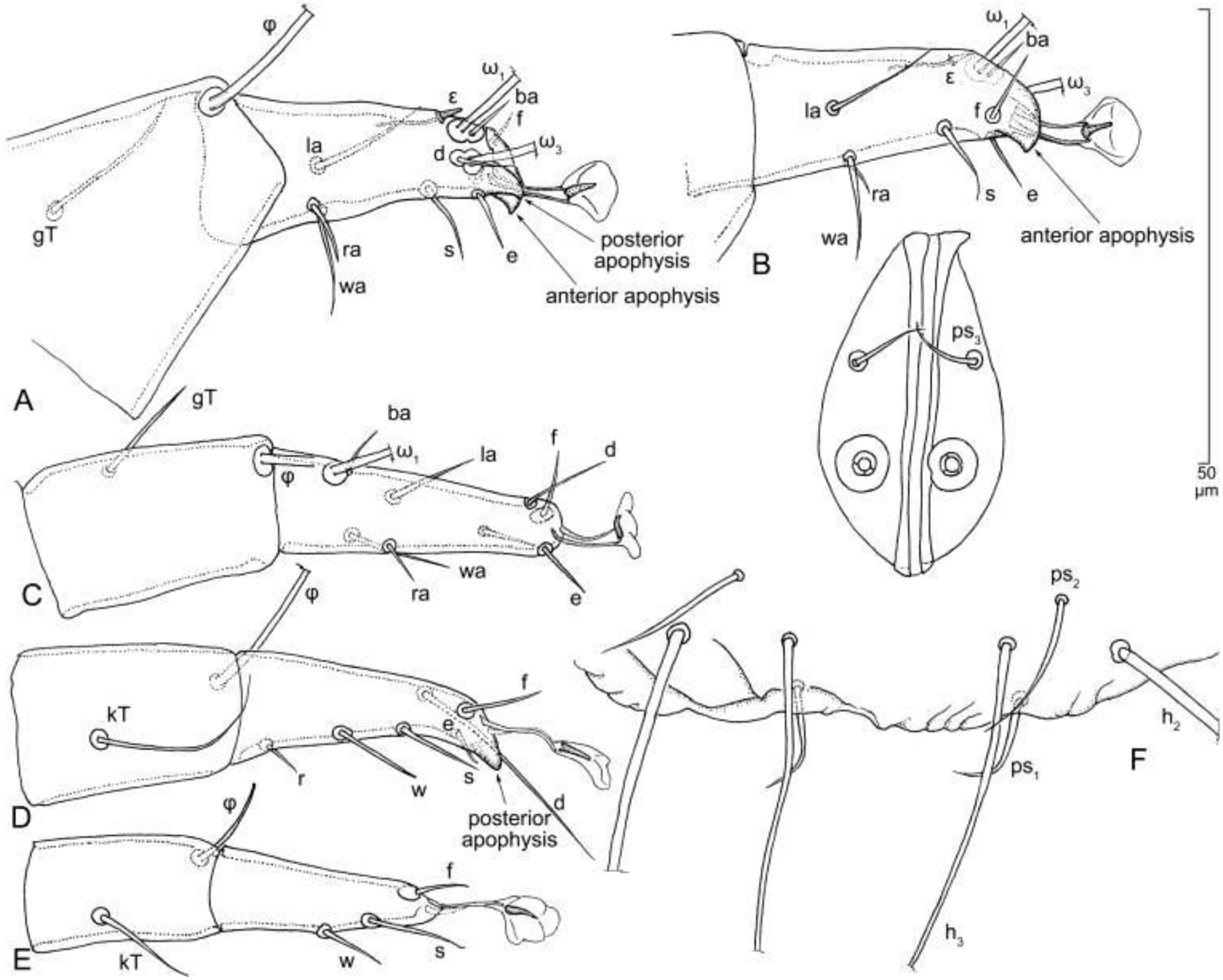
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ARTIGO 3

Horn, T.B., Körbes, J.H., Granich, J., Senter, M., Ferla, N.J. 2016. Influence of laying hen systems on the mite fauna (Acari) community of commercial poultry farms in southern Brazil. Parasitology Research 115:355–366. doi 10.1007/s00436-015-4756-9

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ORIGINAL PAPER

Influence of laying hen systems on the mite fauna (Acari) community of commercial poultry farms in southern Brazil

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Abstract Intensive production of confined laying hens affects their welfare and increases the risk of epidemics. Ectoparasites as hematophagous and feather mites cause low productivity and decreased egg quality. This study aimed to determine the diversity of mites captured with traps in different commercial systems of laying hens (*Gallus gallus* L.) (Phasianidae) in Taquari Valley, Rio Grande do Sul, Brazil. Samplings were conducted from August 2013 to August 2014, totaling 21 sampling events in three different commercial laying hen systems: automatic production systems ($A_{1,\ 2,\ 3}$), semiautomatic systems ($S_{1,\ 2}$), and free-range system (FR). A total of 9981 mites belonging to 21 families, 31 genera, and 35 species were found. Acaridae, Caligonellidae, and Cheyletidae showed the highest richness with four species each. *Megninia ginglymura* (Mégnin, 1877) (Analgidae) was the most abundant ectoparasite species with 1328 specimens and was present in all commercial laying hen systems. No hematophagous mites were found. *Cheyletus malaccensis* (Cheyletidae) (3503), *Typhlodromus transvaalensis* (Phytoseiidae) (304), and *Blattisocius keegani* (Blattisocidae) (181) were the predators present in all systems. The similarity with control system (S_1—without pesticide) was low (36.5 %) when compared to all other commercial laying hen systems, and it had the highest richness. In FR, low populations of mites and highest diversity were observed. The commercial laying hen system and the management influence the mite fauna in poultry farms.

Keywords *Cheyletus malaccensis* · *Megninia ginglymura* · Aviculture · Ectoparasite · Potential biology predators

Introduction

Intensive production of laying hens affects their welfare, increases the risk of epidemics and can be affected by various complications, such us ectoparasites (Berchieri et al. 2009). The proliferation of ectoparasites, especially hematophagous and feather mites can lead to a decrease in egg production, fragility of the eggshell, laying hens becoming anemic, and restless and aggressive towards each other (Sparagano 2009).

In Brazil, three species of hematophagous mites are known to be associated with laying hens: *Ornithonyssus bursa* *Ornithonyssus sylviarum* (Macronyssidae), and *Dermanyssus gallinae* (Dermanyssidae) (Tucci 2004). *O. bursa* (tropical fowl mite) is a parasite of domestic and wild birds (Mascarenhas et al. 2009), but in poultry industry, it seems to have been replaced by *O. sylviarum* over time in Brazilian poultry industry and bit currently being reported (Soares et al. 2008). *O. sylviarum* (northern fowl mite) 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 2004; Soares et al. 2008). It infests laying hens in confinement, pigeons, and wild animals (Guimarães and Leffer 2009). *D. gallinae* (poultry red mite) is a sanitation and economic problem in commercial laying hens, where it is one of the most important pest mites of this production system in Brazil. The skin lesions caused during the blood feeding can be identified in breast and legs of hens (Tucci and Guimarães 1998). This cosmopolitan species is found in laying hen farms, where it causes stress, injury due to bites, anemia, and decreased egg production, and it can also

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be a vector of pathogenic microorganisms (Back 2004; Guimarães and Leffer 2009). In the state of Rio Grande do Sul, Oliveira (1972) recorded attacking on hens. Silva et al. (2013) evaluated commercial poultry houses and abandoned nests of wild birds and found that this species was the most abundant in the municipalities of Lajeado and Teutônia, Taquari Valley, state of Rio Grande do Sul.

Feather mites cause allergic reaction with pruritus (Tucci et al. 2005), causing secondary bacterial infections, which may lead to lower production. *Megninia ginglymura* (Analgidae) attacks the feathers on the back, chest, and parson's nose leaving them gnawed, with barbules cutted or rare, red and swollen follicles, and the feather cannon coated of debris at the point where the stem feather begins (Reis and Nóbrega 1956). Reis (1939) reported the occurrence of *Megninia cubitalis* (Mégnin, 1877) (Analgidae) and *M. ginglymura* for the first time in Brazil. With the use of cardboard traps in laying hen houses, Silva et al. (2013) observed that *M. ginglymura* was associated with nests and laying hen feathers in the Teutônia municipality, Taquari Valley, State of Rio Grande do Sul.

Allopsoroptoides galli (Mironov, 2013) (Psoroptoididae) was described parasitizing laying hens in Brazil, causing dermatitis and severe losses in egg production (Mironov 2013; Hernandes et al. 2014). Currently, studies on population dynamics and efficient techniques for the control of hematophagous and feather mites are scarce in Brazil. Biological control using *Strongylopsalis mathurinii* (Dermaptera: Labiidae) was successful in controlling *D. gallinae* in the poultry industry in the state of São Paulo (Guimarães et al. 1992). Toldi et al. (2014) studied the biology of *Cheyletus malaccensis* (Cheyletidae) feeding on *D. gallinae* under laboratory conditions. This predatory mite showed no preference for any phase of prey, feeding on all the stages, and was considered by these authors a potential natural enemy of *D. gallinae*.

Due to the importance of egg production to the economy of the state of Rio Grande do Sul and Brazil, it is necessary to learn about the associated mites, their frequency, and the damages they cause. In this context, there is also a need to improve certain methods of ectoparasite control in the production system of the poultry industry, because the market is demanding new processes and methodologies that focus on product quality, environmental impact, worker health, and rural animal welfare. This study investigated the diversity of mites associated with different production systems of commercial laying hens captured with traps.

Materials and methods

Experimental laying hen houses

This study was conducted in different commercial laying hen systems between August 2013 and August 2014 in Lajeado municipality, Taquari Valley, state of Rio Grande do Sul, Brazil.

Six poultry houses were sampled, where in three of them, the laying hen system consisted of an automated or semiautomated vertical battery cages. In automated systems ($A_{1,\,2,\,3}$), the laying hens were confined in metal cages on six floors with an area of approximately 450 cm^2/hen (nine hens/cage), and the cages were placed one top of the other in stacks of four. Hen feed was provided in a metal structure and water in nipple-type drinker, and eggs were collected on an automatic treadmill. In addition, feces were collected at least three times per week by treadmills at the bottom of the floor of cages. In this laying hen system, there are screens throughout the laying hen house to prevent wild bird access. However, bird nests were found in the lateral roof side, and the species identified were *Columbina picui*, *C. talpacoti* (Columbidae), *Turdus* sp. (Turdidae), and *Zenaida auriculata* (Columbidae).

Among the A_1 laying hens, 39,000 white laying hens of the Bovans breeds were maintained and two batches were evaluated: the first, 45 weeks old at the beginning of sampling and 94 weeks old in July 2014, when it was replaced by a new batch at 16 weeks old and evaluated up to 20 weeks old in August 2014, giving a total of 20 samples. In A_2, there were 60,000 laying hens, 50 % Bovans breed and 50 % Isa Brown breed. The batch was 68 weeks old at the beginning of sampling and 98 weeks old in March 2014. A new batch was introduced in April 2014 at 17 weeks old and evaluated up to 37 weeks old in August 2014, resulting in 18 samples. In A_1 and A_2, Topline® (fipronil 1 %) was added to the feed in September 2013 and it was routine maintenance targeting parasites. In A_3, there were 35,000 red Isa Brown laying hens, evaluation begging with a batch of 99 weeks old evaluated up to 109 weeks old in October 2013. A new batch of 19 weeks old was introduced in December 2014 and evaluated up to 54 weeks old in August 2014, giving a total of 16 samples. In this system, Couro Limpo® (15 % cypermethrin, 25 % chlorpyrifos, and 1 % citronellal) was applied twice in April 2014.

In the semiautomated laying hen system ($S_{1,\ 2}$), the cages were arranged in the form of stair steps with two stacks of cages in each poultry house. Feed and water were provided in an automated manner and eggs collected manually. The S_1 system was a wood structure in the style of a "California house," and S_2 was a "wide-span model" (Axtell 1986). S_1 did not receive any type of pesticide application during the evaluation period and was considered the semiautomated control. S_1 housed 7750 red DeKalb laying hens, with 45 weeks old at the beginning of sampling and 88 weeks old in July 2014 when the batch was removed, totaling 18 samples. S_2 housed 10,400 red Isa Brown laying hens, 41 weeks old at the beginning of sampling and 95 weeks old in August 2014, totaling 21 samples. This system received

Topline® in the feed in September 2013 and May 2014. S_1 and S_2 allowed the entry of wild birds.

The other laying hen house evaluated was raised free under a sawdust bed arranged overground, popularly known as free range (FR). In Brazil, this system is popularly known as “caipira”. In FR, 3500 red Isa Brown laying hens were housed, they were 44 weeks old and evaluated up to 88 weeks old in July 2014, when they were removed, totaling 19 samples. Feed and water were provided in an automated way and egg collecting was manual. The nests were packed in a wooden structure with sawdust inside for maintenance of eggs. The laying hens were released in the day to sunbathe, if pecking and flapping. The nests were treated with Bolfo® (propoxur 1 %) powder in December 2013 and January and April 2014. Cars’ access from other hen houses has been denied throughout the study.

Mite samplings

To collect the mites, we placed 16 traps of 27-cm PVC pipe (50 mm diameter) with 13 holes of 0.8 mm with the ends closed with caps (PVC cap) in each laying hen house (Tucci, Bruno and Tucci et al. 1988) (Fig. 1). Three lightly crushed paper towel sheets were placed inside the traps, to provide shelter. Attracting substances were not used.

In each laying hen house, we placed 16 traps attached to the cage with a rubber band distributed evenly along the length. Throughout the evaluation period, the traps were maintained at the same point, where they were replaced every 15 days. In A_1, A_2, A_3, S_1, and S_2, the traps were arranged on the second floor of the cages, while in FR, they were placed on perches and inside the nests. At each evaluation, the paper towel was collected, packed individually in plastic bags, labeled, and taken to the laboratory, where it was kept in a freezer (0 °C) for at least 24 h.

For each evaluation, the collected paper towel was placed on Petri plates and observed under a stereomicroscope. 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, extension of legs, and diaphanization of specimens.

Identifications

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

Data analyses

The data analyzed concerned the mites found in the laying hen houses evaluated sampled in traps. Several indices were determined using the software DiVes 2.0 (Rodrigues 2005):

i) Shannon-Wiener index ($H' = -\sum pi \ Log \ pi$, where pi is the proportion of specimens of each species in relation to the total number of specimens found in the assessment performed) expresses richness and uniformity, giving more weight to the rare species (Shannon 1948).

ii) Shannon’s evenness index ($J = H'/Hmax'$, where H' is the Shannon-Wiener index and $Hmax'$ is given by the following expression: $Hmax' = Log \ s$, where s is the number of species sampled) expresses the equitability of abundances in a community and allows the assessment of species stability over time (Brower and Zar 1984).

iii) Berger-Parker dominance (*BPd*) considers the highest proportion of species with the highest number of individuals. *BPd* is determined by the formula $d = Nmax/N_T$, where *Nmax* is the number of specimens from the most abundant species and N_T is the total number of specimens from the sampling (Berger and Parker 1970).

Fig. 1 Mite traps. **a** Trap with paper towel. **b** Trap installed in the cage

Kruskal-Wallis analysis of variance using Bioestat 5.0 software was used to see if there was a significant difference between the Shannon diversity indices of different laying hen systems applied (Ayres et al. 2007).

Species constancy (*C*) was classified as constant when present in more than 50 % of the samples (C>50 %), accessory when present in 25–50 % of the samples (25 %<C< 50 %), and accidental when present in less than 25 % of the samples (C<25 %) (Bodenheimer 1955). Dominance (*D*) was defined by the formula $D\%=(i/t)\times100$, where i=total number of individuals of a species and t=total individuals collected and clustered according to the following categories: eudominant (≥10 %), dominant (5≤10 %), subdominant (2≤ 5 %), eventual (1≤2 %), and rare (D<1 %) (Friebe 1983).

The general similarity between these laying hen environments according to mite families with larger number of species was analyzed by Bray-Curtis clustering analysis, using BioDiversity Professional software (McAleece et al. 1997). Bray-Curtis is a multifactorial analysis technique that uses a similarly matrix to build a tree, in which each branch represents a sample. Samples that share similarities are located on a branch close to each other.

Results

A total of 9981 mites were collected from traps in the different laying hen environments. They belonged to 21 families, 31 genera, and 35 species (Table 1).

The highest richness was observed in S_1 with 23 species, followed by S_2 and FR, with 19 species each. A_2, A_3, and A_1 had low richness, with 13, 12, and 11 species, respectively. The highest abundance was observed in A_2 (2550) and similar in S_2 (1881), A_1 (1644), S_1 (1520), A_3 (1293), and FR (1093). The richest families were Acaridae, Caligonellidae, and Cheyletidae, with four species each, and the most abundant were Cheyletidae (3734), Pyroglyphidae (3263), and Analgidae (1328).

Seven species were common to all six laying hen houses evaluated: *Blattisocius dentriticus* (Blattisocidae), *Brachytydeus oregonensis*, *Brachytydeus tuttlei* (Tydeidae), *C. malaccensis*, *M. ginglymura*, *Pyroglyphus* sp., and *Typhlodromus transvaalensis* (Phytoseiidae). No hematophagous mites were observed.

Morphological characteristics of most important species

The main morphological characteristics that differs each species of sanitary importance and potential predator are given.

B. dentriticus

Female and male with 36 pairs of dorsal setae with one long pair arising from the posterior end of the dorsal shield, these setae are smooth and curved. The peritrematal plate is extended posteriorly to touch the exopodal encircling the posterior edge of coxa IV. A long macroseta arises from the base of tarsus IV (Hughes 1976) (Fig. 2).

Blattisocius keegani

Females: dorsal shield reticulate, with 33 pairs of setae (including *s2*). Genital shield with longitudinal striae, truncate. With two pairs of metapodal plates. The main differences between the two species are in the structure of the peritreme. In *B. keegani,* the peritreme is very short, reaching only the median level of coxa III. Fixed cheliceral digit much shorter than movable cheliceral digit, with three teeth in addition to apical tooth and setiform pilus dentilis; movable digit with one tooth in addition to apical tooth. Spermathecal calyx horn-like, variously constrict near vesicle, atrium globular. Males: dorsal shield and number of dorsal shield setae, insertion of *s2*, as in adult females. Sternogenital shield with scanty striae, with an indentation behind *st4*. Ventrianal shield approximately hemispherical, reticulate. Fixed cheliceral digit with two or three teeth in addition to apical tooth and setiform pilus dentilis; movable digit with one tooth in addition to apical tooth; spermatodactyl distally curved, with a membrane along dorsal surface, subterminal ventral spine-like projection, and concave apex. Spermatheca: calyx horn-like, variously constricted near vesicle; atrium globular (Britto et al. 2012) (Fig. 2).

C. malaccensis

Two palp claw bears unlike basal teeth, distal tooth a rounded cone, are longer than rectangular proximal tooth. Outer comb has 18 to 20 teeth and inner comb has 24 to 30 teeth. Dorsal seta of palp femur is very long (160 μm), flagelliform, and with few very fine barbs. Palp femur robust is completely striated, extending slightly beyond anterior most bend of peritreme. Peritremes are M-shaped. Femur IV with one seta. Tarsus I with solenidion ωI short (22 μm) tapered and pointed (Hughes 1970, Summer and Price 1970) (Fig. 2).

M. ginglymura

Females and males with epimers 1 not fused. Males with elongated opisthosoma lobes with pseudo-joint to the base of adanais setae inflated with “cleaver” shaped. Males with third pair of legs more developed than the others. Females with subsequent epigimio, the central end of the epimers I and between the ends of the epimers II. Epigimio in circumflex shape and C_3 setae longer than C_2 (Gaud et al. 1988) (Fig. 2).

T. transvaalensis

Dorsal shield reticulate. Setae j4, j5, j6, z2, and z5 plumose with blunt tip, J5-S5 smooth and the rest of setae plumose and knobbed. Peritreme extending near coxa I. Venter: sternal shield smooth, with two pairs of setae and posterior margin V-shaped, the third pair of setae on interscutal membrane, and the fourth pair of setae on oval metasternal shields. Venter anal shield pentagonal, with anterior margin slightly convex and lateral margins slightly concave between JV2-JV4, JV3 absent; 135 μm long (130–141 μm) and 79 μm (77–81 μm) wide at level of ZV2 with three pairs of preanal setae and gv2 pore. Three pairs of setae, and a plumose and knobbed

Table 1 Mite species collected in traps in six laying hen houses, between August 2013 and August 2014, in Taquari Valley, Rio Grande do Sul, Brazil

Suborder	Family	Genus/species	A_1			A_2			A_3			S_1			S_2			FR		
			Total	C	D	Total	C	D	Total	C	D	Total	C	D	Total	C	D	Total	C	D
Astigmata	Acaridae	*Aleuroglyphus* sp.				3	I	R				8	I	R				2	I	R
		Suidasia sp.										3	I	R						
		Thyreophagus entomophagus	46	I	U	1	I	R	1	I	R	2	I	R						
		Tyrophagus putrescentiae	8	I	R	6	I	R	36	A	U	6	I	R	6	I	R			
	Analgidae	*Megninia ginglymura*	86	O	M	81	O	U	51	O	U	660	O	E	181	O	M	269	O	E
	Carpoglyphidae	*Carpoglyphus* sp.	1	I	R															
	Chortoglyphidae	*Chortoglyphus arcuatus*													1	I	R	90	O	M
	Glycyphagidae	*Ctenoglyphus* sp.																15	I	V
		Lepidoglyphus destructor	1	I	R										1	I	R	120	A	E
	Pyroglyphidae	*Pyroglyphus* sp.	481	O	E	1273	O	E	377	O	E	184	O	E	932	O	E	16	A	V
Mesostigmata	Ascidae	*Proctolaelaps* sp.							1	I	R									
	Blattisocidae	*Blattisocius dentriticus*	8	I	R	7	A	R	9	A	R	55	A	U	11	I	R	2	I	R
		Blattisocius keegani	54	O	U	16	A	R	45	O	U	62	I	U	4	I	R			
	Laelapidae	*Hypoaspis lubrica*										1	I	R						
	Macrochelidae	*Macrocheles muscaedomesticae*																8	I	R
	Phytoseiidae	*Phytoseiulus macropilis*										1	I	R						
		Typhlodromus transvaalensis	89	O	M	11	A	R	133	O	E	5	A	R	65	O	U	1	I	R
	Uropodidae	*Fuscuropoda* sp.	1	I	R							2	I	R						
Prostigmata	Caligonellidae	Caligonellidae sp.1										1	I	R	1	I	R			
		Molotrognathus sp.																2	I	R
		Neognathus sp.										3	I	R	1	I	R	1	I	R
		Paraneognathus sp.										1	I	R						
	Cheyletidae	*Chelacheles bipanus*										5	A	R	1	I	R			
		Cheyletus eruditus																18	A	V
		Cheyletus malaccensis	768	O	E	1095	O	E	610	O	E	48	A	U	486	O	E	496	O	E
		Hemicheyletia wellsi										169	O	E	39	O	U			
	Cunaxidae	*Rubroscirus nidorum*													7	I	R	3	I	R
		Rubroscirus sp.										65	O	U	11	A	R	1	I	R
	Myobidae	–										3	I	R						
	Stigmaeidae	*Storchia pacificus*																1	I	R
	Tarsonemidae	*Tarsonemus* sp.							1	I	R									
	Tenuipalpidae	*Brevipalpus phoenicis*										1	I	R						
	Tetranychidae	*Tetranychus* sp.										1	I	R	1	I	R	2	I	R
	Tydeidae	*Brachytydeus oregonensis*	59	O	U	17	I	R	1	I	R	23	A	V	25	A	V	29	A	U
		Brachytydeus tuttlei	42	I	U	40	O	V	28	O	U	212	O	E	107	O	M	17	A	V
		Total specimens	1644			2550			1293			1520			1881			1093		
		Species richness	13			11			12			23			19			19		
		N	20			18			16			18			21			19		

JV5. Two pairs of metapodal shields. Spermatheca slightly sclerotized, calix horn like, atrium, duct minor and major difficult to see. Legs: on leg IV, three knobbed macrosetae on genu 26 μm (25–27 μm), tibia 33 μm, and tarsus 42 μm (41–42 μm) (Cédola and Castresana 2014) (Fig. 2).

Diversity indices

The highest diversity (H') was observed in FR (0.80) and S_2 (0.70), and less in A_2 (Table 2). A_1, A_3, and S_1 showed similar diversity (H=3.667; p=0.3).

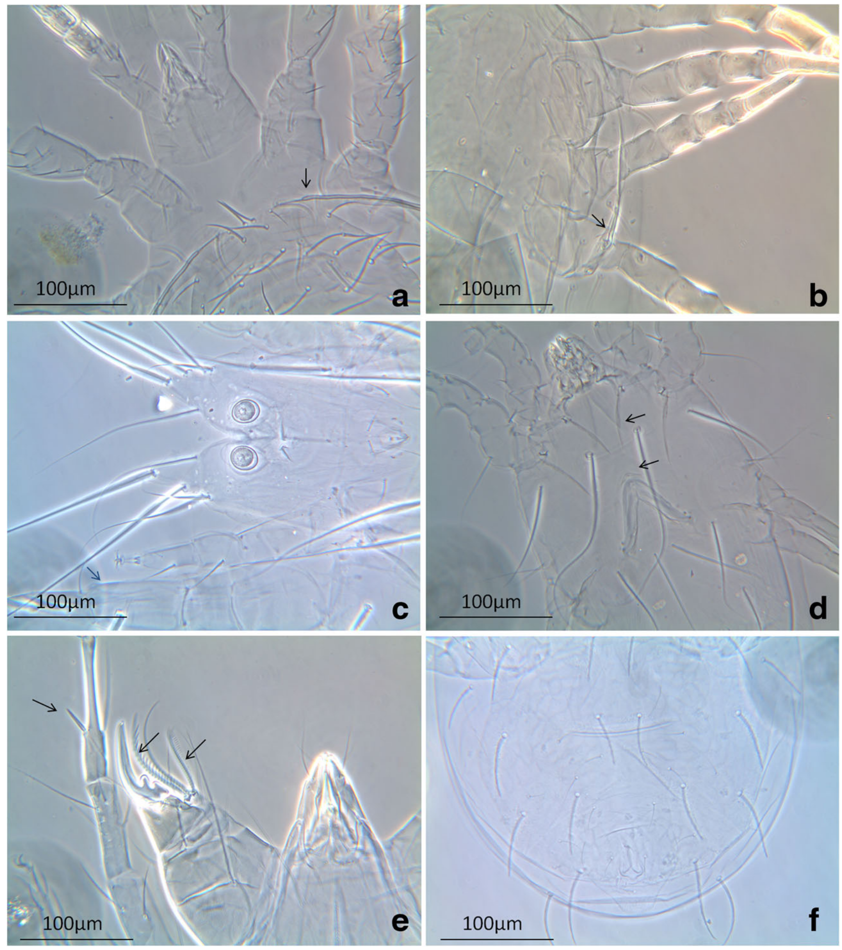

Fig. 2 Morphological characteristics of most important species. **a** Long peritreme in *B. dentriticus*. **b** Short peritreme in *B. keegani*. **c** Leg III in male of *M. ginglymura*. **d** Epimers non-fused in *M. ginglymura*. **e** Tarsus I with solenidion ωI in *C. malaccensis*. **f** Dorsal setae plumose and knobbed in *T. transvaalensis*

A_1 and FR showed higher rates of evenness (both *J*=0.59), with low dominance (*BPd*=0.06 and 0.05, respectively). The evenness index (*J*) was lower in A_2 where there was a low diversity and high dominance (*BPd*=0.14). S_1 showed the second lowest index (*J*=0.50) with high dominance and high abundance of *M. ginglymura* (Fig. 3). In A_3 and S_2, *J* was similar (*J*=0.57 and 0.55, respectively) and dominance was low (*BPd*=0.09 and 0.06, respectively).

Mite fauna community in different laying hen houses

When considering all the laying hen houses evaluated, the most abundant species were *C. malaccensis*, *Pyroglyphus* sp., and *M. ginglymura* (3503, 3263, and 1328 specimens, respectively) (Table 1). These species were found in all laying hen houses, but with different populations.

In automated systems, *C. malaccensis* was the most abundant species in A_1 (768) and A_3 (610) and was the second most abundant in A_2 (1.095), where *Pyroglyphus* sp. (1273) was more abundant (Fig. 3). *C. malaccensis* and *Pyroglyphus* sp. were constant and eudominant in all laying hen houses. However, *Pyroglyphus* sp. showed smaller populations in A_1 and A_3 (481 and 377, respectively). *M. ginglymura* showed low populations in automated systems and was considered constant in A_1 and subdominant in A_2 and A_3 (Table 1, Fig. 3).

Among the potential predator mites, *T. transvaalensis* was considered constant in A_1 (89) and A_3 (133) being dominant and eudominant, respectively; A_2 was considered accessory and rare and low population (11 specimens). *B. keegani* was considered constant and subdominant in A_1 (54) and A_3 (45), and accessory and rare in A_2 (16).

Among mites with unknown food habits, the tydeid *B. oregonensis* was considered constant and subdominant in A_1 (59) and accidental and rare in A_2 (17); only one specimen was observed in A_3. *B. tuttlei* was considered constant in A_2 and A_3, eventual and subdominant, respectively. Despite being present in all three automated systems, *Thyreophagus entomophagus* (Acaridae) showed higher population in A_1 which was considered accidental and subdominant.

In semiautomatic systems, the most abundant species in S_1 was *M. ginglymura* (660), representing 43.4 % of the collected mites and was considered constant and eudominant. In this system, *C. malaccensis* presented extremely low population (48) and is considered accessory and subdominant. *M. ginglymura*, *B. tuttlei* (212), *Pyroglyphus* sp. (184), and

Table 2 Ecological indices of mite communities found in traps from laying hen houses, between August 2013 and August 2014 in Lajeado municipality, Rio Grande do Sul, Brazil

Index	A_1	A_2	A_3	S_1	S_2	FR
Number of species	13	11	12	23	19	19
Number of specimens	1644	2550	1293	1520	1881	1093
Shannon diversity (*H'*)	0.6614	0.4407	0.6217	0.6413	0.7057	0.8079
Shannon evenness (*J*)	0.5938	0.4232	0.5761	0.5015	0.5519	0.5933
Berger-Parker dominance (*BPd*)	0.0607	0.1451	0.0936	0.1381	0.0613	0.0513

Hemicheyletia wellsi (Cheyletidae) (169) were considered constant and eudominant. *B. keegani* (62) and *B. dentriticus* (55) were accidental and accessory, respectively, and both subdominant.

The largest populations in S_2 were *Pyroglyphus* sp. (932), followed by *C. malaccensis* (486), and *M. ginglymura* (181). These three species were considered constant and eudominant except *M. ginglymura,* which was dominant in this system. *B. tuttlei* (107), *T. transvaalensis* (65), and *H. wellsi* (Baker) (39) were constant, where the first was dominant and the others subdominant.

Similarity between laying hen environments

When considering the communities from different laying hen systems, Bray-Curtis analysis revealed that the mite composition between similar management systems showed greatest similarity, which can be observed between the A_1 and A_3 systems with 82.7 % similarity (Fig. 4). Despite that the A_2 community showed high similarity with S_2 (71.4 %), it also showed 68.3 % similarity with A_1 and A_3. FR had 49.4 % similarity with other laying hen systems, except with S_1. S_1 showed a low similarity (36.5 %) with the other systems evaluated.

In the Bray-Curtis analysis, the Cheyletidae mites showed high similarity between A_1 and A_3 populations (88.5 %) (Fig. 5) and a higher similarity between S_2 and FR populations (93 %). The similarity of the populations of A_2, A_1, A_3, FR, and S_2 was 82 % similar, while S_1 was in an isolated branch in dendrograms and showed only 23 % similarity with the other systems.

Discussion

The present study showed that management influences the abundance, richness, and diversity of mites in laying hen systems. There is a global trend to ban traditional cage systems to move towards enriched cages or more open systems such as FR or barns, which unfortunately could see population mites of health interest rocketing, as they would be able to hide and proliferate better under these open environments (Sparagano 2009). However, these environments do not promote the increase of predatory mites since they have less shelter. Studies worldwide about the prevalence of *D. gallinae* seem to indicate this trend (Sparagano et al. 2009). In our observations, lower overall abundance of mites was observed in FR because the mite community in this system was more diverse, and with its high evenness in relation to other systems, there would be a better balance among species, which should promote the presence of predatory mites of health interest. In addition, no hematophagous mite was reported in the present study, where only traps were used. Unexpectedly, the increased confinement systems (A_1, A_2, and A_3) had similar abundance as other laying hen systems, even with larger mite populations in A_2. In the absence of pesticides, in S_1, there was no significantly higher abundance in total mites compared with the other laying hen houses. However, this system showed the highest richness, where this factor may influence mite populations. *M. ginglymura* had higher populations in this system, indicating the need for special handling of this species with the use of pesticides or the identification of a natural enemy that can control populations of this ectoparasite.

Silva et al. (2013) evaluated the mite fauna of laying hen farms in traps, feathers, and nests in the same region and found 31 species. The results of the present study indicated that diversity was high, since only traps were used for the assessment, where 35 species were observed. When considered individually, greater richness was observed in S_1, where potential predators (*B. dentriticus*, *B. keegani*, *H. wellsi*, *Rubroscirus nidorum* and *Rubroscirus* sp. (Cunaxidae)) showed higher abundance. This indicates that the absence of synthetic chemical pesticides benefits the populations of predatory mites. In contrast, *C. malaccensis* was the most abundant predator in all other environments, and in S_1, only 48 specimens were reported. This species seems to benefit from the presence of pesticides. *C. malaccensis* is related to biological control of prey and has proved very effective in controlling *Lepidoglyphus destructor* (Schrank, 1781) (Glycyphagidae) and *Tyrophagus putrescentiae* (Schrank, 1781) (Acaridae) (Cebolla et al. 2009). According to the results obtained in this study, this species would have a great potential to be evaluated for use in biological control programs in environments where the use of synthetic chemical pesticides is necessary. Toldi et al. (2014) conducted studies and found the biology of *C. malaccensis* feeding on *D. gallinae* in laboratory conditions. The predator showed no preference for one phase of prey, feeding on all stages

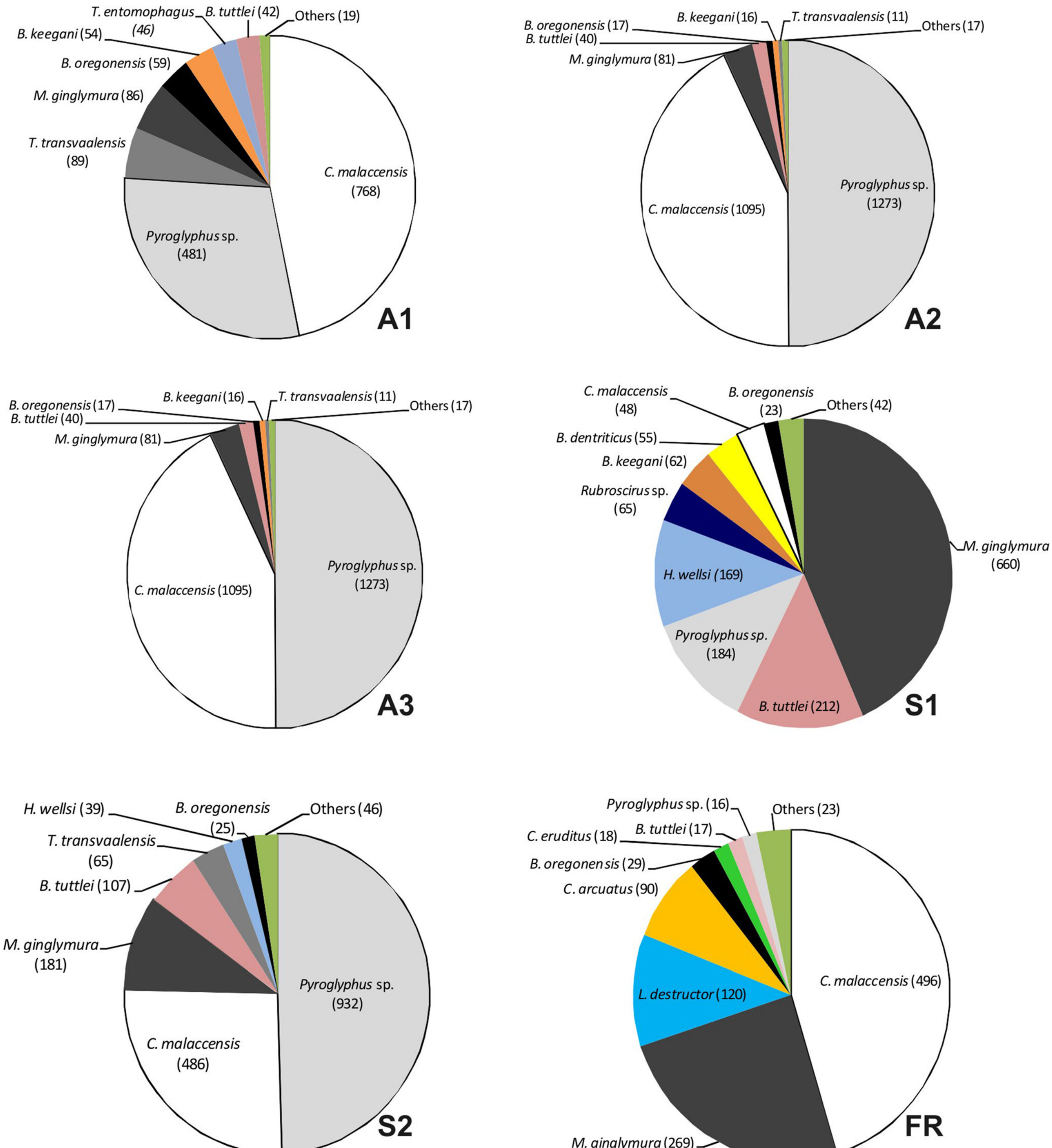

Fig. 3 Abundance of main species found in laying hen houses (A_1, A_2, A_3—automated systems; S_1, S_2—semiautomated systems; FR—free range) between August 2013 and August 2014 in Lajeado municipality, Rio Grande do Sul, Brazil

and being considered by those authors as a potential natural enemy of *D. gallinae*. Another species already reported as an important agent in biological control programs of *D. gallinae* is *Cheyletus eruditus*(Cheyletidae) (Maurer and Hertzberg 2001). In this study, this species was found only in FR, in small populations.

Regarding the diversity indices, higher indices were observed in FR and S_2, and lower in A_2. These results were influenced by the abundance of *C. malaccensis* and *Pyroglyphus* sp., since 92.9 % of the specimens belong to these two species in A_2. These results can also explain the low evenness and high dominance in these systems. The same

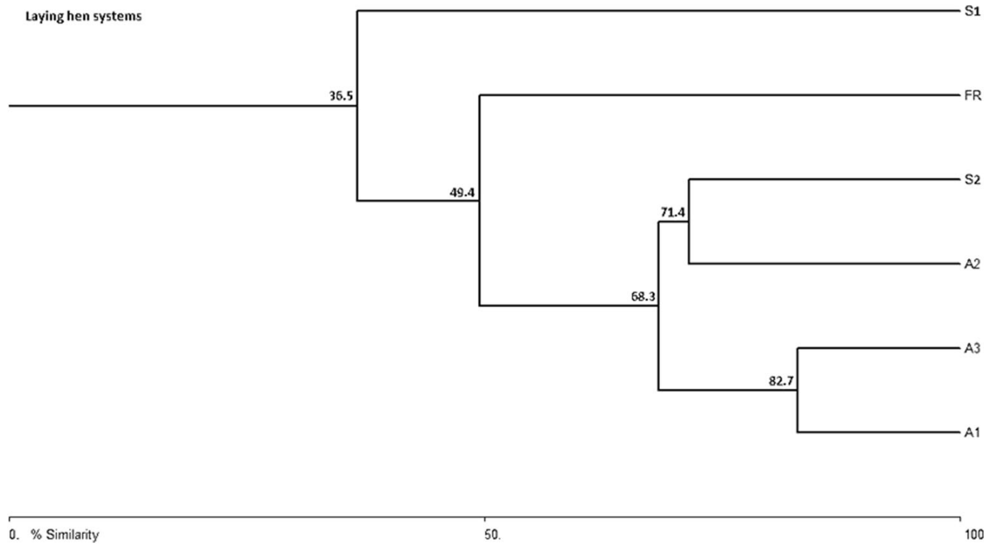

Fig. 4 Bray-Curtis clustering analysis dendrograms of mite communities observed in six laying hen houses between August 2013 and August 2014, in Lajeado municipality, Rio Grande do Sul, Brazil

can be said for S_1, where there was a high abundance of *M. ginglymura*, representing 43.4 % of the total mite population. The A_1 and FR populations showed greater evenness compared to the other systems and low dominance, demonstrating high stability of the mite community.

In general, the predatory species were present in all systems, especially *B. dentriticus*, *C. malaccensis*, and *T. transvaalensis. M. ginglymura* was the only species of potential health interest in all systems. There is still a need for assessment of the ecological niche of *Pyroglyphus* sp. in laying hen houses. Probably, this species is involved in the presence of laying hen feed since species of this genus are reported associated with stored products (Rosa and Flechtmann 1979).

The population composition of different systems showed that the most abundant species were *C. malaccensis*, *Pyroglyphus* sp., and *M. ginglymura*. There is a need to evaluate the role of *C. malaccensis* in the biological control of species with high abundance, especially *M. ginglymura*. This was the most abundant predator and present in all laying hen systems evaluated. The concomitant presence of mites cannot prove a predator-prey relationship, but studies on the potential of the genus *Cheyletus* in the biological control of *D. gallinae* have been demonstrated (Buffoni et al. 1997; Toldi et al. 2014).

M. ginglymura was less abundant in automated systems, but it was present constantly in all of them. There are a few studies relating the presence or distribution of this species to laying hen farms (Tucci et al. 2005; Hernández et al. 2006). In all laying hen houses evaluated, this species showed the greatest potential to cause economic losses because of damages that it may cause to hens lower production (Monteiro 2005). We believe that the sampling traps used in this work influenced the small populations of *M. ginglymura* present in laying hens in automated systems. Mites of the genus

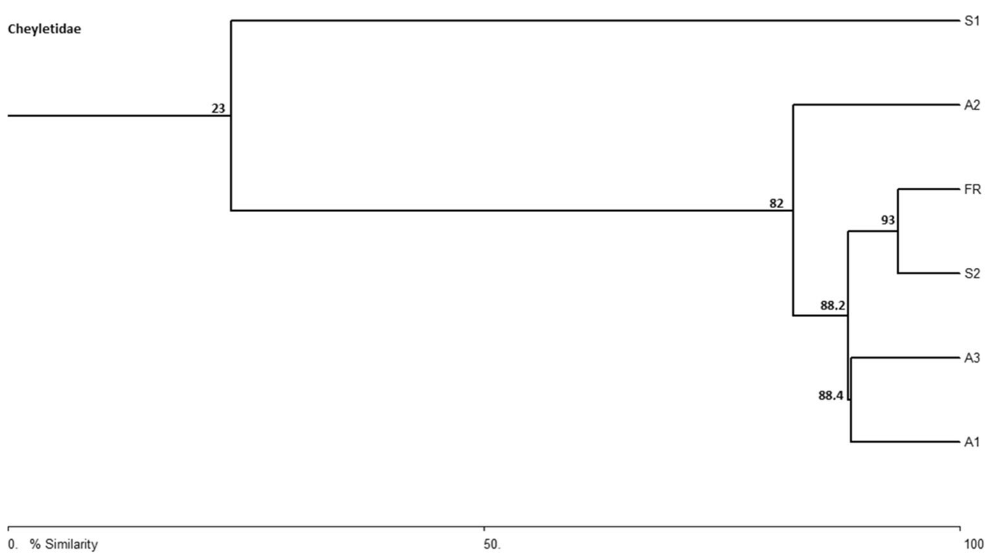

Fig. 5 Bray-Curtis clustering analysis dendrograms of Cheyletidae mites observed in six laying hen houses between August 2013 and August 2014, in Lajeado municipality, Rio Grande do Sul, Brazil

Megninia spend their life cycle on the host, performing oviposition on feathers (Hernández et al. 2007). It is noteworthy that in S_1, the lack of pesticide use for the control of ectoparasites may have influenced the presence of high populations of this species. Thus, it can be concluded that this species needs to be controlled by applying pesticides or other management strategy using a natural enemy or alternative methods such as essential oils, plant extracts, oriental medicinal plant extracts, silica, and garlic (*Allium sativum* L.) that were already tested for *D. gallinae* control (Deh Gorji et al. 2014; Schulz et al. 2014).

There is no in-depth study of the biology of *M. ginglymura*, but Quintero et al. (2010) reported two peaks of population development, one in July and the other in November in Mexico, suggesting seasonality with two biological cycles per year and occurrence all year long.

T. transvaalensis was present in all laying hen systems and was constant in three areas evaluated. This species should be investigated for the biological control of mites in laying hen houses, as has been reported by Silva et al. (2013) in traps and nests of hens in free-range systems. There are records of this species in the state of Rio Grande do Sul in the soil of apple orchards (Ferla and Moraes, 1998), in strawberry fields (Ferla et al. 2007), and native non-cultivated plants (Diehl et al. 2012; Ferla and Moraes 2002; Ferla et al. 2011).

B. dentriticus had higher populations in S_1 showing intolerance to pesticides, even being present in all evaluated systems. The same happened with *B. keegani*. However, it is noteworthy that this species was not present in FR. Both should be evaluated for biological control in poultry farms that do not use synthetic pesticides. There is evidence that this species feeds on lepidopteran eggs and has potential for biological control of fly larvae in orange orchards (Thomas et al. 2011). *B. dentriticus* is a predator that competes with *C. eruditus* (Collins 2012). Probably, these species compete with *C. malaccensis* for prey and benefitted by the low numbers of this predator in S_1.

The tydeid mites *B. oregonensis* and *B. tuttlei* still need further investigation of their role in poultry farms because their feeding habits are unknown. In this study, larger populations of *B. tuttlei* were observed in S_1 and S_2 indicating that this production model is more appropriate for populations of this species. Tydeid mites are generalists and feed on fungi, pollen, and plant sap (Gerson et al. 2003; Silva et al. 2014).

Chortoglyphus arcuatus (Chortoglyphidae) was not an abundant species, present in FR as only one specimen. Silva et al. (2013) found that this species was the third most abundant in laying hen houses. This species is considered a dust mite responsible for allergies in farmers (Schulz et al. 2004).

The analysis of the similarity of the mite fauna between systems showed that S_1 differed most from other systems. This was the only one where laying hens were not treated with pesticides, demonstrating that these products influence the mite community, as well as richness, since S_1 had the highest richness. Acaricides used in attempt to control mites show some limitations, because mites become more and more resistant (Marangi et al. 2009; Roy et al. 2009).

M. ginglymura populations seem to be influenced by the use of pesticides, where this species was less abundant in application systems. In addition, laying hens with similar management showed higher similarity with each other. This proved that the system management influenced the mite community in laying hen houses. When analyzing the Cheyletidae species, the most happened demonstration was that laying hen houses with application of pesticides are more similar to each other than those free of these products (S_1). Thus, these results demonstrated that the management of laying hen systems influences the mite community and may be a strategy to be used for maintenance of certain species, especially predatory mites.

Conclusions

The study of the interaction of the community of mites in the commercial poultry industry needs further investigations. The interaction of wild bird mites and those kept confined in the poultry meat and egg industries has had extensive theoretical reviews. However, the interaction between potential predators to be used on a commercial scale or simple changes in management contributing to the natural presence or increase in predators is still a vast field to be developed.

This study demonstrated that laying hens maintained in a FR system was the confinement model with lower mite populations and a more diverse community. Due to the lack of productivity studies, these results cannot be interpreted as conclusive. It was not the aim of the research but laying hens in the FR system showed improved visual appearance, with no injuries to the skin and practically intact feathers until the discard phase due to senescence and reduced egg productivity. The opposite was observed in all other systems, where laying hens were kept confined in cages preventing contact with the sun, opening wings, scratching and rolling on the ground. Thus, the correlation between the banning of cages and a possible mass proliferation of mites of help interest, mainly *D. gallinae*, did not support our findings. Rather, this process would improve the quality of life of these animals, making it the longer-lived and productive animals.

This is the first study that tried to provide support for possible improvements in Brazilian poultry farms with the aim of defining the best laying hen production model taking into account the mite communities. However, this area also requires studies that would contribute to the production of cleaner poultry without pesticides, which would generate significant improvement in the quality of life of laying hens, poultry farmers, and consumers.

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ARTIGO 4

Horn, T.B., Granich, J., Körbes, J.H., Ferla, N.J. Population fluctuation of predators and sanitary importance mites (Acari) in commercial laying hen: ecological interactions. A ser submetido ao periódico "Acarologia".

POPULATION FLUCTUATION OF PREDATORS AND SANITARY IMPORTANCE MITES (ACARI) IN COMMERCIAL LAYING HEN: ECOLOGICAL INTERACTIONS

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Abstract – This study aimed to evaluate the mite fauna and the ecological interactions in commercial laying hen farms, in the state of Rio Grande do Sul, Brazil. The evaluations were conducted from August 2013 through August 2014 with two sampling strategies: feathers and traps in automated production system ($A_{1,2,3}$), semi-automated ($S_{1,2}$) and free-range (*FR*). A total of 38,383 mites collected belonging to 23 families and 33 species were found, being most of which collected in feather (74%) followed by traps (26%). At S_1 (10,774-28.1%) and S_2 (11,023-28.7%) there was higher abundance followed by *FR* (6,972-18.2%), A_1 (1,896-4.9%), A_2 (4,775-12.4%) and A_3 (2,943-7.7%). Higher richness has been noted at S_1 (23 species), S_2 (18 species) and *FR* (19 species). *Megninia ginglymura* (Mégnin) (Analgidae) has been the species of greater health importance, being eudominant on feathers and its populations correlated positively with temperature. The **n. gen *et* n. sp.** (Pyroglyphidae) seems to be slightly influenced by environmental conditions and the populations of this generalist are negatively correlated with temperature in A_1 (rs = -0.56/p =0.01) and S_2 (rs = -0.78/p<0.00) and positively with relative humidity of air in S_2 (rs = 0.58/p = 0.00). The predators with highest populations were *Cheyletus malaccensis* (Oudemans) (Cheyletidae), *Typhlodromus transvaalensis* (Nesbitt) (Phytoseiidae),

Blattisocius keegani (Fox) and *Blattisocius dentriticus* (Berlese) (Blattisocidae). *Cheyletus malaccensis* was considered a natural enemy of *M. ginglymura*.

Keywords – *Megninia ginglymura*; *Cheyletus malaccensis*; biodiversity.

Introduction

Intensive egg production affects the welfare of laying hens and increases the risk of epidemics, and it can be affected by various complications, such as ectoparasites and commensal mites (Guimarães and Leffer, 2009), decreasing egg production, causing fragility of the eggshell, and in addition, the laying hens become anemic, restless and aggressive towards each other (Sparagano, 2009).

The commercial laying hens are affected by mites of sanitary and economic importance worldwide. *Dermanyssus gallinae* (De Geer) (Dermanyssidae) (poultry red mite), since *Salmonella* vaccination, seems to be the new economic, welfare and epidemiological problem around the world (Sparagano, 2009). In addition to this hematophagous mite, *Ornithonyssus bursa* (Berlese) and *Ornithonyssus sylviarum* (Canestrini and Fanzago) (Macronyssidae) are registered in poultry farms and *O. bursa* seems to have replaced by *O. sylviarum* over time in Brazilian poultry industry and it has recently been reported (Soares *et al.*, 2008).

Among the feathers mites, *Megninia ginglymura* (Mégnin) (Analgidae) is the most reported in commercial laying hen in Brazil (Reis, 1939; Tucci *et al.*, 2005) and in the state of Rio Grande do Sul (Silva *et al.*, 2013; Faleiro *et al.*, 2015; Horn *et al.*, 2016). This species spends its life cycle on its host and oviposits on feathers (Hernández *et al.*, 2007). The ecological studies and its economic influences in poultry farms are scarce worldwide, might not be as abundant as *Dermanyssus* spp. and *Ornithonyssus* spp. and cause less significant damage (Hernández *et al.*, 2006). In Cuba, *M. ginglymura* was the more important sanitary species present in commercial laying hen in all provinces (Hernández *et al.*, 2006). In that country, the population peak of the species indicated relationship with the wet season (Hernández *et al.*, 2007). In Mexico, the presence of two population peaks of *M. ginglymura*, one in July and other in November, suggest that the seasonality affects the population, but the factors that influences the population is yet unknown (Quintero *et al.*, 2010). In the state of Rio Grande do Sul, higher population was related between February to April, reaching a peak in February, with 16.3 mites/hen in free-range and in April with 22.3 mites/hen (Faleiro *et al.*, 2015).

No ecological information about **n. gen *et* n. sp.** (Pyroglyphidae) is known. This species seems to have a strong relationship with poultry farms, since is being observed in all management of laying hens in Rio Grande do Sul (Horn *et al.*, 2016).

Alternative pest control using natural enemies allows the use of cleaner practices and is less environmentally impactful (Lesna *et al.*, 2009). The traditional strategy in the control of pest species in poultry systems, *i.e.*, with synthetic chemical pesticides, tends in the long term to cause development of resistance in mites, and the pesticides also have adverse effects on the birds' nervous system and can be immunosuppressive and carcinogenic as well (Nero *et al.*, 2007; Marangi *et al.*, 2009; Wright *et al.*, 2009). Furthermore, synthetic acaricides can leave residues in eggs, meat, liver and animal adipose tissue. *Androlaelaps casalis* (Berlese) (Laelapidae), *Gaeolaelaps aculeifer* (Canestrini) (Laelapidae) (Lesna *et al.*, 2009) and *Cheyletus eruditus* (Schrank) (Cheyletidae) (Maurer and Hertzberg, 2001) are recognized as natural enemies of *D. gallinae.* The predators *Blattisocius dentriticus* (Berlese) (Blattisocidae) and *Cheyletus malaccensis* (Oudemans) (Cheyletidae) were evaluated in laboratory feeding on *M. ginglymura* (Silva *et al.*, 2016; Artigo 6) and the greatest potential for control was presented by *C. malaccensis.*

Studies on population dynamics and efficient techniques for the control of sanitary mites are scarce in poultry farms in Brazil (Silva *et al.*, 2013). Due to the importance of this activity to the economy of the state of Rio Grande do Sul, it is necessary to know the associated mites, their frequency and damages caused by them. Considering that *M. ginglymura* seems to be influenced by environmental conditions (Quintero *et al.*, 2010) and predatory mites presented potential for biological control of this ectoparasite in laboratory (Silva *et al.*, 2016; Artigo 6), the present study expect (1) that environmental conditions influence *M. ginglymura* populations and **n. gen *et* n. sp.** in laying hen systems, (2) that there is an association between the populations of *M. ginglymura* and **n. gen *et* n. sp.** with predatory mites present in these systems, and (3) assume that *C. malaccensis* is the most common predatory mite when occurs the reduction of populations of *M. ginglymura* in laying hen houses. Therefore, this study aimed to evaluate the mite fauna and the ecological interactions in commercial laying hen farms, in Rio Grande do Sul, Brazil, and to support future studies using predatory mites as biocontrol strategy applied in laying hen farms.

Material and Methods

This study was conducted in different commercial laying hen systems between August 2013 through August 2014 in Lajeado municipality, Vale do Taquari, state of Rio Grande do Sul, Brazil.

Six poultry houses were sampled, where in three of them the laying hen system consisted of an automated vertical battery cages ($A_{1,2,3}$), two semi-automated ($S_{1,2}$) and one free range (*FR*). In automated system, the laying hen were confined in metal cages on six floors with an area of approximately 450 cm^2/hen (nine hens/cage), and the cages were placed on top of the other in stacks of four. Hen feed was provided in a metal structure and water in nipple-type drinker, and eggs were collected on an automatic treadmill. In addition, feces were collected at least three times per week by treadmills at the bottom of the floor of cages. In this laying hen system, there are screens throughout the laying hen house to prevent wild bird access.

Among the A_1 laying hens, 39,000 white laying hens of the Bovans breeds were maintained and two batches were evaluated: the first, with 45 weeks old at the beginning of sampling and 94 weeks old in July 2014, when it was replaced by a new batch at 16 weeks old and evaluated up to 20 weeks old in August 2014, giving a total of 21 samples (nA_1: 210). In A_2, there were 60,000 laying hens, 50% Bovans breed (left side of the laying hen house) and 50% Isa Brown breed (right side of the laying hen house). The batch was 68 weeks old at the beginning of sampling and 98 weeks old in March 2014. A new batch was introduced in April 2014 at 17 weeks old and evaluated up to 37 weeks old in August 2014, resulting in 20 samples (nA_2: 200). In A_1 and A_2, Topline® (fipronil 1%) was added to the feed in September 2013 as routine management to control parasites. In A_3, there were 35,000 red Isa Brown laying hens, the evaluation began with a batch of 99 weeks old evaluated up to 109 weeks old in October 2013. A new batch of 19 weeks old was introduced in December 2014 and evaluated up to 54 weeks old in August 2014, giving a total of 17 samples (nA_3: 170). In this system, Couro Limpo® (15% cypermethrin, 25% chlorpyrifos and 1% citronellal) was applied twice in April 2014.

In the semi-automated laying hen system the cages were arranged in the form of stair steps with two stacks of cages in each poultry house. Feed and water were provided in an automated manner and eggs collected manually. The S_1 system was a wood structure in the style of a “California house,” and S_2 was a “wide-span model” (Axtell, 1986). S_1 did not receive any type of pesticide application during the evaluation period and was considered the semi-automated control. S_1 housed 7,750 red DeKalb laying hens, with 45 weeks old at the beginning of sampling and 88 weeks old in July 2014 when the batch was removed, totaling 18 samples (nS_1: 180). S_2 housed 10,400 red Isa Brown laying hens, 41 weeks old at the beginning of sampling and 95 weeks old in August 2014, totaling 22 samples (nS_2: 220). This system received Topline® in the feed in September 2013 and May 2014. The systems S_1 and S_2 allowed the entry of wild birds.

The other laying hen house evaluated was raised free under a sawdust bed arranged over ground, popularly known as free-range (*FR*). In Brazil, this system is popularly known as "caipira". In *FR*, 3,500 red Isa Brown laying hens were housed, they were 44 weeks old and evaluated up to 88 weeks old in July 2014, when they were removed, totaling 19 samples (n*FR*: 190). Feed and water were provided in an automated way and egg collecting was manual. The nests were packed in a wooden structure with sawdust inside for maintenance of eggs. The laying hens were released in the day to sunbathe, ground pecking and wing flapping. The nests were treated with Bolfo® (propoxur 1%) powder in December 2013 and January and April 2014. The sampling efforts were different in the laying hen houses due to the absence of laying hen in some periods depending on the pause between the disposal of the old bath and entrance to the new laying hen batch. Cars' access from other hen houses has been denied throughout the study.

Mite samplings

To collect the mites, we placed 16 traps of 27-cm PVC pipe (50 mm diameter) with 13 holes of 0.8 mm with the ends closed with caps (PVC cap) and attached to the cages with a rubber band in each laying hen house (Tucci *et al.*, 1989). Three lightly crushed paper towel sheets were placed inside the traps, to provide shelter. Attracting substances were not used. Throughout the evaluation period, the traps were maintained at the same point, where they were replaced every 15 days. In A_1, A_2, A_3, S_1 and S_2, the traps were arranged on the second floor of the cages, while in *FR* they were placed on perches and inside the nests. At each evaluation, the paper towel was collected, packed individually in plastic bags, labeled and taken to the laboratory, where it was kept in a freezer (0°C) for at least 24 hours. For each evaluation, the collected paper towel was placed in Petri plates and observed under a stereomicroscope.

To collect the ectoparasites, it was examined ten laying hen for each laying hen houses, selecting chickens along the length of laying hen house. From each laying hen, it was collected a total of five feathers/hen every 15 days. The feathers were placed in plastic containers 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.

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, extension of legs and diaphanization of specimens. The identification of specimens to the species level was done using a phase contrast light microscope and key of identifications. Representative specimens of each species were deposited on the mites reference collection of the Museum of Natural Sciences at Centro Universitário UNIVATES (ZAUMCN), Lajeado, Rio Grande do Sul, Brazil.

Data analysis

The data analyzed concerned the mites found in the laying hen houses evaluated sampled in traps and feathers. Several ecological indices were determined using the software DiVes 2.0 (Rodrigues, 2005):

i) Shannon-Wiener index (*H'*) expresses richness and uniformity, giving more weight to the rare species. *H'* is determined by the formula $H'=-\sum pi \, Log \, pi$, where *pi* is the proportion of specimens of each species in relation to the total number of specimens found in the assessment performed (Shannon, 1948);

ii) Shannon's evenness index (*J*) expresses the equitability of abundances in a community and allows the assessment of species stability over time. *J* is determined by the formula

J=H'/Hmax', where the *H'* is the Shannon-Wiener index and *Hmax'* is given by the following expression: *Hmax'=Log s*, where *s* is the number of species sampled) (Brower and Zar, 1984).

iii) Berger-Parker dominance (*BPd)* considers the highest proportion of species with the highest number of individuals. *BPd* is determined by the formula $d = Nmax/N_T$, where *Nmax* is the number of specimens from the most abundant species and N_T is the total number of specimens from the sampling (Berger and Parker, 1970).

Species constancy (*C*) was classified as constant when present in more than 50% of the samples ($C > 50\%$), accessory when present in 25 – 50% of the samples ($25\% < C < 50\%$) and accidental when present in less than 25% of the samples ($C < 25\%$) (Bodenheimer, 1955). The dominance (*D*) was defined by the formula $D\% = (i/t) \times 100$, where i = total number of individuals of a species and t = total individuals collected and clustered according to categories: eudominant (≥ 10%), dominant (5 ≤ 10%), subdominant (2 ≤ 5%), eventual (1 ≤ 2%) and rare ($D < 1\%$) (Friebe, 1983).

Spearman's correlations (rs) and significance were calculated with the help of the software BIOESTAT 5.0 (Ayres *et al*., 2007). Climate parameters precipitation (mm) (Pp), relative humidity of air (%) (RH) and temperature (ºC) (Temp) for the study period were provided by UNIVATES University Center Meteorological Station, Lajeado, state of Rio Grande do Sul.

Results

A total of 38,383 mites collected in feathers and traps belonging to 23 families and 33 species were found (Table 1). Most mites were sampled in feathers (74%) and the others in traps (26%). In the semi-automated systems there was a great abundance, S_1 (10,774) and S_2 (11,023), followed by *FR* (6,972), while the automated systems (A_1: 1,896; A_2: 4,775 and A_3: 2,943) were observed lower abundance. The richness follows the same logic of abundance, it was greater in S_1 (23) and S_2 (18), followed by *FR* (19) and less richness in A_1, A_2 (13) and A_3 (12). Higher richness were associated to traps (32 species) than feathers (13 species) in the evaluated systems. The sampling effort has been enough because the collector curve show most areas reached stability, except in *FR* whose stability did not observe until the 19th sampling (Figure 1). The laying hen house with less richness reached stability before those with more richness. A_1 reached stability in the sixth sampling, *i.e.*, A_3 in the seventh, A_2 in the 13th, while the laying hen house with greater richness was stabilized later, S_1 in the 14th and S_2 in the 21th sampling.

Ecological Diversity indices

The automated systems presented greater indices of diversity and evenness (A_1 – *H'*: 0.7018, *J:* 0.6301; A_2 – *H'*: 0.5078, *J:* 0.4558 and A_3 – *H'*: 0.546, *J:* 0.5046) than semi-automated systems (S_1 – *H':* 0.1977, *J:* 0.1452; S_2 – *H'*: 0.2764, *J:* 0.2202) or free range (*FR* – *H':* 0.233, *J:* 0.1822) (Table 2). The lowest indices of Berger-Parker dominance were observed in A_1 (*BPd:* 0.0538), S_1 (*BPd:* 0.0644), S_2 (*BPd:* 0.064) and *FR* (*BPd:* 0.0839) and greatest indices in A_2 (*BPd:* 0.128) and A_3 (*BPd:* 0.1927).

Biodiversity and mite fauna fluctuation

The families with the great richness were Cheyletidae with four species (*Chelacheles bipanus* Summers & Price, *Cheletomimus (Hemicheyletia*) *wellsi* (Baker), *C. eruditus* and *C. malaccensis* followed by Acaridae with three (*Aleuroglyphus ovatus* (Troupeau), *Thyreophagus entomophagus* (Laboulbéne) and *Tyrophagus putrescentiae* (Schrank)).

Megninia ginglymura was the species with sanitary importance and presented greater abundance with 29,633 specimens (77.2%). It was present throughout the year in all systems evaluated, excepting A_1 where it was present since the fifth sampling (Figures 1 and 2 - A_2 with graph different scale). This species was considered constant in feathers and traps in all laying hen houses evaluated, except in A_1 where *M. ginglymura* was accessory in the feathers. In the feathers, it was eudominant in all systems. Besides, it was eudominant in traps of S_1 and *FR*, dominant in A_1 and S_2 and subdominant in A_2 and A_3. In A_1 and A_2, the population peak of *M. ginglymura* occurred between January and March/2014 with highest average in February/2014, with 1.6 and 11.6 mites/feathers, respectively. The application of synthetic chemical pesticide in September/2013 occurred in the period of low populations. In A_3, there was a late population peak, in April/2014, with the average of 11.1 mites/feathers. In the semi-automated systems the populations remained in high numbers in most of the period. In S_1, high population extended from November/2013 to April/2014, averaging 12.8 mites/feathers in December/2013 and January/2014; in S_2 the averages were high between December/2013 and June/2014, with the highest average, 13.4 mites/feather, in April/2014. In *FR*, population with high number were observed during September to November/2013, with the high population peak, 10.9 mites/feathers, in October/2013. The mite populations had increased immediately after the application of synthetic chemical pesticide, with a new population peak between February and June/2014.

Megninia ginglymura showed a positive significant correlation with temperature in A_1 (Feathers: rs = 0.77/p<0.00; Traps: rs = 0.52/p = 0.01), A_2 (Feathers: rs = 0.63/p =0.00) and S_1 (Feathers: rs = 0.52/p =0.02) and negative in *FR* (Feathers: rs = -0.68/p = 0.00; Traps: rs = -0.59/p = 0.00) (Table 3). Only the feather population of A_1 (rs = -0.50/p = 0.02) and A_3 (rs = 0.49/p = 0.04) correlated significantly with RH. Trap population of A_1 (rs = 0.48/p =0.03) and A_2 (rs = 0.51/p = 0.03) correlated positively and significantly with the precipitation.

Among the generalist species, **n. gen *et* n. sp.**, with 3,294 (8.6%) was the species more abundant and present during the sampled period in the laying hen houses, except in *FR* where the population was low. This species was considered constant and eudominant in the traps, except in

FR where it was accessory and eventual. In the feathers, was accessory and rare in A_3; accidental and rare in A_2 and S_2; accidental and subdominant in A_1. This species was absent in the feathers of S_1 and *FR*. In A_1, the synthetic chemical pesticide application in September/2013 did not prevent high populations between December/2013 and February/2014, with higher average in January/2014 (6.3 mites/feathers). In A_2, population with high average occurred between June and August/2014, with population peak in August/2014 (23.1 mites/traps). Due to this high population average in this system, this graph was presented in different scale of others (Figure 2). In A_3, the population remained low and the average oscillate between 0.7 and 4.4 mites/traps with the peak registered in January/2014. In S_1, the population remained low with any significant population peak. In S_2, two population peaks were present between September and October/2013 and another from March to August/2014 with high average registered in August/2014 (16.2 mites/traps). In *FR*, the population remained low with high average, 0.13 mites/traps, in December/2013. This species presented negative and significant correlation with temperature in A_2 (Traps rs = -0.56/p = 0.01) and S_2 (Feathers rs = -0.44/p = 0.03; Traps rs = -0.78/p<0.00) (Table 3). Only in S_2 (rs = 0.58/p = 0.00) there was positive and significant correlation with the RH. This species was not correlated significantly with precipitation in this study.

Among the predators, *C. malaccensis,* with 3,511 (9.1%) was present in the systems during all the sampling period. This species stood out as constant and eudominant in traps of all systems, except in S_1, where it was accessory and subdominant. In the feathers, this predator was observed in A_1 and in the other laying hen house was accidental and rare. In A_1, *C. malaccensis* populations increased after the start of the population peak of *M. ginglymura* in January/2014, but no significant correlation between these populations. In A_2, laying hen house with high abundance of *C. malaccensis*, the population peak occurred between January and March/2014, when coinciding with the population peak of *M. ginglymura*. In the traps of A_2 there was positive and significant correlation between this predator and *M. ginglymura* (rs = 0.54/p = 0.01). Also in this laying hen house, *C. malaccensis* population correlated negatively and significantly with **n. gen *et* n. sp.** population (rs = -0.53/p = 0.02) in traps. In A_3, the population peak of *C. malaccensis* occurred between February and August/2014. *Megninia ginglymura* population present in the feathers correlated positively and significantly with *C. malaccensis* present in traps (rs = 0.53/p = 0.03). In S_1 there was low populations of this predator, but with positive and significant correlation with *M. ginglymura* in traps (rs = 0.47/p = 0.04). In S_2, the population peak was between December/2013 and February/2014 (4.9 mites/traps in January/2014). The population of this predator in the traps had positive and significant correlation with *M. ginglymura* in the feathers (rs = 0.49/p = 0.02). In this laying hen house, *C. malaccensis* and **n. gen *et* n. sp.** negatively and significantly correlated with each other (rs = -0.50/p = 0.01) in traps. In *FR*, this predator population remained high, with various population peaks between September to November/2013, in February and March to May/2014. There was positive and significant correlation between this predator and *M. ginglymura* in the feathers (rs = 0.52/p = 0.02) and traps (rs = 0.54/p = 0.01).

The other Cheyletid mite, *C. eruditus*, was present only in *FR* in lower population in traps (18 specimens – 0.05%) and presented a positive and significant correlation with *M. ginglymura* population of traps (rs = 0.51/p = 0.02) and the population of this predator in traps and the population of *M. ginglymura* of feathers (rs = 0.72/p = 0.00).

The second more abundant predatory mite present in all systems was *Typhlodromus transvaalensis* (Nesbitt), with 309 specimens (0.8%), considered constant in traps of A_1, A_2 and S_2, where they were dominant, eudominant and subdominant, respectively. This species was observed in the feathers in S_1 and S_2, being considered accidental and rare. In A_1 there was a period of population slightly higher between October and December/2013 and in June/2014. In

A_3, the population peak occurred between June and August/2014 with averaging 2.3 mites/traps in July/2014. In S_2, the high population were registered between October/2013 and January/2014, with 1 mite/traps. In A_2, S_1 and *FR* the populations were very low. *Typhlodromus transvaalensis* presented negative and significant correlation with *M. ginglymura* in traps of S_2 (rs = -0.54/p = 0.01) and in A_1, when this predator correlated negatively with *M. ginglymura* in feathers (rs = -0.54/p = 0.01).

Blattisocius dentriticus and *Blattisocius keegani* (Fox) (Blattisocidae) were the predatory mites with low abundance evaluated for potential biological control. Populations of both predators remained low during the study period. *Blattisocius keegani* was the third predator most abundant present in at least five laying hen houses (A_1, A_2, A_3, S_1 and S_2), totalizing 187 specimens (0.5%). This predator was constant and subdominant in the traps of A_1 and A_3; accessory and rare in A_2; accidental in S_1 and S_2 where it was subdominant and rare, respectively. In the feathers, *B. keegani* was observed also in low numbers and considered accidental and rare, except in A_1 where it was absent. This species was absent in *FR* system. *Blattisocius keegani* from traps correlated negatively and significantly with *M. ginglymura* in S_2 (rs = -0.46/p = 0.03). *Blattisocius dentriticus* presented only 93 specimens (0.2%), it was considered accessory and subdominant in the traps of S_1 and accessory and rare in A_2 and A_3. In the traps of other laying hen houses it was considered accidental and rare. In the feathers, the species was present in A_1 where it was accidental and rare; in S_1 presented a population peak between September and November/2013 and correlated positively and significantly with **n. gen *et* n. sp.** in traps (rs = 0.45/p = 0.05).

Discussion

Data presented in this study are important as a preliminary for the identification of associated species and evaluation of its population dynamics in different laying hen houses management.

The management influences the abundance, richness, and diversity of mites in laying hen systems (Horn *et al.*, 2016). Furthermore, it highlights *M. ginglymura* as the mainly sanitary importance mite associated to laying hen in the region of the study. This species is strongly associated to feathers, but in the laying hen systems with high population densities it seems to leave the hen and move looking for a new host, and could thus be captured by traps designed to catch predatory mites and other ectoparasites as *D. gallinae*, which it rises the hen only to blood feeding. No hematophagous mites were registered. *Megninia ginglymura* feed on skin, fat and parts of feathers, and the mite saliva can cause lesions, allergic reactions, serious scabs, stress, crust formation and secondary bacterial infections (Tucci *et al.*, 2005). Few studies that confirm the percentage of economic loss are known. Therefore, it must be highlighted the importance to improve the knowledge of the management of this species in commercial laying hen. The laying hen in the *FR* system showed improved visual appearance, with no injuries to the skin and practically intact feathers until the discard phase due to senescence and reduced egg productivity. The opposite was observed in all other systems (Horn *et al.*, 2016).

The highest richness was found in the traps, while highest abundance has been associated to feathers. Automated systems seem to induce a lower abundance of sanitary importance mites than the other systems. Even with more confinement hens, the automated systems had lower or similar to the abundance as other laying hen systems (Horn *et al.*, 2016). While most richness was observed in semi-automated systems (S_1; S_2) and *FR*. The highest richness were associated to the laying hen in the absence of synthetic chemical pesticides, and no significant higher abundance in total mites was found, when compared with the other laying hen houses (Horn *et al.*, 2016). The automated laying hen houses had highest diversity (*H'*) and evenness (*J*) than the other systems. The lowest dominance was observed in semi-automated laying hen houses, *FR* and A_1.

Cheyletus malaccensis, *T. transvaalensis*, *B. keegani* and *B. dentriticus* were the most common and abundant predatory mites, with population variation depending on husbandry systems evaluated, and considered with potential to be evaluated for biological control of sanitary importance mites in the laying hen farms. Besides, *C. eruditus* even with low populations and found only in FR was considered due to its recognized potential in biological control of *D. gallinae* in commercial laying hen farms (Lesna *et al.*, 2009). *Blattisocius dentriticus*, *C. eruditus* and *C. malaccensis* were the predators more common in the same geographical region (Faleiro *et al.*, 2015).

Overall, the mite fauna showed obvious population peaks, and some species seemed to demonstrate resistance to synthetic chemical pesticides or these products were not efficient to the control of *M. ginglymura*.

Quintero *et al.*, (2010) reported the presence of two population peaks of *M. ginglymura* in Mexico, one in July and other in November suggesting that the seasonality affects the population, but the factors that influence the population is yet unknown. Population peaks of *M. ginglymura* in the laying hen systems occurred between September/13 and April/2014, coinciding with periods of high average temperatures. Also corroborate with the period of high population from February to April, reaching a peak in February, with 16.3 mites/hen in free-range and in April with 22.3 mites/hen (Faleiro *et al.*, 2015). These authors associate such differences to the seasonal temperature with the population peaks of free-range in warmer month and in colder months in battery cages.

The application of synthetic chemical pesticide in A_1 e A_2 seems to not have been effective in population control of *M. ginglymura*, because in short period of time after the application there was a population increase. In A_3, there was a late population peak probably due to introduction of a new batch of laying hen only in January/2014. There was a decrease of *M. ginglymura* populations with the use of pesticides. However, due to the late peak, it is uncertain the real capacity of the pesticides to contain the population, or, actually, the decrease was related to environmental conditions. In *FR*, the populations were influenced by pesticides in December/2013 and January/2014. However, it is noteworthy that immediately after application there was fast increase in population. The laying hen houses without use of pesticides (S_1) act as a blank, aiding elucidate the ecology of this species, who seemed to have population peaks during periods of higher average temperatures. Besides, A_1, A_2, S_1 and *FR* correlated positively with the temperature. Our data showed more relationship of *M. ginglymura* population with temperature than relative humidity of air or precipitation. The population increases of this species in Cuba occurred between the months of May and June and extending until December, indicating that the population is related to the wet season (Hernández *et al.*, 2007).

Regarding the **n. gen *et* n. sp.**, although there was no apparent sanitary risk for laying hens due probably to be a dust mite, as are most of the representatives mites of Pyroglyphidae family, it was decided to clarify some information about it, since nothing is known about this species described from this environment (Artigo 2). The **n. gen *et* n. sp.** has a strong relationship with poultry farms, being observed in all systems of management of laying hens throughout the year and in high populations (second species more abundant in feathers and traps).

The **n. gen *et* n. sp.** was collected in feathers and traps. The population peaks were not concomitant in the laying hen systems, but oscillated between September/2013 and February/2014 (A_1, A_2, A_3 and S_2) and an additional peak in A_2 was observed between June and August/2014. The relationship of this species with the environmental conditions needs further investigation. There was negative and significant correlation with the temperature in two laying hen houses (A_2 and S_2) and positive with RH (S_2). These data corroborated our Hypothesis 1, that environmental conditions influence populations of *M. ginglymura* and **n. gen *et* n. sp.**.

Cheyletus malaccensis seems to be the most important predatory mite observed. The same was reported by Faleiro *et al.*, (2015) that suggested *D. gallinae* as a suitable prey of this predator. This predator was evaluated with the preys *Acarus siro* L. (Acaridae), *A. ovatus*, *Caloglyphus redickorzevi* Zachvatkin (Acaridae), *Caloglyphus rodriguezi* Samšiňák (Acaridae), *T. putrescentiae* and *M. ginglymura* (Pekár and Hubert, 2008; Palyvos and Emmanouel, 2009; 2011; Cebolla *et al.*, 2009; Al-Shammery, 2014; Artigo 6). When the results obtained in the life table of *C. malaccensis* feeding on *M. ginglymura* are compared with studies that evaluate other preys, the best results so far (Ro = 135.6; T = 41.6; λ = 1.13; rm = 0.12) were obtained when feeding on *M. ginglymura* (Artigo 6). The population peaks of this predator seem to coincide with *M. ginglymura* peaks, however the correlation between their population were significative in traps of A_2, S_1 and *FR*, and between the populations of *M. ginglymura* in the feathers with *C. malaccensis* in the traps of A_3, S_2 and *FR*. The relationship between *C. malaccensis* and **n. gen *et* n. sp.** populations were obtained only in traps of A_2 and S_2. *Cheyletus eruditus* was present only in *FR* in lower population, correlated significantly its population with *M. ginglymura* in traps and between population of this predator in traps and *M. ginglymura* present in feathers. This data support our Hypothesis 3, that *C. malaccensis* seems to be the most common predator when there is a decrease in populations of *M. ginglymura*. This species showed higher population when *Chortoglyphus arcuatus* Troupeau was present in large numbers, indicating a predator-prey association between them (Faleiro *et al.*, 2015). *Cheyletus eruditus* commonly occur in stored foods, feeding on pest mites and reducing pest populations (Pulpan and Verner, 1965).

Typhlodromus transvaalensis was the second more abundant predator in the laying hen systems. Faleiro *et al.*, (2015) found this species in laying hen farms associated to traps and nests of wild birds in low populations. In our observations, only the traps population of S_2 correlated negative and significatively with *M. ginglymura* population of feathers and between the trap population of this predator in A_1. However, the real role of this predator in these environments remains to be elucidate. Laboratory tests showed that it is able to feed on *M. ginglymura* (unpublished results - first author). The populations of *T. transvaalensis* has no relation to **n. gen *et* n. sp.** in the evaluated systems.

The predators *B. dentriticus* and *B. keegani* were the predatory mites with less abundance and low populations during the sampled period. *Blattisocius keegani* is associated to beetles in stored products and shows potential for the control of the navel orangeworm *Amyelois transitella* Walker (Lepidoptera: Pyralidae) (Thomas *et al.*, 2011) and *B. dentriticus* feeds on arthropod eggs and *T. putrescentiae* (Schrank) (Fenilli and Flechtmann, 1990). Three species of this genus were associated to laying hen farms: *B. dentriticus*, *B. keegani* and *Blattisocius tarsalis* (Berlese) where *B. dentriticus* was the most commom in traps, coinciding with population of *D. gallinae* and *M. ginglymura* (Faleiro *et al.*, 2015). *Blattisocius dentriticus* fed on *M. ginglymura* showed lower values (Ro = 2.79; T = 23.76; λ = 1.04; rm = 0.04) than when the prey was *T. putrescentiae,* since the population of this predator increased about 7.53 times every 14.3 days (Ro = 7.53; T = 14.3; λ= 1.15; rm = 0.14) (Silva *et al.*, 2016). *Blattisocius dentriticus* had no relationship with *M. ginglymura* populations in the systems, and only with the traps population of **n. gen *et* n. sp.** in S_1. *Blattisocius keegani* and *M. ginglymura* presents in traps had relationship in *FR* and this predator was not influenced by **n. gen *et* n. sp.**. The Hypothesis 2 was supported by the data that there is a relationship between *M. ginglymura* and the predators *C. malaccensis*, *C. eruditus*, *T. transvaalensis* and *B. keegani*. In addition, **n. gen *et* n. sp.** had relationship with the predators *C. malaccensis* and *B. dentriticus*.

The results obtained in the present study are corroborated by the data obtained in Faleiro *et al.*, (2015) that *C. malaccensis* could be considered a natural enemy with potential for future biological control studies of ectoparasites associated with laying hens. In laboratory, this predator proved to be effective in biological control of *M. ginglymura* resulting in a high fertility rate with more than 310 eggs/female (Artigo 6). For cleaner control without the use of synthetic chemical pesticides, inoculative releases would be a better choice to control of poultry pest mites, involving the release of low numbers of this natural enemy several times before periods of infestation (Faleiro *et al.*, 2015). In addition, the management provides greater permanence, and natural proliferation of predatory mites becomes a cleaner strategy, thus, avoiding the use of synthetic chemical pesticides that are harmful to human and animal health, since the sanitary importance mites had already demonstrated resistance or these products are not efficient to its control.

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Table captions

Table 1 Mite fauna collected in traps and feathers of laying hen houses, between August 2013 and August 2014, in Vale do Taquari, Rio Grande do Sul, Brazil

Table 2 Ecological indices of mite communities found in six laying hen houses, between August 2013 and August 2014 in state of Rio Grande do Sul, Brazil

Table 3 Association level between *Megninia ginglymura* and *Tuccioglyphus tuccii* and the climate information by Spearman Correlation Coefficient (rs) and the probability of error (*p*) in laying hen houses between August 2013 to August 2014, in Rio Grande do Sul, Brazil

Table 4 Association level between *Megninia ginglymura* and **n. gen *et* n. sp.** with predators by Spearman Correlation Coefficient (rs) and the probability of error (*p*) in laying hen houses between August 2013 to August 2014, in Rio Grande do Sul, Brazil

Figure captions

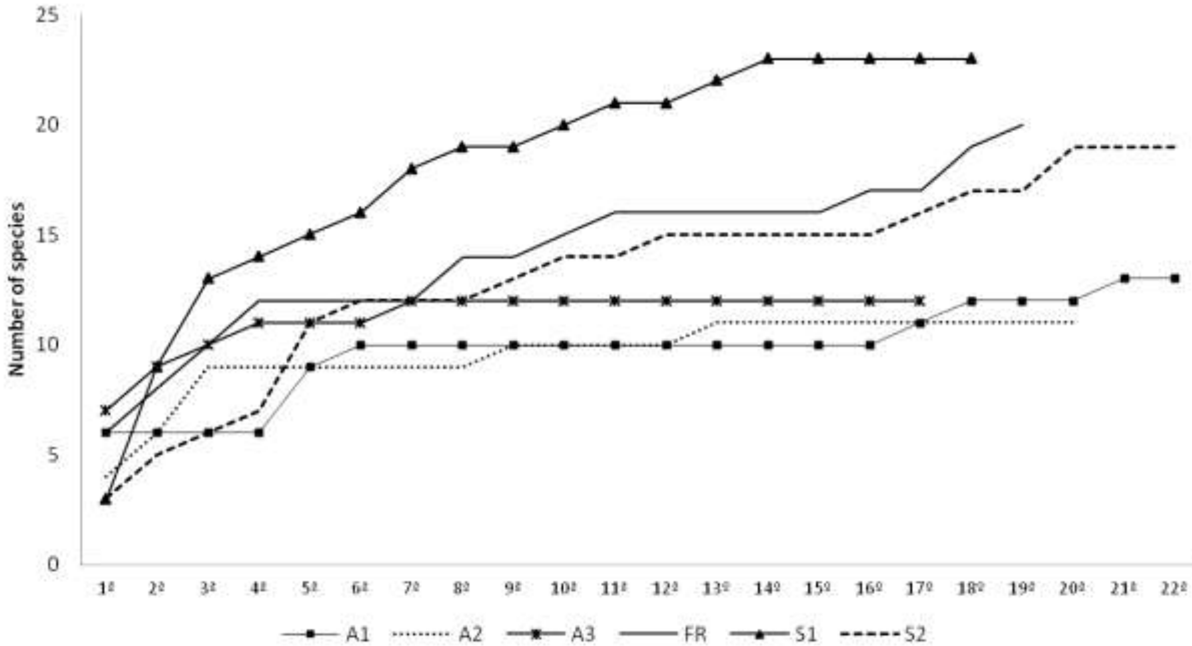
Figure 1 Collector curve showing sampling effort carried out in six laying hen houses in Lajeado, state of Rio Grande do Sul, Brazil between August 2013 to August 2014

Figure 2 Population fluctuation of mites in automated (A_1, A_2^* and A_3) laying hen houses between August 2013 to August 2014 in Lajeado municipality, state of Rio Grande do Sul, Brazil

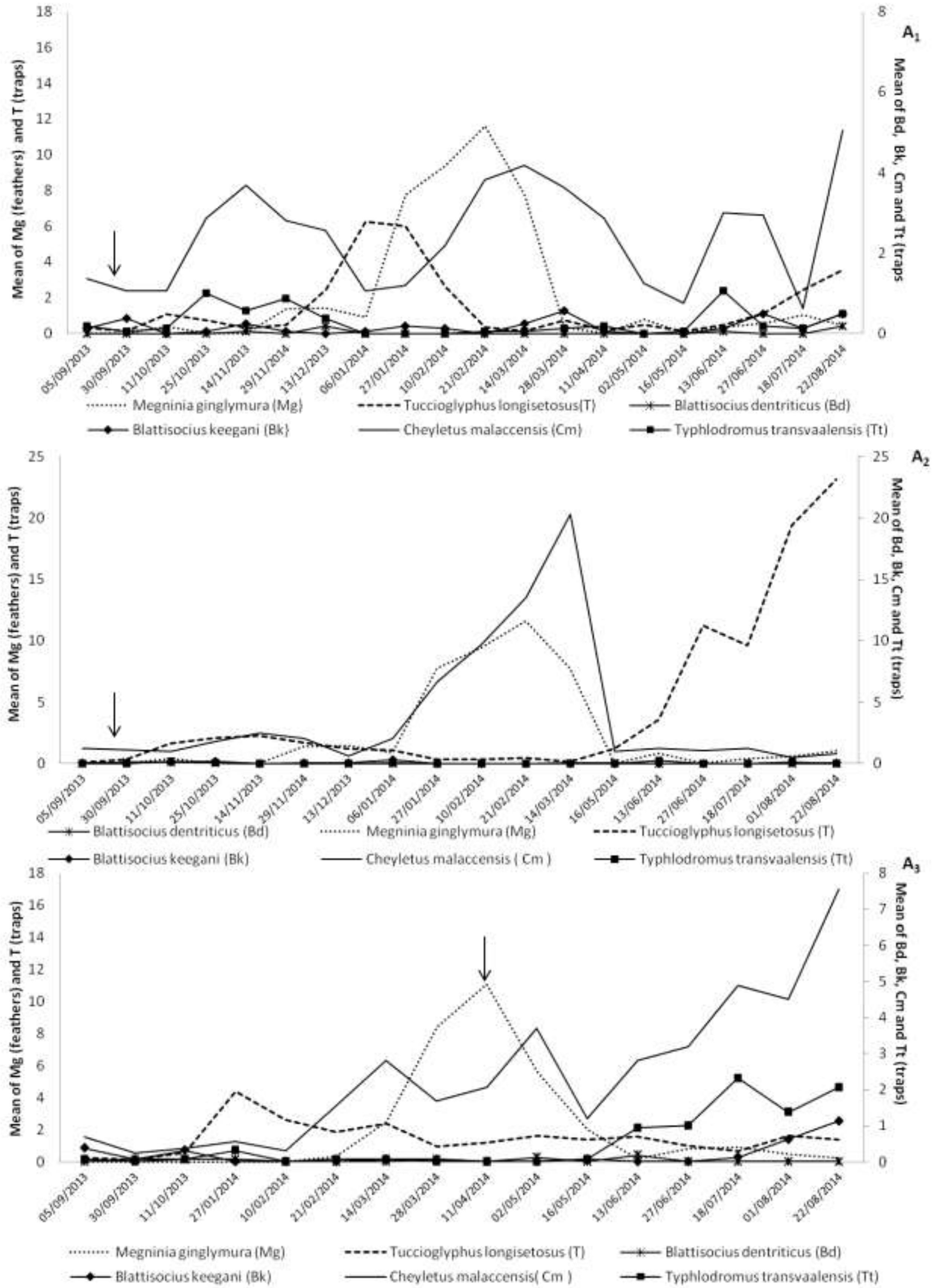
* the scale of A_2 is different of others due a high population peak of **n. gen *et* n. sp.**.

Figure 3 Population fluctuation of mites in semi-automated (S_1 and S_2) and free range (*FR*) laying hen houses between August 2013 to August 2014 in Lajeado municipality, state of Rio Grande do Sul, Brazil

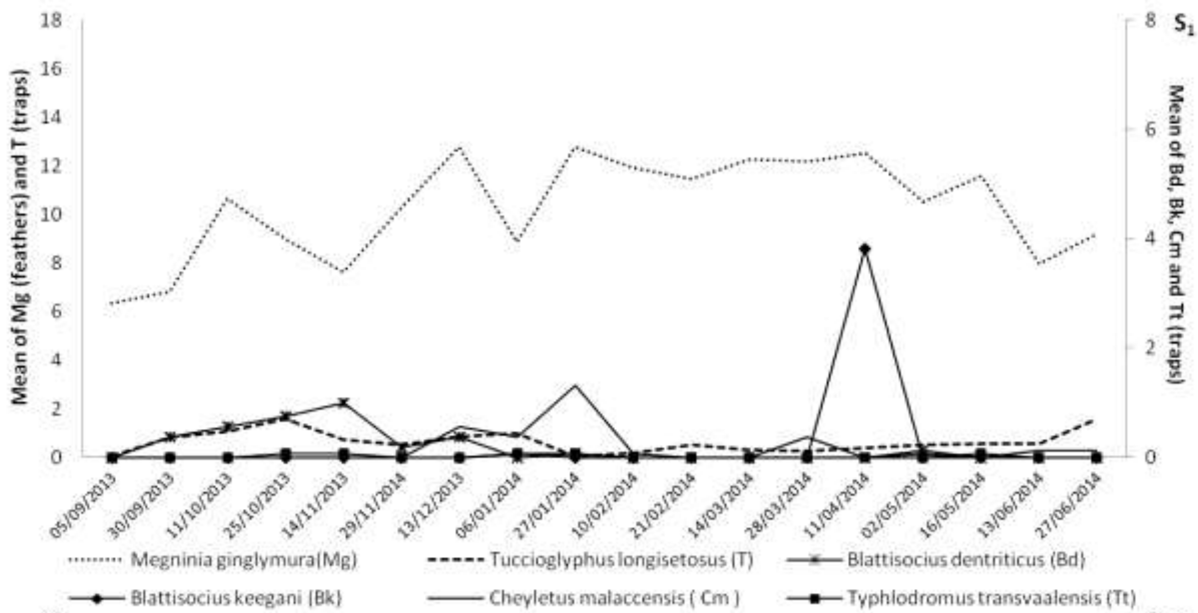
Figure 4 Meteorological data precipitation (Pp) (mm), temperature (Temp) (ºC) and relative humidity (RH) (%) in Lajeado, state of Rio Grande do Sul between August 2013 to August 2014

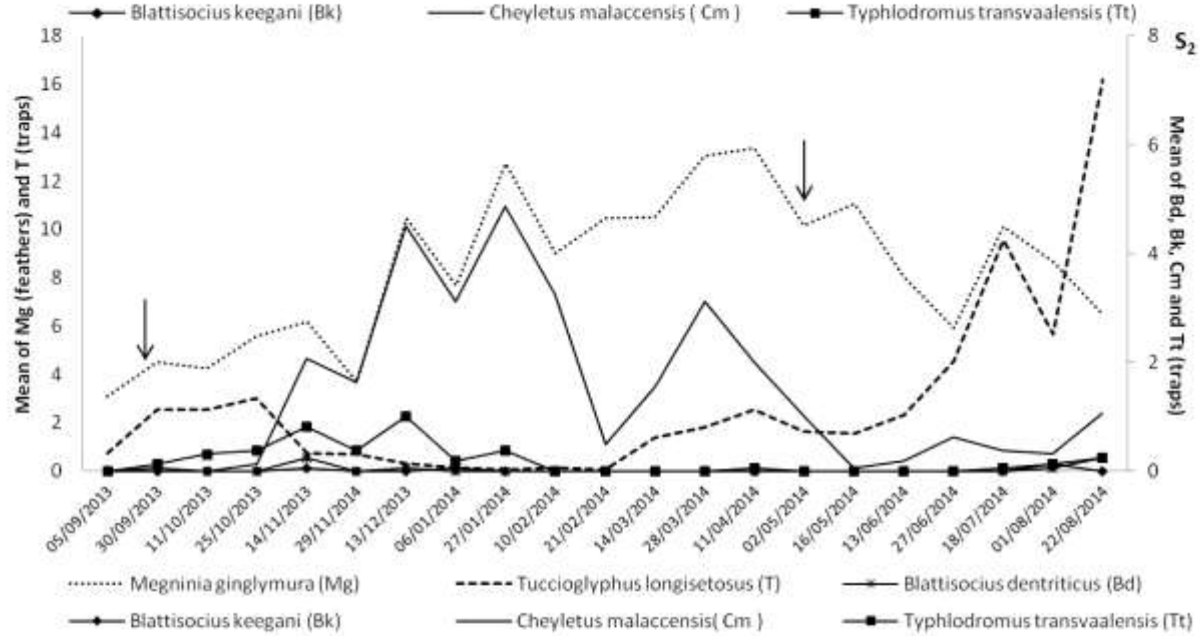


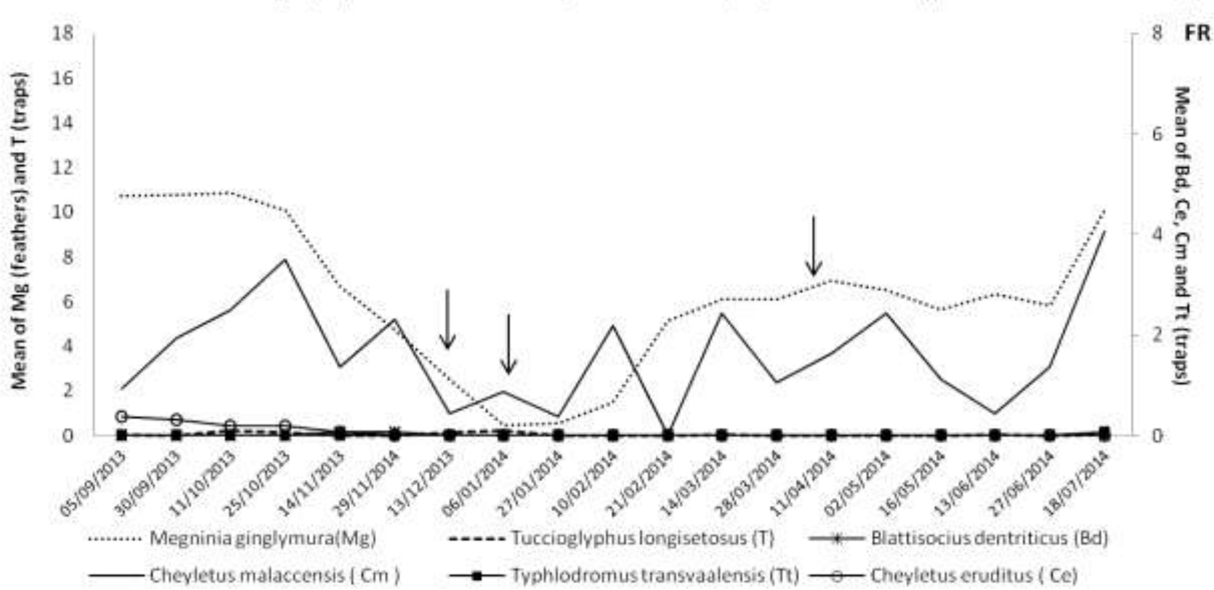
Number of species
25
20
15
10
5
0
1ª
2ª
3ª
4ª
5ª
6ª
7ª
8ª
9ª
10ª
11ª
12ª
13º
14º
15º
16º
17º
18º
19º
20ª
21ª
22ª
A1
A2
A3
FR
S1
S2

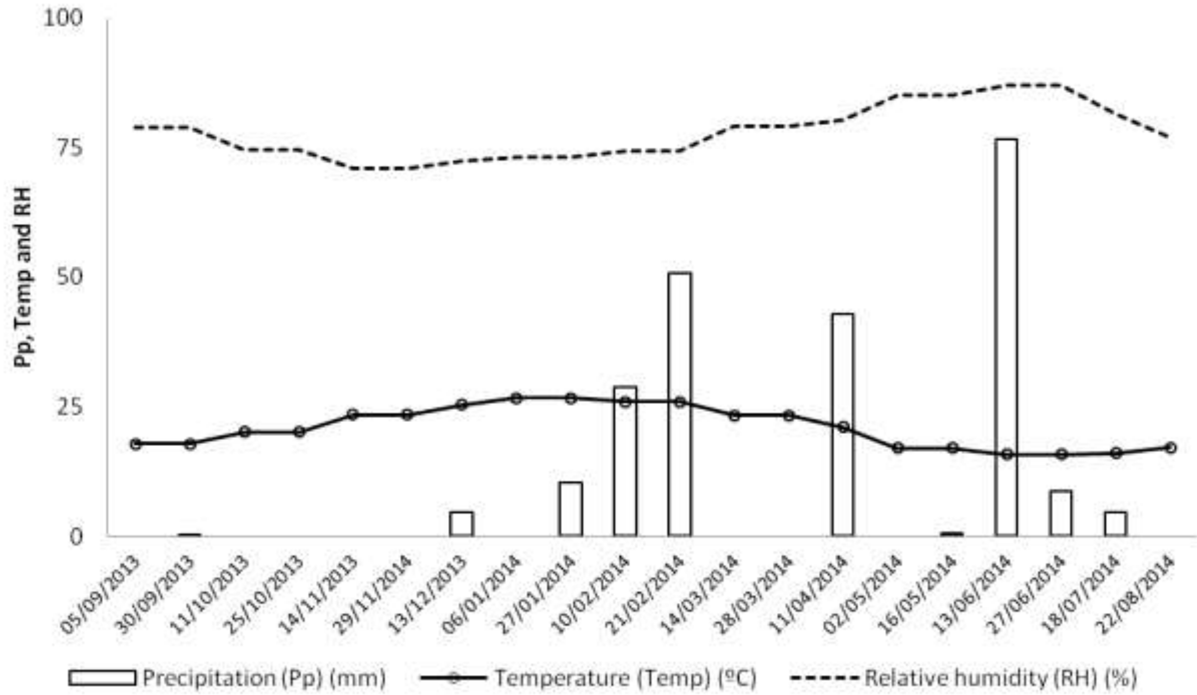


A1
Mean of Mg (feathers) and T (traps)
Mean of Bd, Bk, Cm and Tt (traps
Megninia ginglymura (Mg)
Tuccioglyphus longisetosus(T)
Blattisocius dentriticus (Bd)
Blattisocius keegani (Bk)
Cheyletus malaccensis (Cm)
Typhlodromus transvaalensis (Tt)
A2
Mean of Mg (feathers) and T (traps)
Mean of Bd, Bk, Cm and Tt (traps)
Blattisocius dentriticus (Bd)
Megninia ginglymura (Mg)
Tuccioglyphus longisetosus (T)
Blattisocius keegani (Bk)
Cheyletus malaccensis (Cm)
Typhlodromus transvaalensis (Tt)
A3
Mean of Mg (feathers) and T (traps)
Mean of Bd, Bk, Cm and Tt (traps)
Megninia ginglymura (Mg)
Tuccioglyphus longisetosus (T)
Blattisocius dentriticus (Bd)
Blattisocius keegani (Bk)
Cheyletus malaccensis(Cm)
Typhlodromus transvaalensis (Tt)


S1
Mean of Mg (feathers) and T (traps)
Mean of Bd, Bk, Cm and Tt (traps)
Megninia ginglymura(Mg)
Tuccioglyphus longisetosus (T)
Blattisocius dentriticus (Bd)
Blattisocius keegani (Bk)
Cheyletus malaccensis (Cm)
Typhlodromus transvaalensis (Tt)


S2
Mean of Mg (feathers) and T (traps)
Mean of Bd, Bk, Cm and Tt (traps)
Megninia ginglymura (Mg)
Tuccioglyphus longisetosus (T)
Blattisocius dentriticus (Bd)
Blattisocius keegani (Bk)
Cheyletus malaccensis(Cm)
Typhlodromus transvaalensis (Tt)


FR
Mean of Mg (feathers) and T (traps)
Mean of Bd, Ce, Cm and Tt (traps)
Megninia ginglymura(Mg)
Tuccioglyphus longisetosus (T)
Blattisocius dentriticus (Bd)
Cheyletus malaccensis (Cm)
Typhlodromus transvaalensis (Tt)
Cheyletus eruditus (Ce)



100
75
50
25
0
Pp, Temp and RH
05/09/2013
30/09/2013
11/10/2013
25/10/2013
14/11/2013
29/11/2014
13/12/2013
06/01/2014
27/01/2014
10/02/2014
21/02/2014
14/03/2014
28/03/2014
11/04/2014
02/05/2014
16/05/2014
13/06/2014
27/06/2014
18/07/2014
22/08/2014
Precipitation (Pp) (mm)
Temperature (Temp) (ºC)
Relative humidity (RH) (%)

TABLE 2: Mite fauna collected in traps and feathers of laying hen houses (A_1, A_2, A_3 – automated systems; S_1, S_2 – semiautomated systems; FR – free range), between August 2013 and August 2014, in Vale do Taquari, Rio Grande do Sul, Brazil

	Family	Genus/species		A_1			A_2			A_3			S_1			S_2			FR		
			O	Total	*C*	*D*	Total	*C*	*D*	Total	*C*	*D*	Total	*C*	*D*	Total	*C*	*D*	Total	*C*	*D*
Astigmata	Acaridae	*Aleuroglyphus ovatus*	F													1	Ai	R	1	Ai	R
			T				3	Ai	R				8	Ai	R				2	Ai	R
		Thyreophagus entomophagus	T	50	Ai	S	1	Ai	R	1	Ai	R	2	Ai	R						
		Tyrophagus putrescentiae	F	1	Ai	R	1	Ai	R	7	Ai	R	7	Ai	R	2	Ai	R	4	Ai	R
			T	8	Ai	R	6	Ai	R	36	Ae	S	6	Ai	R	6	Ai	R			
	Analgidae	*Megninia ginglymura*	F	238	Ae	E	2211	Co	E	1628	Co	E	9234	Co	E	9121	Co	E	5873	Co	E
			T	86	Co	M	81	Co	S	51	Co	S	660	Co	E	181	Co	M	269	Co	E
	Carpoglyphidae	*Carpoglyphus lactis*	T	1	Ai	R															
	Chortoglyphidae	*Chortoglyphus arcuatus*	T													1	Ai	R	90	Co	M
	Glycyphagidae	*Ctenoglyphus* sp. nov.	T																15	Ai	V
		Glycyphagus destructor	T	1	Ai	R										1	Ai	R	120	Ae	E
	Epidermoptidae	-	T										3	Ai	R						
	Pyroglyphidae	*Dermatophagoides farinae*	F				1	Ai	R												
		n. gen *et* n. sp.	F	5	Ai	S	6	Ai	R	13	Ae	R				7	Ai	R			
			T	481	Co	E	1273	Co	E	377	Co	E	184	Co	E	932	Co	E	16	Ae	V
	Suidasiidae	*Suidasia pontifica*	T										3	Ai	R						
Mesostigmata	Ascidae	*Proctolaelaps pomorum*	T							1	Ai	R									
	Blattisocidae	*Blattisocius dentriticus*	F	1	Ai	R															
			T	8	Ai	R	7	Ae	R	9	Ae	R	55	Ae	S	11	Ai	R	2	Ai	R
		Blattisocius keegani	F				1	Ai	R	1	Ai	R	1	Ai	R	3	Ai	R			
			T	54	Co	S	16	Ae	R	45	Co	S	62	Ai	S	4	Ai	R			
	Laelapidae	*Hypoaspis lubrica*	T										1	Ai	R						
	Macrochelidae	*Macrocheles muscaedomesticae*	F										1	Ai	R						
			T																8	Ai	R
	Phytoseiidae	*Typhlodromus transvaalensis*	F	3	Ai	V							1	Ai	R	1	Ai	R			
			T	89	Co	M	11	Ae	R	133	Co	E	5	Ae	R	65	Co	S	1	Ai	R
	Uropodidae	*Fuscuropoda* sp.	T	1	Ai	R							2	Ai	R						
Prostigmata	Caligonellidae	*Molotrognathus* sp.	T										1	Ai	R	1	Ai	R			
		Paraneognathus wangae	T										4	Ai	R	1	Ai	R	1	Ai	R

Cheyletidae	*Chelacheles bipanus*	T										5	Ae	R	1	Ai	R			
	Cheyletus eruditus	T																18	Ae	V
	Cheyletus malaccensis	F				2	Ai	R	1	Ai	R	1	Ai	R	3	Ai	R	1	Ai	R
		T	768	Co	E	1095	Co	E	610	Co	E	48	Ae	S	486	Co	E	496	Co	E
	Cheletomimus	F													2	Ai	R			
	(Hemicheyletia) wellsi	T										169	Co	E	39	Co	S			
Cunaxidae	*Rubroscirus nidorum*	F										9	Ai	R	2	Ai	R			
		T										65	Co	S	18	Ae	R	4	Ai	R
Raphignatidae	*Raphignathus* sp.	T																2	Ai	R
Stigmaeidae	*Storchia pacificus*	T																1	Ai	R
Tarsonemidae	*Tarsonemus granarius*	T							1	Ai	R									
Tenuipalpidae	*Brevipalpus phoenicis*	T										1	Ai	R						
Tetranychidae	*Tetranychus* sp.	F				3	Ai	R							1	Ai	R			
		T										1	Ai	R	1	Ai	R	2	Ai	R
Tydeidae	*Brachytydeus oregonensis*	T	59	Co	S	17	Ai	R	1	Ai	R	23	Ae	V	25	Ae	V	29	Ae	S
	Brachytydeus tuttlei	T	42	Ai	S	40	Co	V	28	Co	S	212	Co	E	107	Co	M	17	Ae	V
	Total in feathers		248			2,225			1,650			9,254			9,143			5,879		
	Total in traps		1,648			2,550			1,293			1,520			1,880			1,093		
	Total specimens		1,896			4,775			2,943			10,774			11,023			6,972		
	Richness in feathers		5			7			5			7			10			4		
	Richness in traps		13			11			12			22			17			18		
	Total richness		13			13			12			23			18			19		
	$\mathbf{n_{traps}}$		20			18			16			18			21			19		
	$\mathbf{n_{feathers}}$		21			20			17			18			22			19		

O: occurrence, where F-feathers; T-traps.

C: Constancy index, where Co-constant (species present in more than 50% of the samples); Ae- accessory (species present in 25 to 50% of the samples); Ai- accidental (species present in less than 25% of the samples).

D: Dominance where E- eudominant (≥10%); M- dominant (5≤10%); S- subdominant (2≤5%); V- eventual (1≤2%); R- rare (D<1%).

n: number of samples.

TABLE 2: Ecological indices of mite communities found in six laying hen houses, between August 2013 and August 2014 in state of Rio Grande do Sul, Brazil

Index	**A_1**	**A_2**	**A_3**	**S_1**	**S_2**	**FR**
Number of species	13	13	12	23	18	19
Number of specimens	1,896	4,775	2,943	10,774	11,023	6,972
Shannon diversity (*H'*) 2.0	0.7018	0.5078	0.5446	0.1977	0.2764	0.233
Shannon evenness (*J*)	0.6301	0.4558	0.5046	0.1452	0.2202	0.1822
Berger-Parker dominance (*BPd*)	0.0538	0.128	0.1927	0.0644	0.064	0.0839

TABLE 3: Association level between *Megninia ginglymura* and **n. gen *et* n. sp.** and the climate information by Spearman Correlation Coefficient (rs) and the probability of error (*p*) in laying hen houses between August 2013 to August 2014, from Rio Grande do Sul, Brazil

		Feathers				Traps			
		Mg		T		Mg		T	
		rs	*p*[1]	rs	*p*	rs	*p*	rs	*p*
Temp	A_1	0.77	<0.00	-0.18	Ns	0.52	0.01	0.26	Ns
	A_2	0.63	0.00	0.04	Ns	0.29	Ns	-0.56	0.01
	A_3	0.00	Ns	-0.33	Ns	-0.00	Ns	0.39	Ns
	S_1	0.52	0.02	-	-	0.04	ns	-0.27	Ns
	S_2	0.36	Ns	-0.44	0.03	-0.02	Ns	-0.78	<0.00
	FR	-0.68	0.00	-	-	-0.59	0.00	-0.01	Ns
RH	A_1	-0.50	0.02	0.22	Ns	-0.10	Ns	-0.30	Ns
	A_2	-0.39	Ns	-0.20	Ns	-0.10	Ns	0.10	Ns
	A_3	0.49	0.04	0.41	Ns	0.23	Ns	-0.47	Ns
	S_1	-0.06	Ns	-	-	-0.14	Ns	0.08	Ns
	S_2	0.18	Ns	0.33	Ns	0.20	Ns	0.58	0.00
	FR	0.37	Ns	-	-	0.41	ns	-0.15	ns
Pp (mm)	A_1	-0.07	Ns	-0.24	Ns	0.48	0.03	0.04	Ns
	A_2	0.08	Ns	0.24	ns	0.51	0.03	0.10	Ns
	A_3	-0.30	Ns	0.24	Ns	-0.10	Ns	0.38	Ns
	S_1	0.13	Ns	-	-	-0.13	Ns	-0.13	Ns
	S_2	-0.06	Ns	0.11	Ns	0.25	Ns	-0.04	Ns
	FR	0.04	Ns	-	-	-0.26	ns	-0.29	ns

1 values of probability $p>0.05$ were considered non-significat (ns).

\- no present in this system.

TABLE 4: Association level between *Megninia ginglymura* and **n. gen *et* n. sp.** with predators by Spearman Correlation Coefficient (rs) and the probability of error (*p*) in laying hen houses between August 2013 to August 2014, from Rio Grande do Sul, Brazil

		Feathers				Traps				Feathers (Mg) Traps (Bd, Bk, Ce, Cm, Tt)	
		Mg		T		Mg		T		Mg	
		rs	*p*[1]	rs	*p*	rs	*p*	rs	*p*	rs	*p*
Bd	A_1	0.20	ns	-0.09	ns	-0.08	ns	0.17	ns	-0.02	ns
	A_2	-	-	-	-	-0.44	ns	-0.26	ns	-0.34	ns
	A_3	-	-	-	-	0.00	ns	-0.06	ns	-0.10	ns
	S_1	-	-	-	-	0.02	ns	0.45	0.05	-0.18	ns
	S_2	-	-	-	-	-0.24	ns	0.23	ns	-0.18	ns
	FR	-	-	-	-	-0.04	ns	-0.28	ns	-0.06	ns
Bk	A_1	-	-	-	-	0.17	ns	0.07	ns	-0.03	ns
	A_2	-0.13	ns	-0.09	ns	-0.39	ns	0.04	ns	-0.20	ns
	A_3	0.40	ns	0.23	ns	-0.34	ns	-0.45	ns	-0.11	ns
	S_1	0.02	ns	-	-	-0.08	ns	0.05	ns	0.08	ns
	S_2	0.12	ns	-0.15	ns	-0.46	0.03	-0.03	ns	-0.12	ns
Ce	FR	-	-	-	-	0.51	0.02	0.26	ns	0.72	0.00
Cm	A_1	-	-	-	-	0.25	ns	-0.13	ns	0.06	ns
	A_2	-0.13	ns	-0.09	ns	0.54	0.01	-0.53	0.02	0.40	ns
	A_3	-0.10	ns	-0.17	ns	0.26	ns	0.09	ns	0.53	0.03
	S_1	-0.25	ns	-	-	0.47	0.04	-0.05	ns	0.33	ns
	S_2	0.32	ns	-0.08	ns	-0.04	ns	-0.50	0.01	0.49	0.02
	FR	-0.34	ns	-	-	0.54	0.01	0.13	ns	0.52	0.02
Tt	A_1	-0.18	ns	-0.09	ns	-0.39	ns	-0.11	ns	-0.54	0.01
	A_2	-	-	-	-	0.04	ns	0.31	ns	-0.14	ns
	A_3	-	-	-	-	-0.40	ns	0.03	ns	-0.16	ns
	S_1	0.25	ns	-	-	0.02	ns	0.21	ns	-0.09	ns
	S_2	-0.15	ns	-0.08	ns	-0.54	0.01	-0.02	ns	-0.27	ns
	FR	-	-	-	-	0.21	ns	0.16	ns	0,21	ns

2 values of probability $p>0.05$ were considered non-significat (ns).

\- no simultaneous presence in the laying hen system.

ARTIGO 5

Horn, T.B., Rocha, M.S., Granich, J., Körbes, J.H. Ectoparasitism of commercial laying hen by *Megninia ginglymura* (Mégnin) (Acari): population dynamic and distribution on the body regions. Artigo submetido ao periódico “Experimental and Applied Acarology” (sob revisão).

Experimental and Applied Acarology

Ectoparasitism of commercial laying hen by Megninia ginglymura (Mégnin) (Acari): population dynamic and distribution on the body regions

--Manuscript Draft--

Manuscript Number:	
Full Title:	Ectoparasitism of commercial laying hen by Megninia ginglymura (Mégnin) (Acari): population dynamic and distribution on the body regions
Article Type:	Regular articles
Section/Category:	Mites
Keywords:	Body distribution, Ectoparasites, Mites, Analgidae
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Abstract:	Ectoparasites are temporary or permanent skin dwellers to get food. Megninia ginglymura (Mégnin) (Analgidae) causes economic damage in commercial poultry farms as a result of lower egg production or even death of the host. Little is known about Megninia ginglymura's life cycle and infestation. This study aimed to evaluate the preference of M. ginglymura for different body region of the host Gallus gallus L. and its abundance and population dynamics in different laying hen houses. Samplings were conducted from August 2013 to August 2014 in three different commercial laying hen systems: automatic production systems (A1,2,3); semiautomatic systems (S1,2) and free-range system (FR). Ten laying hen were sampled each laying hen house and it were collected feathers from different body regions. A total of 28,305 specimens belonging to M. ginglymura were collected. Higher abundance were noted in S1 (9,234), S2 (9,121) and FR (5,873) and lower in A2 (2,211), A3 (1,628) and A1 (238). The dorsum region showed the highest abundance, mean abundance and prevalence, representing 29.5% of the total specimens collected. The cloacal region was the second with 21.1% of the total of this ectoparasite. The abdomen and neck represented 20.8% and 19.6%, respectively. The inner wings presented the lower

	abundance, mean abundance and prevalence in all laying hen houses (9.0% of specimens). The prevalence was significantly different in the evaluated systems. The population peaks seems to coincide with periods of high temperatures and precipitation. Populations of this species already present indicative of synthetic chemical pesticide resistance.

Ectoparasitism of commercial laying hen by *Megninia ginglymura* (Mégnin) (Acari): population dynamic and distribution on the body regions

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Abstract Ectoparasites are temporary or permanent skin dwellers to get food. *Megninia ginglymura* (Mégnin) (Analgidae) causes economic damage in commercial poultry farms as a result of lower egg production or even death of the host. Little is known about *Megninia ginglymura's* life cycle and infestation. This study aimed to evaluate the preference of *M. ginglymura* for different body region of the host *Gallus gallus* L. and its abundance and population dynamics in different laying hen houses. Samplings were conducted from August 2013 to August 2014 in three different commercial laying hen systems: automatic production systems ($A_{1,2,3}$); semiautomatic systems ($S_{1,2}$) and free-range system (FR). Ten laying hen were sampled each laying hen house and it were collected feathers from different body regions. A total of 28,305 specimens belonging to *M. ginglymura* were collected. Higher abundance were noted in S_1 (9,234), S_2 (9,121) and FR (5,873) and lower in A_2 (2,211), A_3 (1,628) and A_1 (238). The dorsum region showed the highest abundance, mean abundance and prevalence, representing 29.5% of the total specimens collected. The cloacal region was the second with 21.1% of the total of this ectoparasite. The abdomen and neck represented 20.8% and 19.6%, respectively. The inner wings presented the lower abundance, mean abundance and prevalence in all laying hen houses (9.0% of specimens). The prevalence was significantly different in the evaluated systems. The population peaks seems to coincide with periods of high temperatures and precipitation. Populations of this species already present indicative of synthetic chemical pesticide resistance.

Keywords Body distribution, Ectoparasites, Mites, Analgidae.

Introduction

Parasitism is now widely recognized as a factor that can influence the composition and structure of natural animal communities (Minchella and Scott 1991; Combes 1996; Hudson and Greenman 1998; Poulin 1999). The presence of certain species, or their abundance relative to other species in a community, may be entirely dependent on the action of parasites. Ectoparasites are temporary or permanent skin dwellers to get food (skin, blood, lymph and skin appendices), heat and protection.

Several groups of ectoparasites can attack avian and are classified into two large groups, where the first is represented by those who feed only on tegumental surface and epithelial attachments, such as feathers or dead skin cells, and the other group may cause higher impact, through spoliation (blood or lymph), irritation and more significant economic loss (Rezende et al. 2013; De Vaney 1986).

Avian ectoparasites, which include arthropods, play an important role in the poultry industry. It is also responsible for influencing the health, animal welfare and the egg quality. One important group of ectoparasites are the feather mites, which occurs in every order of birds worldwide (Gaud and Atyeo 1996; Mironov and Proctor 2008). They inhabit the skin (dermicoles), the surface of feathers (plumicoles) or the inner calamus (syringicoles) (Proctor 2003). The transmission of the feather mites is generally realized by direct physical contact between birds of the same species, which results in high specificity of these mites to their hosts, often revealing impressive cases of parallel evolution (Mironov and Dabert 1999; Dabert 2004). As a result, the infestation of avian ectoparasites in confinement, as laying hen in a poultry farm, spread fast over almost all creation.

Feather mites of the genus *Megninia* Berlese are found in various genera and species of poultry, in particular *Megninia ginglymura* (Mégnin) (Analgidae) that causes up to 20% lower egg production or even death in poultry (Monteiro 2005; Sparagano et al. 2009). *Megninia ginglymura* lives in association with feathers remaining in the laying hen body and attacks feathers of the dorsum, chest and uropygium, leaving theses areas chewed, cut or rarified. In addition, the mite saliva can cause lesions, allergic reactions, serious scabs, stress, crust formation and secondary bacterial infections (Tucci et al. 2005). *M. ginglymura* infestation in different body regions of laying hen showed that higher densities were observed on the dorsum and tail, while lower densities were observed on the wings and chest (Hernández et al. 2007).

Silva et al. (2013) found *M. ginglymura* associated with nests and feather of laying hens, while Horn et al. (2016) when evaluating different commercial laying hens systems observed that *M. ginglymura* was the main species of veterinary health. The knowledge on the distribution of *M. ginglymura* in the laying hen body region as well as in the different laying hen management guarantees most successful control strategies by synthetic chemicals, biological control, and acaricidal activity of some plant extracts or alternative control.

Thus, the aim of this study was to compare the population dynamics of the feather mite *M. ginglymura* in the host *Gallus gallus* L. under three different ways of creating commercial laying hens. It also aims to understand the distribution of *M. ginglymura* in the different body regions of the host *G. gallus*. Considering that different laying hen management change the characteristics of the mite fauna (Horn et al. 2016), and that poultry ectoparasites differ in their population dynamics according to body regions of the host (Hernández et al. 2007), it was assumed that (1) different laying hen systems change the population dynamics of *M. ginglymura*. Additionally, it was expected (2) different distribution of *M. ginglymura* between the body regions of the host, due to the differences in conditions and resource availability.

Material and Methods

This study was conducted in different commercial laying hen systems between August 2013 and August 2014 in Lajeado municipality, Taquari Valley, state of Rio Grande do Sul, Brazil.

Six poultry houses were sampled, where in three of them the laying hen system consisted of an automated vertical battery cages, two semi-automated and one free range. In automated systems ($A_{1,2,3}$), the laying hen were confined in metal cages on six floors with an area of approximately 450 cm^2/hen (nine hens/cage), and the cages were placed on top of the other in stacks of four. Hen feed was provided in a metal structure and water in nipple-type drinker, and eggs were collected on an automatic treadmill. In addition, feces were collected at least three times per week by treadmills at the bottom of the floor of cages. In this laying hen system, there are screens throughout the laying hen house to prevent wild bird access.

Among the A_1 laying hens, 39,000 white laying hens of the Bovans breeds were maintained and two batches were evaluated: the first, with 45 weeks old at the beginning of sampling and 94 weeks old in July 2014, when it was replaced by a new batch at 16 weeks old and evaluated up to 20 weeks old in August 2014, giving a total of 21 samples (nA_1: 210). In A_2, there were 60,000 laying hens, 50% Bovans breed (left side of the laying hen house) and 50% Isa Brown breed (right side of the laying hen house). The batch was 68 weeks old at the beginning of sampling and 98 weeks old in March 2014. A new batch was introduced in April 2014 at 17 weeks old and evaluated up to 37 weeks old in August 2014, resulting in 20 samples (nA_2: 200). In A_1 and A_2, Topline® (fipronil 1%) was added to the feed in September 2013 as routine management to control parasites. In A_3, there were 35,000 red Isa Brown laying hens, the evaluation began with a batch of 99 weeks old evaluated up to 109 weeks old in October 2013. A new batch of 19 weeks old was introduced in December 2014 and evaluated up to 54 weeks old in August 2014, giving a total of 17 samples (nA_3: 170). In this system, Couro Limpo® (15% cypermethrin, 25% chlorpyrifos and 1% citronellal) was applied twice in April 2014.

In the semi-automated laying hen system ($S_{1,2}$), the cages were arranged in the form of stair steps with two stacks of cages in each poultry house. Feed and water were provided in an automated manner and eggs collected manually. The S_1 system was a wood structure in the style of a “California house,” and S_2 was a “wide-span model” (Axtell 1986). S_1 did not receive any type of pesticide application during the evaluation period and was considered the semi-automated control. S_1 housed 7,750 red DeKalb laying hens, with 45 weeks old at the beginning of sampling and 88 weeks old in July 2014 when the batch was removed, totaling 18 samples (nS_1: 180). S_2 housed 10,400 red Isa Brown laying hens, 41 weeks old at the beginning of sampling and 95 weeks old in August 2014, totaling 22 samples (nS_2: 220). This system received Topline® in the feed in September 2013 and May 2014. The systems S_1 and S_2 allowed the entry of wild birds.

The other laying hen house evaluated was raised free under a sawdust bed arranged over ground, popularly known as free range (FR). In Brazil, this system is popularly known as "caipira". In FR, 3,500 red Isa Brown laying hens were housed, they were 44 weeks old and evaluated up to 88 weeks old in July 2014, when they were removed, totaling 19 samples (nFR: 190). Feed and water were provided in an automated way and egg collecting was manual. The nests were packed in a wooden structure with sawdust inside for maintenance of eggs. The laying hens were released in the day to sunbathe, ground pecking and wing flapping. The nests were treated with Bolfo® (propoxur 1%) powder in December 2013 and January and April 2014. The sampling efforts were different in the laying hen houses due to the absence of laying hen in some periods depending on the pause between the disposal of the old bath and entrance to the new laying hen batch. Cars’ access from other hen houses has been denied throughout the study.

Mite samplings

To collect the ectoparasites, it were examined ten laying hen for each laying hen houses, selecting chickens along the length of laying hen house. The number of mites collected from each body regions was recorded. From each laying hen, it was collected a total of five feathers, being one from each body regions: abdomen (Ab), cloaca (C), dorsum (D), inner wings (W) and neck (N) (Fig. 1).

The feathers were placed in plastic containers 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. The 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, extension of legs and diaphanization of specimens.

Data analyses

Infestations of mites were described and calculated by abundance (number of mites on host), mean abundance (the total number of mites in a sample of the host divided by the total number of hosts) and prevalence (number of hosts infected with one or more mite divided by the number of hosts examined) (Bush et al. 1997). The abundance (number of mites on each body region of the hosts), mean abundance (the total number of mites in a body region of the host divided by the total number of hosts) and prevalence (number of host infected in a particular body region divided by number of host examined) was also calculated for each body region.

Finally, to evaluate preference of mites for a particular body region and for the different laying hen system, randomization analyses with contrasts and 1000 permutations were made with software MULTIV 3.47 (Pillar 2006). To evaluate the influence of abiotic factors (relative humidity, temperature and precipitation) on the abundance of *M. ginglymura* in the different laying hen house, multiple linear regressions were carried out using the statistical program SYSTAT 13 (Systat Inc.).

Results

A total of 1,170 laying hens were sampled during this study and 28,305 mite specimens belonged to *M. ginglymura* species (Figure 2).

Mite abundance and prevalence in laying hens

The abundance was significantly different among the evaluated confinement systems (F= 1.17; p<0.001). Higher abundance were associated to the semiautomatic systems S_1 (9,234), S2 (9,121) and in the FR system (5,873) (Table 1). Lower abundance occurred in the automated systems A_2 (2,211), A_3 (1,628) and A_1 (238). When the systems were compared in pairs, only A_2 and A_3 showed no significant difference between them.

Only the laying hens present in the system S_1 showed to be one hundred percent parasitized by *M. ginglymura,* with a mean abundance of 51.30 mites/host. The prevalence and the mean abundance in other systems was 96.8% and 41.46 mites/host in S_2; 93.2% and 30.91 mites/host in FR; 51% and 9.58 mites/host in A_3; 43.5% and 11.06 mites/host in A_2; and only 11.9% and 1.13 mites/host in A_1 (Table 1; Figure 3). The prevalence was significantly different between the different laying hen systems (F= 2677; p<0.001). When the systems were compared in pairs, A_2 and A_3 had significant difference between them. The highest individual intensity was 106 mites/host in FR, and in all systems at least one laying hen without infestation of *M. ginglymura* along the evaluations was observed, except in S_1, in which the lower individual intensity was two specimens of mites.

The *M. ginglymura* populations were influenced by abiotic factors as humidity relative, temperature and precipitation (R^2A_1=0.69, F= 12.624, p<0.001; R^2A_2=0.558, F= 6.738, p<0.001; R^2S_1=0.61, F= 7.295, p<0.001; R^2S_2=0.596, F=8.837, p<0.001 and R^2FR=0.669, 10.094; p<0.001), except in A_3 where the environmental variables did not influence their populations (Figure 4).

The population peaks were registered in January 2014 in A_1, January-February 2014 in A_2, coinciding with periods of high temperatures and precipitation; in A_3 the population peak was registered between March and April 2014; in S_1, the population peak was in October 2013 to April 2014 coinciding also with periods of high temperature; in S_2, between December 2013 to May 2014; in FR, high population were observed between August to November 2013.

Mite distribution in corporal regions

In the laying hens evaluated, all body regions presented *M. ginglymura* infestation, however this species showed distinct preferences for microhabitats on the host (F= 0.019787; p<0.001) (Table 1). The dorsum region showed the highest mite abundance, mean abundance and prevalence in the systems, representing 29.5% of total specimens collected, except in A_1 (Figure 5). The cloaca region was the second body region with higher numbers, representing 21.1% of total of *M. ginglymura*. The abdomen represented 20.8% and the neck region 19.6% of specimens of mites. The inner wings region presented the lower abundance, mean abundance and prevalence in all laying hen systems, representing 9.0% of specimens. The prevalence was significantly different in the laying hen systems evaluated (F= 1471; p<0.001). When the prevalence was compared in pairs, the body regions abdomen - cloaca, cloaca - wings, dorsum - wings and neck - wings presented significant difference between them.

Discussion

Mite abundance and prevalence in laying hens

In the present study, the analyzed data showed evidences that the management influences the abundance, mean abundance and prevalence of *M. ginglymura* in laying hen systems, corroborating with our first hypothesis. The same was reported for the general community of mites associated with laying hens (Horn et al. 2016). Intensive confinement of laying hen induces greater proliferation of ectoparasitic mites (Sparagano 2009) leaving the chickens constantly subjected to stress conditions (Tucci et al. 2005).

However, the opposite was observed in this study since the automated laying hen house (A_1, A_2 and A_3) seems to induce less abundance and prevalence than other types of management systems where there is less intensive confinement. Automated systems allow a greater confinement of laying hen in less area being commercially more advantageous to increase the productivity per area.

Although, considering the animal welfare, there is a worldwide trend to opt for the management of free laying hen (FR). The FR management induces to a more diverse community of mites and richness allowing greater presence of predatory mites that help the balance between the communities of mites of health importance (Horn et al. 2016). The number of chickens by cage and the number of chickens by square meter were not significant parameters for increase the *M. ginglymura* infestation (Rezende et al. 2015).

Even in laying hen house with a considerable abundance of *M. ginglymura*, it was observed that all systems had hosts with zero intensity, except S_1 in which one hundred percent of the chickens were parasitized by *M. ginglymura*. Although not a variable evaluated in this study, it is noteworthy that this was the only system that had no application of synthetic chemical pesticides during the period of sampling. No association was observed between the use of acaricides and the occurrence of infestations by *M. ginglymura,* due to fact that these pesticides are used on the control of other species of mites (Rezende et al. 2015).

When evaluating laying hen houses in Cuba, Hernández et al. (2006) showed that 89.6% of them were infested by *M. ginglymura* and the prevalence of this species was 89.8% of total laying hen houses evaluated. In Brazil, 18.09% of laying hen houses in Minas Gerais State were infested by *M. ginglymura* (Rezende et al. 2015).

In the automated systems, the population peaks seems to coincide with periods of high temperatures and precipitation. In A_3, the peak was late, between March-April 2014, due to the new batch of laying hen introduced only in January 2014. The application of synthetic chemical pesticides has been able to reduce populations in these systems and maintain it in low numbers for several months. In semi automated systems, the population peak was broader (S_1: October 2013 to April 2014; S_2: December 2013 to May 2014), coinciding with high temperature periods. It is worth mentioning that there was no application of chemical pesticides in S_1, and there was application of pesticides in two different times in S_2, in which it failed to reduce *M. ginglymura* populations that very soon returned to growth. In FR, high populations were drastically affected after application of pesticides in December 2013. However, in

February 2014, *M. ginglymura* population returned to grow and was never influenced by new pesticide application held in April 2014. Populations of this species already present indicative of synthetic chemical pesticide resistance.

The population peak of *M. ginglymura* occurred in April in the laying hen kept in battery cage system (22.3 mites/hen), and between February to April in the laying hen kept in free range (16.3 mites/hen) (Faleiro et al. 2015), being both in same geographical region. These differences may be related to the seasonal temperature, with population peaks occurring in warmer months in free-range chickens, but in the colder months in battery cages (Quintero et al. 2010).

Mite distribution in corporal regions

Regarding the body region distribution of *M. ginglymura* in the host, this species showed infestations throughout of the body of laying hen with preferences in distinct microhabitats, thus corroborating with our second hypothesis. The *M. ginglymura* body region distribution seems to be different in laying hen houses with lower abundances than those with higher abundances. Overall, the dorsum region showed the highest infestation, followed by the cloaca and adbome. These preference can be explained because these areas offer a large availability of space and also probably the laying hen had more difficult to removal the mites from dorsal region. This body region also presents the higher infestations in other studies, being an interesting body region to be considered for the application of pesticides or Integrated Pest Management (Hernández et al. 2007).

Lower infestations were registered in the inner wings. During the observation of laying hen feather in stereomicroscopic to account the mites, it was found that the feathers collected from the inner wings body region always had large amounts of *M. ginglymura* eggs, when compared to other body regions. However, it was not accounted for such disproportion. Since this area had the lowest values of abundance, mean abundance and prevalence, probably this mites use this body region for oviposition due to greater protection and maintenance of body heat.

According to the degrees of model criteria of *M. ginglymura* infestation proposed by Hernández et al. (2007), the infestations in all evaluated systems varies between the degree very light (1-5 mites/feather) to light (6-25 mites/feather). The damage caused by this mite to laying hen is still not well defined. Tucci et al. (2005) reported that laying hens parasitized by *Megninia* spp. seemed to be weakened, angry, smelly, and in some cases the feather had lost their plumage or occurred lack of feathers on the head, besides loss in egg production.

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Legends to figures

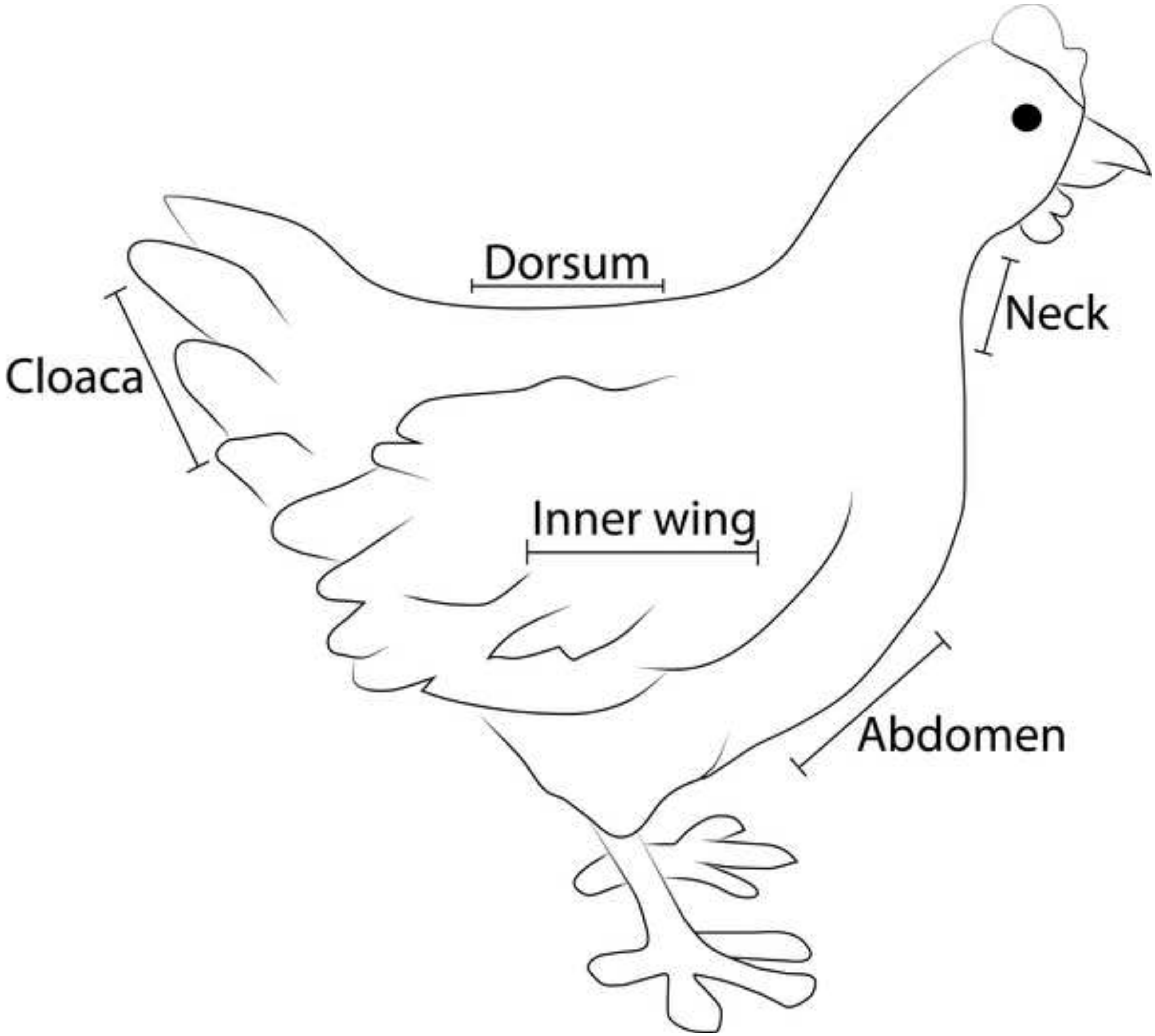
Fig. 1 Body regions sampled in the laying hens: abdomen, cloaca, dorsum, inner wings and neck.

Fig. 2 *Megninia ginglymura*: male (**A**) (A: 20x) and female (**B**) (40x). Detail of epimers I unfused.

Fig. 3 *Megninia ginglymura* abundance in laying hen houses ((**A**): A_1, (**B**): A_2, (**C**): A_3 – automated systems; (**D**): FR- free range; (**E**): S1, (**F**): S2-semi automated system) between August 2013 and August 2014 in Lajeado municipality, Rio Grande do Sul, Brazil

Fig. 4 Populational fluctuation of *M. ginglymura* between August 2013 and August 2014 in Lajeado municipality, Rio Grande do Sul, Brazil. **A**: A_1, A_2, A_3 – automated systems; **B**: S_1, S_2-semi automated system, FR- free range (arrows indicate the application of synthetic chemical pesticides)

Fig. 5 Frequency distribution of *Megninia ginglymura* on body regions (abdomen (Ab), cloaca (C), dorsum (D), neck (N) and inner wings (W)) of laying hen (A_1, A_2, A_3 – automated systems; FR- free range; S_1, S_2-semi automated system) between August 2013 and August 2014 in Lajeado municipality, Rio Grande do Sul, Brazil


Dorsum
Neck
Cloaca
Inner wing
Abdomen

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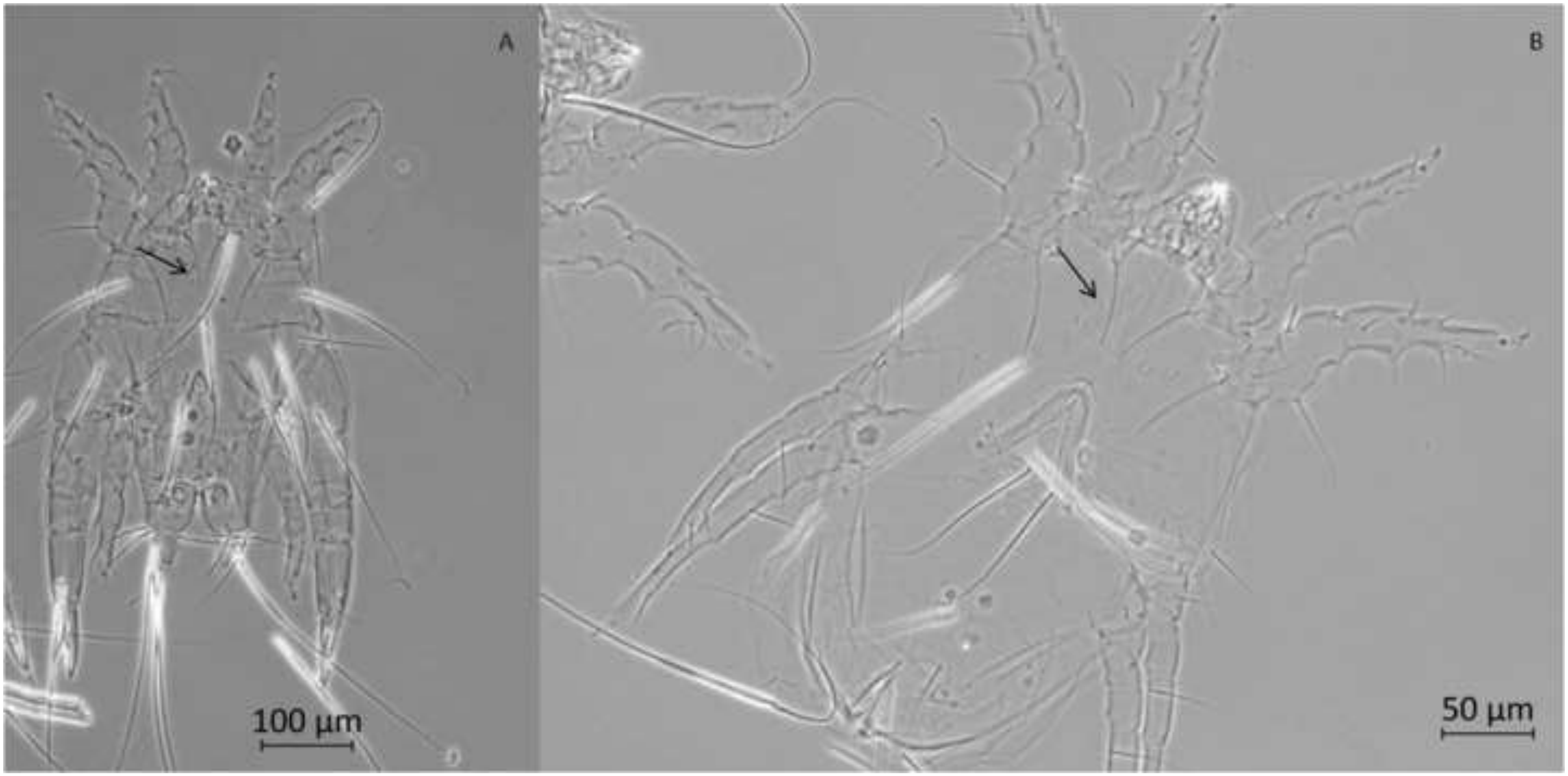

Figure 3

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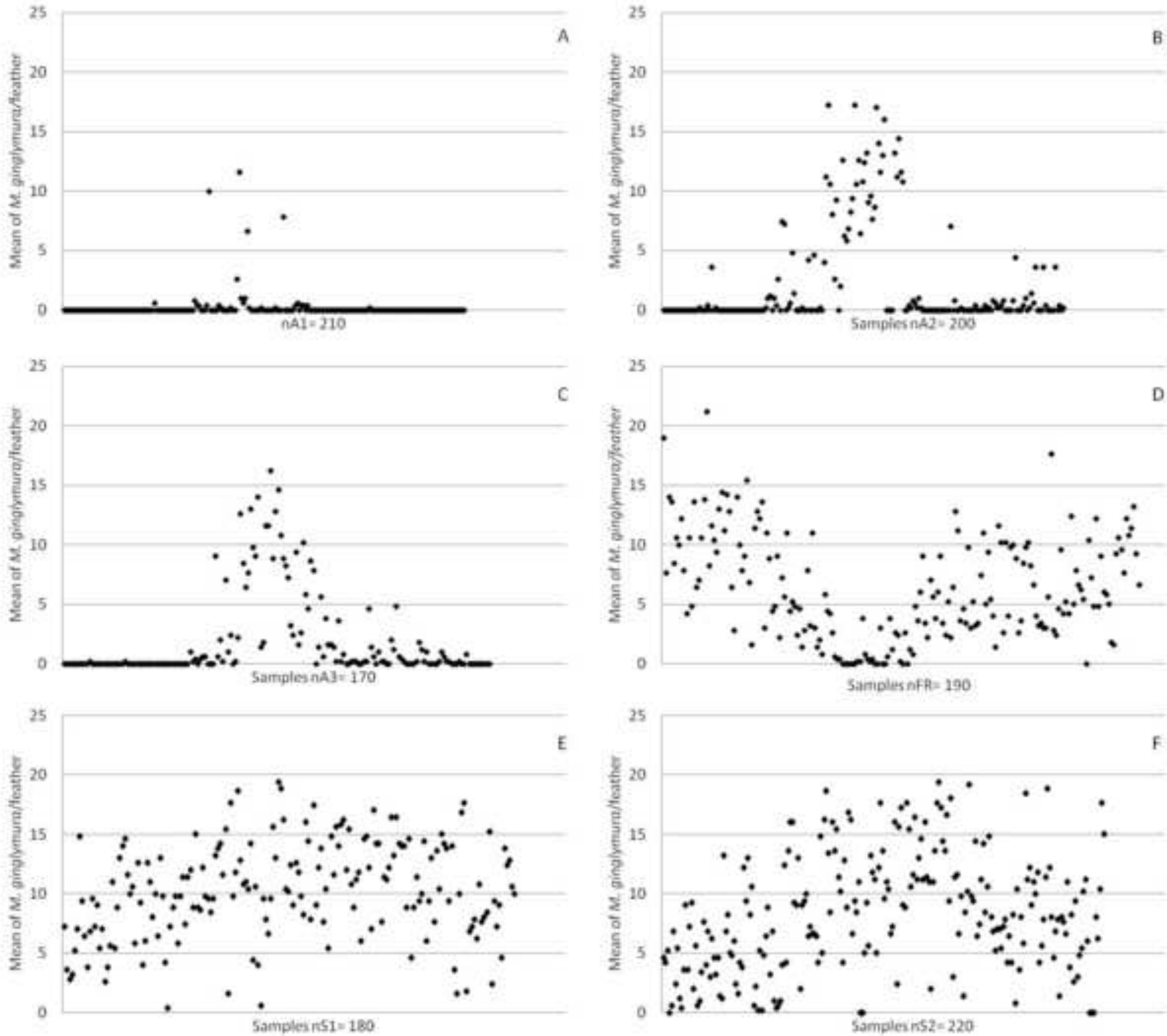

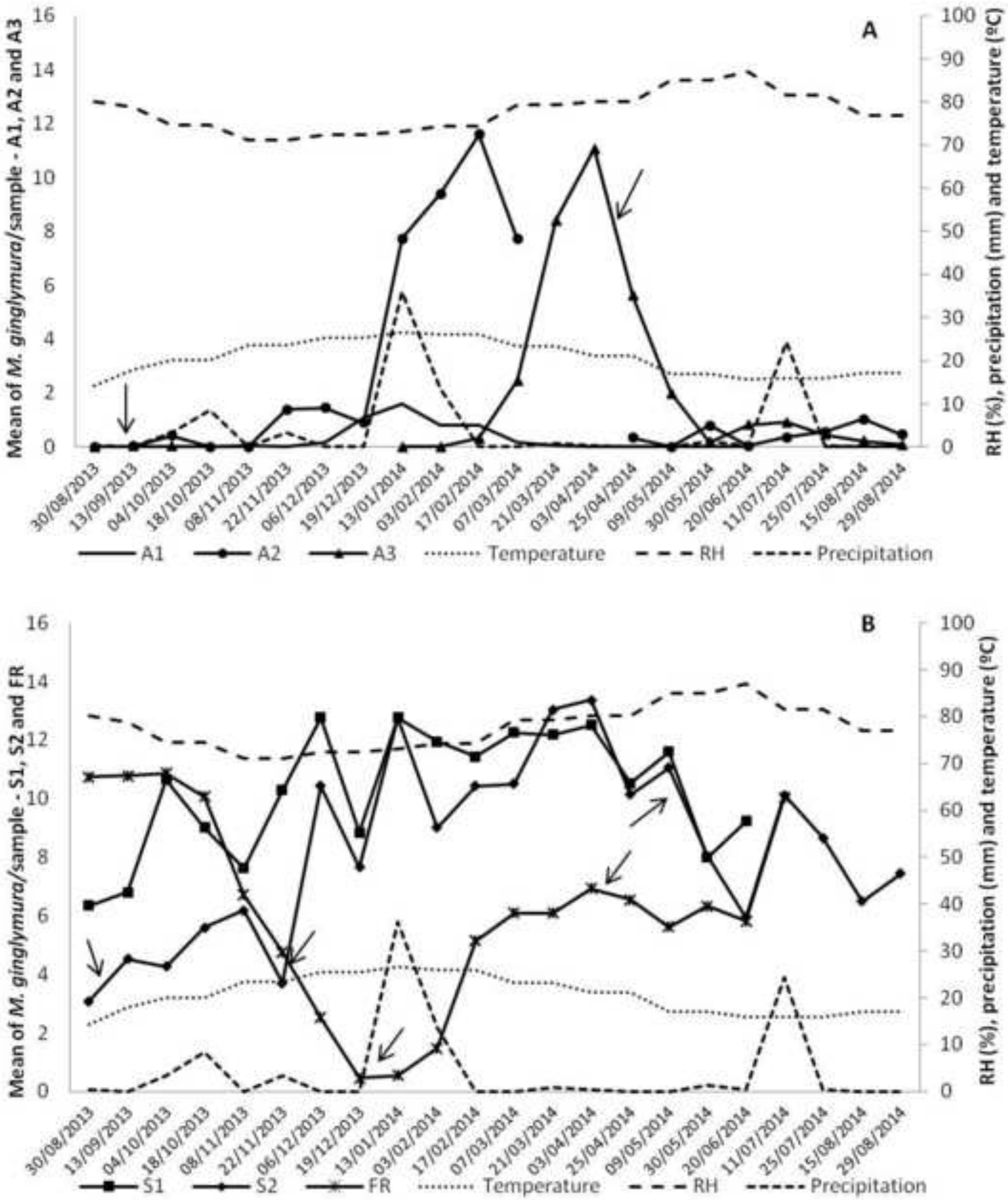
A
Mean of M. ginglymura/sample - A1, A2 and A3
RH (%), precipitation (mm) and temperature (ºC)
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
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80
90
100
30/08/2013
13/09/2013
04/10/2013
18/10/2013
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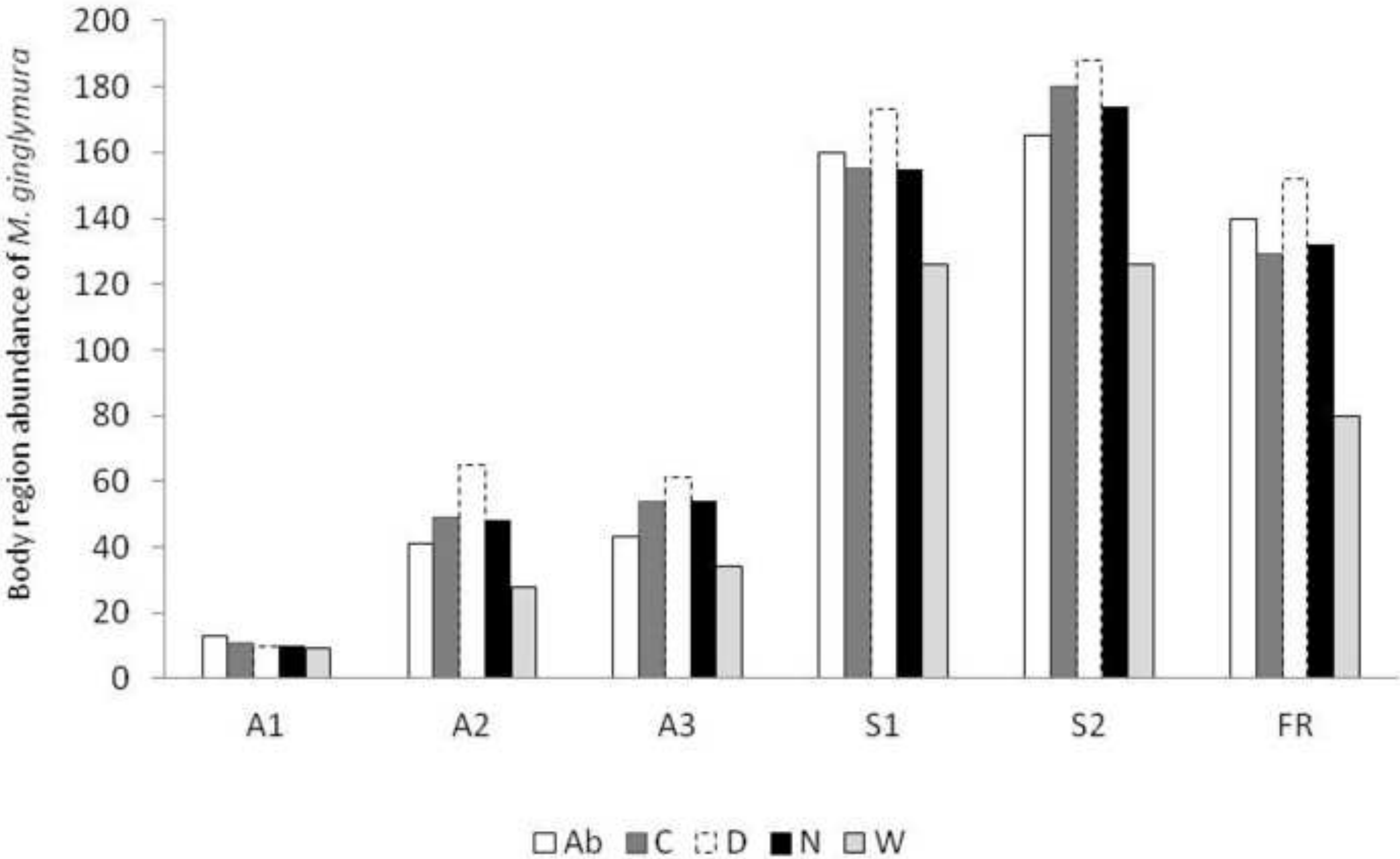
09/05/2014
30/05/2014
20/06/2014
11/07/2014
25/07/2014
15/08/2014
29/08/2014
A1
A2
A3
Temperature
RH
Precipitation
B
Mean of M. ginglymura/sample - S1, S2 and FR
RH (%), precipitation (mm) and temperature (ºC)
S1
S2
FR
Temperature
RH
Precipitation



Body region abundance of *M. ginglymura*
200
180
160
140
120
100
80
60
40
20
0
A1
A2
A3
S1
S2
FR
Ab
C
D
N
W

Table 1. Parasitic descriptors of *Megninia ginglymura* extracted from different body regions of laying hen in different systems of confinement

	Abundance[a]						Mean abundance[b]						Prevalence (%)[c]					
BD	A_1	A_2	A_3	S_1	S_2	FR	A_1 n: 210	A_2 n: 200	A_3 n: 170	S_1 n: 180	S_2 n: 220	FR n: 190	A_1	A_2	A_3	S_1	S_2	FR
Ab	86	447	299	1,833	1,794	1,437	0.41 (0-3.20)	2.24 (0-11.20)	1.76 (0-11.50)	10.18 (0.43-14.20)	8.15 (2.90-15.20)	7.56 (1.00-14.00)	6.19±1.21	20.50±1.05	25.29±1.06	88.89±1.04	75.00±1.04	73.68±1.08
C	38	505	355	2,002	2,033	1,037	0.18 (0-2.50)	2.53 (0-17.30)	2.09 (0-11.40)	11.12 (0.62-19.30)	9.24 (1.00-17.50)	5.46 (0.20-14.50)	5.24±0.79	24.50±1.22	31.76±1.06	86.11±1.07	81.82±1.07	67.89±0.96
D	44	647	493	2,597	2,746	1,812	0.21 (0-2.00)	3.24 (0-15.20)	2.90 (0-13.10)	14.43 (1.14-18.20)	12.48 (4.30-18.60)	9.54 (0.3-17.30)	4.76±0.87	32.50±1.14	35.88±1.12	96.11±1.06	86.45±1.06	80.00±1.05
N	58	454	288	1,869	1,701	1,189	0.28 (0-2.10)	2.27 (0-12.10)	1.69 (0-13.90)	10.38 (0.40-15.70)	7.73 (0.40-16.10)	6.26 (0.1-13.40)	4.76±0.94	24.00±1.10	31.76±0.96	86.11±1.05	79.09±1.05	69.47±1.10
W	12	158	193	933	847	398	0.06 (0-0.40)	0.79 (0-5.20)	1.14 (0-10.00)	5.18 (0.12-9.80)	3.85 (0.20-10.00)	2.09 (0-6.00)	4.29±0.14	14.00±0.81	20.00±0.83	70.00±0.97	57.27±0.97	42.11±0.68
Total	238	2,211	1,628	9,234	9,121	5,873	1.13	11.06	9.58	51.30	41.46	30.91	11.9	43.5	51	100	96.8	93.2

BD: body region; Ab: abdomen, C: cloaca, D:dorsum, N: neck, W: wings.

[a]Abundance: number of mites collected.

[b]Mean abundance: total number of mites collected/total number of host.

[c]Prevalence: number of host infected in a body region/host examined (This percentage can be repeated because the hosts may be infected in equal numbers in different body regions) and the 95% confidence intervals.

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ARTIGO 6

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Development of *Cheyletus malaccensis* (Acari: Cheyletidae) feeding on mite species found in commercial poultry systems: *Megninia ginglymura* (Acari: Analgidae) and *Tyrophagus putrescentiae* (Acari: Acaridae)

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Abstract

Intensive egg production affects the welfare of confined laying hens, which increases the risk of epidemics. Ectoparasitic hematophagous mites and saprophagous feather mites cause low productivity and decreased egg quality. This study aimed to compare the biology of *Cheyletus malaccensis* (Oudemans) (Prostigmata: Cheyletidae) feeding on the prey *Megninia ginglymura* (Mégnin) (Astigmata: Analgidae) and *Tyrophagus putrescentiae* (Schrank) (Astigmata: Acaridae) in order to support the potential use of this predator in biological control strategies in the poultry industry. The study started with 30 eggs of *C. malaccensis*, isolated in experimental units, which developed into their different stages while feeding on the feather mite *M. ginglymura* and the stored product mite *T. putrescentiae* at 25±1ºC, 80±5% relative humidity and 12-hour photoperiod. Immature stages were evaluated three times a day and the adult stage once a day. Adult females were unmated. *Cheyletus malaccensis* feeding on *M. ginglymura* resulted in a higher fertility rate, with 310.7±45.8 eggs/female, than with *T. putrescentiae* as prey, with 32.7±4.5 eggs/female. Furthermore, the oviposition period was higher feeding on *M. ginglymura*, 53.0±6.3 days, than on *T. putrescentiae*, 12.6±1.9 days. The net reproductive rate (R_o), the innate capacity for increase (r_m), the mean generation time (T) and the finite rate of increase (λ) were higher for the generation fed on *M. ginglymura*. *Cheyletus malaccensis* is a likely natural enemy of *M. ginglymura*, and it is able to develop and reproduce while feeding exclusively on it.

Keywords: ectoparasite, saprophage, chicken, predatory mites, feather mites, Brazil

Introduction

Aviculture has undergone changes in the production process resulting from technological innovations that have led to automation of activities, and increasing scale and productivity (Belusso & Hespanhol 2010). However, intensive egg production affects the welfare of laying hens and increases the risk of epidemics, and it can be affected by various complications, such as ectoparasites and commensal mites (Guimarães & Leffer 2009).

Mite infestations can cause low productivity and decreased egg quality. Among these, feather mites can cause allergic reactions with pruritus (Tucci *et al.* 2005), leading to secondary bacterial contamination and thus to lower production. Moreover, such infestation may trigger stress in these birds. Besides, such stressed birds may have high levels of corticosteroids, which can result in reduced food intake, decrease in gonadal activity, cardiovascular disorders and less effective immune response (De Vaney 1986).

The feather mites pass their life cycle on the host, ovipositing on feathers (Hernandez *et al.* 2007), fragments of which form part of their diet. The mites of the genus *Megninia* Berlese can be clustered in body parts such as head, chest, back and wings. In Brazil, *M. ginglymura* (Mégnin) and *M. cubitalis* (Mégnin) have been reported parasitizing commercial laying hens (Tucci *et al.* 2005). The parasitized birds are quite weak, angry, and smelly, with damaged feathers and dermatitis with secretions (Tucci *et al.* 2005). Among the consequences of the infestation is particularly the appearance of lesions caused by saliva, itching and scabs formed from serous exudate. Fungal contamination on lesions is also quite common (Tucci *et al*. 2005). A 20% decrease in yield in egg production has been reported to be caused by infestation by this group of mites (Quintero *et al.* 2010).

Tyrophagus spp. are best known as fungivorous pests of stored foods, but some also live in field habitats where they may feed on invertebrate eggs and immatures, and on living higher plant material (Hughes 1976; Gerson *et al*. 2003). *Tyrophagus putrescentiae* (Schrank) is an important cosmopolitan stored food mite that, in the temperate climate of the UK, is most frequently found in high fat and protein content food (Hughes 1976), and may represent a more ancient source of mite allergen exposure than *Dermatophagoides* spp. (Colloff 2009). In commercial laying hens, higher populations of this species have been found in nests and lower populations in feathers (Faleiro *et al.* 2015).

Most cheyletid mites are known to have a predatory habit and a few species have been considered as biological control agents of pest mites (Gerson *et al*. 2003). *Cheyletus eruditus* (Schrank) is reported to be a natural enemy of *Dermanyssus gallinae* (De Geer) (Mesostigmata: Dermanyssidae) an ectoparasite of laying hens in poultry systems (Lesna *et al.* 2009), and also of stored food pests (Žďárková 1998; Žďárková & Horák 1990). *Cheyletus malaccensis* (Oudemans) is known to be effective in attacks on *T. putrescentiae* and another stored products pest as *Glycyphagus destructor* (Schrank) (Astigmata: Glycyphagidae) and besides already tested with these mites as prey: *Acarus siro* L., *Aleuroglyphus ovatus* (Troupeau), *Caloglyphus redickorzevi* Zachvatkin and *Caloglyphus rodriguezi* Samšiňák (Astigmata: Acaridae) (Cebolla *et al*. 2009; Al-Shammery 2014) and has been proposed as an effective biocontrol species of these pests.

The traditional strategy in the control of pest species in poultry systems, *i.e*., with synthetic chemical pesticides, tends in the long term to cause resistance to develop in mites, and the pesticides have adverse effects on the birds' nervous system and can be immunosuppressive and carcinogenic as well (Nero *et al.* 2007; Marangi *et al.* 2009; Wright *et al.* 2009). Furthermore, synthetic acaricides can leave residues in eggs, meat, liver and animal adipose tissue.

Alternative pest control using natural enemies allows the use of cleaner practices and is less environmentally impactful (Lesna *et al.* 2009). In stored foods, several other strategies have been tested such as juvenile hormone analogues, moulting hormone (ecdysone) agonists, chitin synthesis inhibitors, inert dust, plant extracts and others (Collins 2006). This avoids the use of synthetic acaricides (Chirico & Tausan 2002) and the handling of toxic products by the farmer (Guimarães 2000), who often uses unsuitable products in various situations (Sparagano *et al.* 2009). Alternative control with natural enemies involves mass rearing, but it is still not known how to maintain and increase the populations of many potential control species. Moreover, finding an alternative food that facilitates population growth in the laboratory is also essential, because successful biological control strategies should take into account that in time of prey shortage, a good predator needs to have the ability to make use of some alternative food in the field.

In southern Brazil, the veterinarily important *M. ginglymura* was the most abundant mite infesting chickens in different commercial systems of laying hens and *C. malaccensis* the most abundant predator (Silva *et al.* 2013; Horn *et al.* 2016). We studied the capacity of *C. malaccensis* to develop on *M. ginglymura* in order to support the potential use of this predator in applied biological control strategies in the poultry industry and also evaluated *T. putrescentiae* as an alternative food in this situation. These data are a fragment of wider research about candidate predators of mites in the poultry industry already partly published in Silva *et al.* (2016).

Materials and methods

This study was conducted from June to December 2015 and voucher specimens of *C. malaccensis*, *M. ginglymura* and *T. putrescentiae* were deposited in the mite reference collection of the Museu de Ciências Naturais of Centro Universitário UNIVATES (ZAUMCN), Lajeado, Rio Grande do Sul State, Brazil.

Stock colonies

Tyrophagus putrescentiae individuals were obtained from corn flour used to feed laying hens in Lajeado. The stock colony was started about six months before this study. The units in which the colony was maintained were composed of a plastic plate (12 x 10 cm) placed on a foam mat permanently soaked with distilled water on another plastic plate. The margins of the plate were covered with a layer of cotton wool to prevent the mites escaping. Each colony unit was filled with corn flour and *T. putrescentiae*. The experiments were conducted in a rearing chamber at 25±1ºC, 80±5% relative humidity (RH) and 12-hour photoperiod.

Megninia ginglymura mites were obtained directly from chicken (*Gallus gallus* L.) feathers from poultry houses; the feathers were examined under a stereoscopic microscope to collect the mites, which were then put in experimental units.

Cheyletus malaccensis individuals were obtained from PVC (polyvinyl chloride) traps (Tucci *et al.* 1988) collected from poultry farms of laying hens. *Cheyletus malaccensis* colonies were established and maintained using the same conditions as *T. putrescentiae*.

Different stages and eggs of *T. putrescentiae* and *M. ginglymura* were offered one month before the study started.

Experimental units

The experimental units for the prey *M. ginglymura* consisted of a circle of dark plastic plate (6 cm in diameter and 1.5 cm in height) on a plastic plate covered with plastic film. The margins of the plate were covered with a layer of cotton wool to prevent the mites escaping. In evaluations with *T. putrescentiae*, the prey were tested in experimental units of 2.5 cm in diameter and 1.5 cm in height covered with Parafilm (Silva *et al.* 2016). The units were kept in a rearing chamber at 25±1ºC and 80±5% RH, with a 12-hour photoperiod. Thirty experimental units per food type were studied.

The study started with 30 eggs of *C. malaccensis,* which were individualized and obtained from fertilized females per type of food from the stock colony for each experimental unit. Post-embryonic stages of the predators were fed with a mixture of all prey stages considered as active forms. The control consists of five replicates kept without food.

The females were removed after oviposition leaving a single egg in each unit. Immature stages were evaluated three times a day (7 a.m., 1 p.m. and 7 p.m.). Events that occurred after 7 p.m. were estimated to have occurred halfway to the next observation, *i.e*., at 1 a.m. During the oviposition phase, a single observation was made daily at 1 p.m. In the adult stage, sex determination was performed visually, and unmated females provided parthenogenetic reproduction. During the oviposition phase, the eggs were counted and removed from the experimental units. Inside the experimental units, there was a piece of black plastic folded in the shape of an inverted 'V' to function as a place of refuge for *C. malaccensis*.

Data analysis

The data for the immature phases were compared using the Student's t-test at the 5% significance level with the software BioEstat 5.0 (Ayres *et al.* 2007). The data obtained were organized for life table calculations using the jackknife method (Maia *et al.* 2000), and net reproductive rate (R_o = Σ*mx.lx* – *mx*: total eggs/number of females; *lx*: live specimens/total specimens), average length of a generation (T = *mx.lx.x/mx.lx* Σ), innate capacity for increase (r_m = log R_o/T.0.4343), finite rate of increase (λ = antilog r_m) and doubling time (DT = ln(2)/rm) were calculated. Given the significant differences, means were compared with the bilateral t-test ($p \leq 0.05$), using the software SAS™ (SAS Institute 2000).

Results

The results obtained throughout incubation, and larval and protochrysalis phases showed no significant difference in duration on either prey tested (Table 1). The mortality of all *C. malaccensis* occurred as larvae in the control studies. However, the duration of the protonymph, nymphochrysalis and deutonymph stage were significantly greater for *M. ginglymura* than *T. putrescentiae*. Comparing the egg–adult period, there was a significant difference between the two test prey, being 25.0±0.4 days for *M. ginglymura* and 20.9±0.5 days for *T. putrescentiae*. Therefore, *C. malaccensis* had a shorter life cycle feeding on *T. putrescentiae*.

Both prey were suitable as food for the immature stages, with high survivorship (96.6%), where only one specimen of *C. malaccensis* died with each prey. With *M. ginglymura* as food, the death of this specimen occurred in the teliochrysalis and for *T. putrescentiae* in the nymphochrysalis stage.

The sex ratio obtained in the parental generation was 0.45 females for both prey tested (Table 4). The fertility of *C. malaccensis*, *i.e.*, total number of eggs per female, was more than nine times when supplied with *M. ginglymura*, 310.7±45.8 compared to 32.7±4.5 for *T. putrescentiae* (Table 2). The longevity of females and males was greater when feeding on *M. ginglymura* (♀ - 59.7±6.8 and ♂ - 45.4±4.3) than on *T. putrescentiae* (♀ - 21.5±2.5 and ♂ - 21.9±2.0). Females feeding on *M. ginglymura* survived longer than males and the opposite occurred when this predator fed on *T. putrescentiae*, however, these differences were not significant.

The pre-oviposition and post-oviposition phases did not differ in duration with the two prey (Table 2). However, the oviposition period was four times longer feeding on *M. ginglymura*

(53.0±6.3 days) than on *T. putrescentiae* (12.6±1.9 days). *Megninia ginglymura* was indeed more suitable as food, because the predator laid more eggs (Fig. 1).

The mean generation time (*T*), net reproductive rate (R_o), intrinsic rate of increase (r_m) and finite rate of increase (λ) were all significantly higher with *M. ginglymura* as food. Most notably, R_o was more than nine times higher. However, the doubling time (*DT*) was significantly lower for the generation tested with *M. ginglymura* (Table 3).

A total of 4,040 eggs were obtained in the generation feeding on *M. ginglymura* and only 416 on *T. putrescentiae* (Fig. 1). The maximum daily oviposition was reached on the 37th day, with about 9.3 eggs/female/day, on *M. ginglymura* and 6 eggs/female/day on the 55th day on *T. putrescentiae*. We observed a behavior of sheltering in the refuge for most of the life time, and it was used as a place for laying eggs. Generally, the eggs were found in the bottom of the refuge where there was less light. Parental care of eggs by females was also observed, where they became aggressive when the eggs were removed from experimental units.

Discussion

Biology studies of predator species feeding on different prey are important to support applied biological control strategies. The predatory potential of cheyletid mites has already been reported here and the mass rearing of cheyletid mites in the laboratory has been described previously (Ždárkova 1986; Pekár & Hubert 2008). Horn *et al.* (2016) conducted a survey of mite species associated with laying hens to determine the species of animal health interest and to find potential predators associated with these species. *Cheyletus malaccensis* was found to be the most abundant predatory mite in association with *M. ginglymura* populations, even in hen houses where chemical pesticides were used. In addition, the presence of *T. putrescentiae* was reported, a species of public health interest.

Cheyletus malaccensis has already been tested feeding on several acarid prey species: *T. putrescentiae* (Palyvos & Emmanouel 2009, 2011; Al-Shammery 2014), and *Caloglyphus rodriguezi* Samšiňák and *Acarus siro* L. (Al-Shammery 2014). However, this is the first study of *C. malaccensis* evaluating its control potential and life table parameters when feeding on *M. ginglymura*. The data showed that *C. malaccensis* is a natural enemy of *M. ginglymura* because the latter supports its development and results in the best life table parameters, and also that *T. putrescentiae* can serve as alternative food in confined systems of laying hens or in mass rearing.

When the results of this study are compared with those of other authors who evaluated *C. malaccensis* as a predator, the best results so far, evaluating net reproductive rate (R_o), innate capacity for increase (r_m) and finite rate of increase (λ) were obtained feeding on *M. ginglymura* (Table 4). Moreover, the doubling time (*DT*) was the lowest when maintained on this prey.

The survivorship of *C. malaccensis* in the immature phases was high when feeding on *M. ginglymura* and *T. putrescentiae*. The larval and protochrysalis phases were similar for the two prey. Probably at the larval phase the predator does not require access to significant food resources because it uses few nutrients and has enough stored reserves (Pozzebon & Duso 2008). This was observed in the control studies. However, in the protonymph phase, nutritional differences were noticed, indicating that *M. ginglymura* is less suitable than *T. putrescentiae*, since this predator had a longer duration in this phase, consuming more prey. Therefore, due to the longer duration of this phase the egg–adult period was longer feeding on *M. ginglymura*. Differently, in the adult phase, this prey proved to be more suitable because there was greater longevity and oviposition. From these results, we devised the hypothesis that immatures have difficulty in feeding on *M. ginglymura* because it may be difficult to consume the prey or because there is a defense strategy of the prey. However, further investigation is needed to support this hypothesis. There was a significant difference in the duration of the egg–adult period with *C. malaccensis*, which was shorter when feeding on *T. putrescentiae* than on *C. rodriguezi* (Al-Shammery 2014). There was also a difference between the longevity and oviposition periods, where they were greater on *M. ginglymura* than on *T. putrescentiae*. Furthermore, even though the periods were longer, indicating that it requires more time to complete the life cycle feeding on *M. ginglymura*, fecundity and the amount of eggs were significantly higher on this prey. These results indicate a greater association between *C. malaccensis* and *M. ginglymura* than with *T. putrescentiae*. Al-Shammery (2014) observed greater longevity in females (33.9±3.2 days) and males (27.4±2.6 days) feeding on *A. siro* and shorter longevity in females (28.4±2.8 days) and males (23.1±2.4 days) on *T. putrescentiae*. In our observations, *C. malaccensis* showed slightly shorter longevity for both females and males when *T. putrescentiae* was the prey evaluated. Additionally, the fertility of *C. malaccensis* evaluated with this prey was lower than that obtained in other studies testing this species (Palyvos & Emmanouel 2011; Al-Shammery 2014). This is in contrast to when the predatory mite *Blattisocius dentriticus* (Berlese) (Mesostigmata: Blattisociidae) was tested with *M. ginglymura* and *T. putrescentiae* in the laboratory in the same conditions (Silva *et al.* 2016). The predator population feeding on *T. putrescentiae* increased about 7.53 times (R_o = 7.53) every 14.3 days (T = 14.3), corresponding to a daily population growth of about 15% (λ = 1.15) and a production of 0.14 females per female per day (r_m = 0.14) and when feeding on *M. ginglymura* showed lower values (R_o = 2.79; T = 23.76; λ = 1.04; r_m = 0.04).

Longevity was greater for females and males tested with *M. ginglymura*. For unmated females, the sex ratio of *C. malaccensis* was equal in both prey tested (45% females). Fecundity and oviposition period were greater in mated females of *C. malaccensis* feeding on *T. putrescentiae* than virgin females (Palyvos & Emmanouel 2011). *Cheyletus* mites are frequently assessed as biological control agents of stored-product mite pests (Lukás *et al.* 2007; Cebolla *et al.* 2009). In Czech stored grain, *C. malaccensis* showed the lowest potential of four *Cheyletus* species for biocontrol because of its low frequency and its density independence from prey density (Lukás *et al.* 2007), while it was recorded as the most abundant predator in stored seed cotton in Greece (Athanassiou *et al.* 2002) and considered a beneficial predatory mite present in very high numbers which might have controlled the population of pest mites in stored grains in India (Putatunda 2002). However, only *C. eruditus* is employed for the biocontrol of stored-pest arthropods (Lukás *et al.*, 2007).

When *C. malaccensis* fed on *T. putrescentiae*, it showed a lower net reproductive rate than in other studies (Palyvos & Emmanouel 2011; Al-Shammery 2014) (Table 4). The mean duration of each generation (T) obtained in our assessment was similar to the results obtained by Palyvos & Emmanouel (2011). However, our results are lower than those obtained by Al-Shammery (2014) when testing *T. putrescentiae* as a prey of this predator. The doubling time (DT) was similar in our assessments to that observed by Palyvos & Emmanouel (2011).

When *C. malaccensis* feeds on the feather mite *M. ginglymura*, higher values of R_o and λ are observed than with any other prey tested with this predator, showing that this prey seems to be the most suitable food (Table 4). These results indicate a great potential for *C. malaccensis* and it should be considered for biological control strategies against *M. ginglymura* in laying hen production systems. Horn *et al.* (2016) reported the concomitant presence of this predator and *M. ginglymura* and the tolerance of *C. malaccensis* in environments where synthetic chemical pesticides are used. They reported that this species seems to be of benefit even with pesticide presence. Moreover, the long period of oviposition when supplied with *M. ginglymura* seems to be an important difference that can be highlighted in biological control strategies. The females of this predator remain for a longer time laying eggs, generating more than nine times more progeny than when fed on other prey. It would take more than nine generations of *C. malaccensis* feeding on *T. putrescentiae* to achieve the same amount of eggs laid by a generation feeding on *M. ginglymura*. In addition, the shorter doubling time (*DT*) seen in the generation tested with *M. ginglymura* is also a positive feature for biological control, since a new generation is produced faster with more females laying eggs in the environment, possibly leading to the control of the pest. Moreover, the high fertility rate with the prey *M. ginglymura* is very beneficial in the use of *C. malaccensis* in biological control programs.

The *C. malaccensis* behavior of staying most of the time in the refuge is in accordance with the characteristic of cheyletid mites which hunt by ambush. This strategy requires them to remain hidden in refuges, being attracted by prey when they pass nearby (Gerson *et al.* 2003). This predator would be suitable for confined laying hens systems because there are many protective sites such as cracks in the shed structure, and curvature of the cages and feeding structure, which can be used as a refuge when not feeding.

Our data provide fundamental information for understanding the relationship of the development of *C. malaccensis* feeding on the veterinarily important *M. ginglymura*. This feather mite is an important pest of laying hens in Brazil in the poultry industry. Better knowledge of the biology of *C. malaccensis* will increase its use as a biological control agent and can support applied studies where confined laying hens are infested with *M. ginglymura*. Furthermore, *T. putrescentiae* can be an alternative food. In addition to these results, we believe it necessary to conduct studies on the ability of this predator to bite the chickens since it can apparently feed on human body fluids (Yoshikawa 1987).

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TABLE 1. Mean duration (±SE) in days and survivorship (%) of the immature phases of *Cheyletus malaccensis* feeding on *Megninia ginglymura* and *Tyrophagus putrescentiae* at 25±1°C, 80±5% relative humidity and 12-hour photoperiod in the laboratory.

	N	Egg	Larva	Protochrysalis	Protonymph	Nymphochrysalis	Deutonymph	Teliochrysalis	Egg–adult	S (%)
Megninia ginglymura	30	4.9±0.1a*	4.2±0.1a	1.8±0.1a	5.1±0.2a	2.2±0.08a	5.6±0.2a	1.1±0.09a**	25.0±0.4a	96.6
Tyrophagus putrescentiae	30	4.4±0.3a	4.0±0.2a	2.1±0.1a	3.4±0.2b	1.7±0.1b**	4.0±0.2b	1.2±0.1a	20.9±0.5b	96.6

SE - standard error; N - number of mites evaluated; S - survivorship.
*Means followed by the same letter in the column do not differ statistically according to the Student's t-test at 5% significance level; **Death of a specimen.

TABLE 2. Mean duration (±SE) in days of longevity, pre-oviposition, oviposition and post-oviposition periods, and fecundity (total number eggs/female) of *Cheyletus malaccensis* feeding on *Megninia ginglymura* and *Tyrophagus putrescentiae* at 25±1°C, 80±5% relative humidity and 12-hour photoperiod in the laboratory.

Parameter	N	*Megninia ginglymura*	N	*Tyrophagus putrescentiae*
Fecundity	13	310.7±45.8a	13	32.7±4.5b*
Female longevity	13	59.7±6.8a	13	21.5±2.5b
Male longevity	16	45.4±4.3a	16	21.9±2.0b
Pre-oviposition	13	3.5±0.1a	13	4.8±0.7a
Oviposition	13	53.0±6.3a	13	12.6±1.9b
Post-oviposition	13	3.1±1.0a	13	4.0±0.8a

N - number of mites evaluated.
*Means followed by the same letter in the column do not differ statistically according to the Student's t-test at 5% significance level.

TABLE 3. The mean generation time (*T*), the net reproductive rate (R_o), the innate capacity for increase (r_m), the finite increase rate (λ) and the doubling time (*DT*) of *Cheyletus malaccensis* feeding on *Megninia ginglymura* and *Tyrophagus putrescentiae* at 25±1°C, 80±5% relative humidity and 12-hour photoperiod in the laboratory.

Parameter*	*Megninia ginglymura*	*Tyrophagus putrescentiae*
T	41.6a*	30.3b
R_o	135.6a	13.9b
r_m	0.12a	0.09b
λ	1.13a	1.09b
DT	5.8b	7.9a

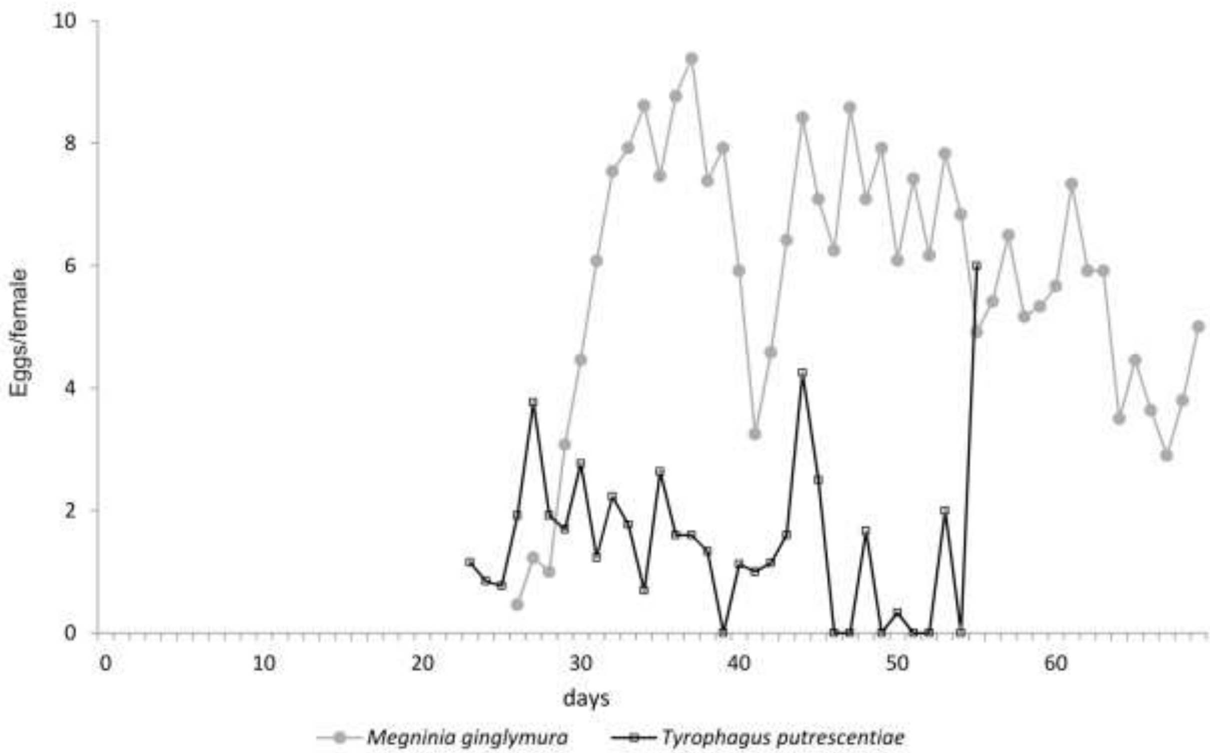
*Means followed by the same letter in the column do not differ statistically according to the jackknife method, using the software SAS™ (SAS Institute 2000).

TABLE 4. Mean generation time (*T*), net reproductive rate (R_o), innate capacity for increase (*rm*), finite rate of increase (λ) and doubling time (*DT*) of *Cheyletus malaccensis* feeding on different prey species.

	Prey species	N	Sex ratio (% ♀)	R_o	r_m	*T*	λ	*DT*
Present study	*Megninia ginglymura*	30	45	135.6	0.12	41.6	1.13	5.8
Present study	*Tyrophagus putrescentiae*	30	45	13.9	0.09	30.3	1.09	7.9
Al-Shammery, 2014	*Acarus siro*	50	56	14.5	0.03	72.0	1.03	21.6
Al-Shammery, 2014	*Caloglyphus rodriguezi*	50	58	24.6	0.04	70.1	1.04	15.7
Al-Shammery, 2014	*Tyrophagus putrescentiae*	50	62	26.4	0.05	55.2	1.06	11.7
Palyvos and Emmanouel, 2011	*Tyrophagus putrescentiae*	22	-	70.0	0.11	37.0	1.12	6.0

Legend to figure

FIGURE 1. Mean daily oviposition*of *Cheyletus malaccensis* feeding on *Megninia ginglymura* and *Tyrophagus putrescentiae* at 25±1°C, 80±5% relative humidity and 12-hour photoperiod in the laboratory



*SE 0.2741 (*M. ginglymura*) and 0.2741 (*T. putrescentiae*).

DISCUSSÃO GERAL

A criação de galinhas poedeiras comerciais é uma atividade importante para a economia do Vale do Taquari e estado do Rio Grande do Sul e, portanto, se faz necessário conhecer as espécies de ácaros associados a estes ambientes, sua frequência e danos (SILVA *et al.*, 2013). Em virtude do pouco conhecimento prático na identificação de ácaros por parte dos profissionais técnicos que prestam consultorias às granjas, este trabalho traz a primeira chave de identificação de ácaros associados a ambientes avícolas.

Os dados do presente trabalho mostram que o tipo de manejo influencia na abundância, riqueza e diversidade de ácaros em criações de galinhas poedeiras comerciais (HORN *et al.*, 2016). Menor abundância foi observada no ambiente caipira (galinhas mantidas livres) sendo sua diversidade e equitabilidade maiores, havendo provavelmente um equilíbrio entre as espécies que promovem a presença de ácaros predadores.

Megninia ginglymura foi a espécie de importância sanitária associada a todos os tipos de manejos avaliados. Silva *et al.* (2013) também relatam a presença desta espécie em todas as formas de coleta empregadas para captura de ácaros associados em ambientes avícolas. Cabe destacar que nenhum exemplar de *M. ginglymura* foi observado em ninhos de aves silvestres abandonados. Suas populações correlacionaram com positivamente com a temperatura. Maior abundância de *M. ginglymura* foram observados nos sistemas semiautomatizados, caipira e por último nos automatizados. Diferente do esperado, o maior confinamento de galinhas poedeiras nos sistemas automatizados apresentou menor infestação por *M. ginglymura* (HORN *et al*., 2016) do que os demais sistemas. A região dorso apresentou a maior abundância, abundância e prevalência média, seguido pela cloaca, abdômen, pescoço e a região interna das asas apresentou a menor abundância, abundância média e prevalência em todos os sistemas avaliados.

As populações de *M. ginglymura* demonstraram um indicativo à resistência ou os pesticidas químicos sintéticos utilizados não são específicos para controle desta espécie. O controle biológico de ácaros pragas com predadores naturais podem ajudar a reduzir altas infestações, impedindo que os ectoparasitas se tornem um problema econômico e de saúde sendo essencial conhecer acarofauna que galinhas poedeiras e aves silvestres são portadores (SILVA *et al.*, 2013) permitindo que práticas mais limpas sejam empregadas (LESNA *et al.*, 2009). *Cheyletus malaccensis*, *T. transvaalensis*, *B. keegani* e *B. dentriticus* foram os ácaros predadores mais comuns e abundantes com variação populacional dependendo do sistema de criação avaliado e foram considerados com potencial a ser avaliada para o controle biológico de ácaros de importância sanitária nas criações de galinhas poedeiras.

n. gen. *et* n. sp. é descrita pertencendo a subfamília Dermatophagoidinae em razão da ausência de tégmen (tectum) cobrindo parte do gnatossoma, tegumento com estrias regulares e uniformes da cutícula. Esta espécie parece ser fracamente influenciada pelas condições ambientais e as populações deste generalista correlacionaram negativamente com a temperatura em A_1 e S_2 e positivamente com umidade relativa do ar em S_2.

Estudos de biologia de espécies de predadores se alimentando de diferentes presas são importantes para apoiar as estratégias de controle biológico aplicado. Este é o primeiro trabalho que avalia o potencial de controle de *C. malaccensis* e tabela de vida quando alimentado com *M. ginglymura*. O predador foi considerado um inimigo natural de *M. ginglymura* porque suporta seu desenvolvimento e apresentou os melhores resultados dos parâmetros da tabela de vida. Estes resultados indicam um grande potencial para *C. malaccensis* para estratégias de controle biológico contra *M. ginglymura* em sistemas de produção galinhas poedeiras. Este ácaro da pena é uma importante praga das galinhas poedeiras no Brasil na indústria avícola. Melhor conhecimento da biologia de *C. malaccensis* vai aumentar a sua utilização como agente de controle biológico e podem suportar estudos aplicados quais as galinhas poedeiras confinadas infestadas com *M. ginglymura*. Além disso, *T. putrescentiae* pode ser um alimento alternativo no campo quanto para criação massal em laboratório.

CONCLUSÕES

- A chave dicotômica dá suporte para a identificação das espécies da acarofauna presente na avicultura poedeira comercial do Vale do Taquari, Estado do Rio Grande do Sul, Brasil;

- A diversidade e a abundância de ácaros na avicultura poedeira comercial são distintas entre os sistemas de manejo automatizado, semiautomatizado e caipira;

- *Megninia ginglymura* é uma espécie de importância sanitária e econômica para a avicultura poedeira comercial no Vale do Taquari;

- Aviários semiautomatizados são mais favoráveis ao desenvolvimento de *M. ginglymura*;

- *Blattisocius dentriticus, B. keegani*, *Cheyletus malaccensis* e *Typhlodromus transvaalensis* são as espécies predadoras com maiores populações na avicultura poedeira comercial no Vale do Taquari;

- *Cheyletus malaccensis* completa o ciclo de vida e se reproduz quando alimentados com *M. ginglymura* e *Tyrophagus putrescentiae*;

- *Cheyletus malaccensis* é inimigo natural de *M. ginglymura* apresentando potencial para o controle biológico deste ácaro sendo que *T. putrescentiae* pode ser usado para alimento alternativo para criação massal deste predador.

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DECISÃO DO PERIÓDICO SYSTEMATIC AND APPLIED ACAROLOGY A RESPEITO DO "ARTIGO 6" DA PRESENTE TESE

[saa] Editor Decision

D

Dr Anne S Baker

Responder|

qui 04/08, 13:02

Você;

mais 5

Tamara Bianca Horn:

We have reached a decision regarding your submission to Systematic and Applied Acarology, "Development of Cheyletus malaccensis (Acari: Cheyletidae) feeding on species of public and veterinary health: Megninia ginglymura (Acari: Analgidae) and Tyrophagus putrescentiae (Acari: Acaridae)".

Our decision is: Revisions required.

Please contact me directly if you cannot access the Reviewers uploaded comment files.

Kind regards,

Dr Anne S Baker
asb@nhm.ac.uk

SYSTEMATIC AND APPLIED ACAROLOGY: 2015 impact factor is 1.378 (rank 34 of 94 entomology journals in JCR 2016 edition).

NORMAS DE PUBLICAÇÃO

Systematic & Applied Acarology

ISSN 1362-1971

An international journal of the Systematic and Applied Acarology Society

[Aims] [Editors] [Content] [Subscriptions] [Contact details] [Society Homepage]

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Aims and scope

Systematic and Applied Acarology (SAA) is an international journal of the Systematic and Applied Acarology Society (SAAS). The journal is intended as a publication outlet for all acarologists in the world.

There is no page charge for publishing in SAA. If the authors have funds to publish, they can pay US$20 per page to enable their papers published for open access.

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Taxonomic revisions and phylogenetic studies are preferred, although manuscripts that simply describe a single new species are also considered for publication. New taxa, new combinations and new synonyms should be indicated as **fam.nov.**, **gen.nov.**, **sp.nov**., **com. nov.** and **syn. nov.** The data for holotype and paratype(s) and their depositories must be provided in the original descriptions. All material examined should also be listed.

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B Xin, J.-L. (1988) *Agricultural Acarology* . Shanghai, Fudan University Press. 466pp.

C Zhu, X.X., Zhang, W.Y. & Oliver, J.H. Jr. (1995) Immunocytochemical mapping of FMRFamide-like peptides in the argasid tick *Ornithodoros parkeri* and the ixodid tick *Dermacentor variabilis* . *Experimental & Applied Acarology*, 19, 1–9.

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Manuscripts must be submitted using the online submission system (http://biotaxa.org/saa/). Pre-submission questions should be sent to Dr. Zhi-Qiang Zhang (zhangz@landcareresearch.co.nz).

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Information are reviewers is here and that for section/subject editors here.

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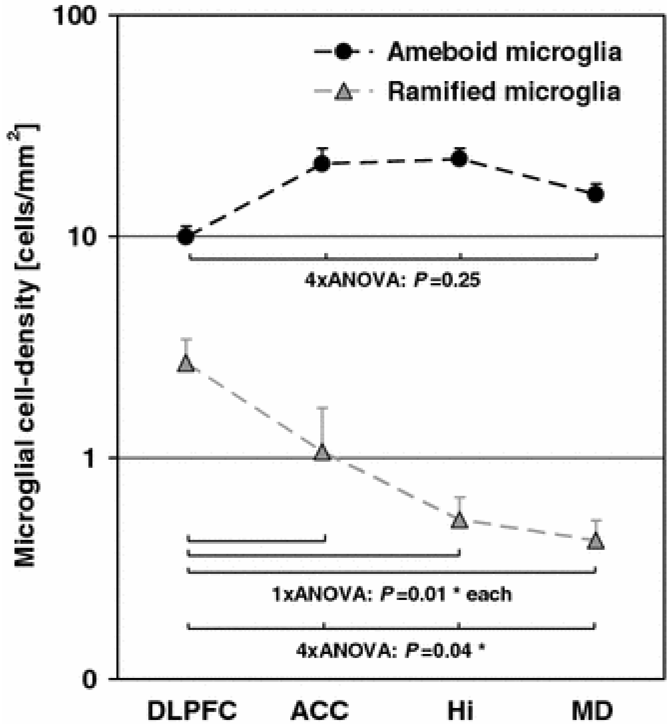

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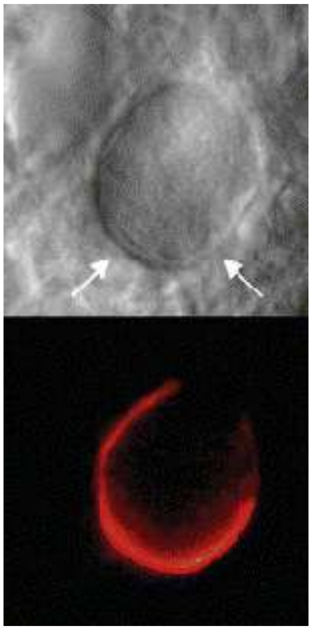

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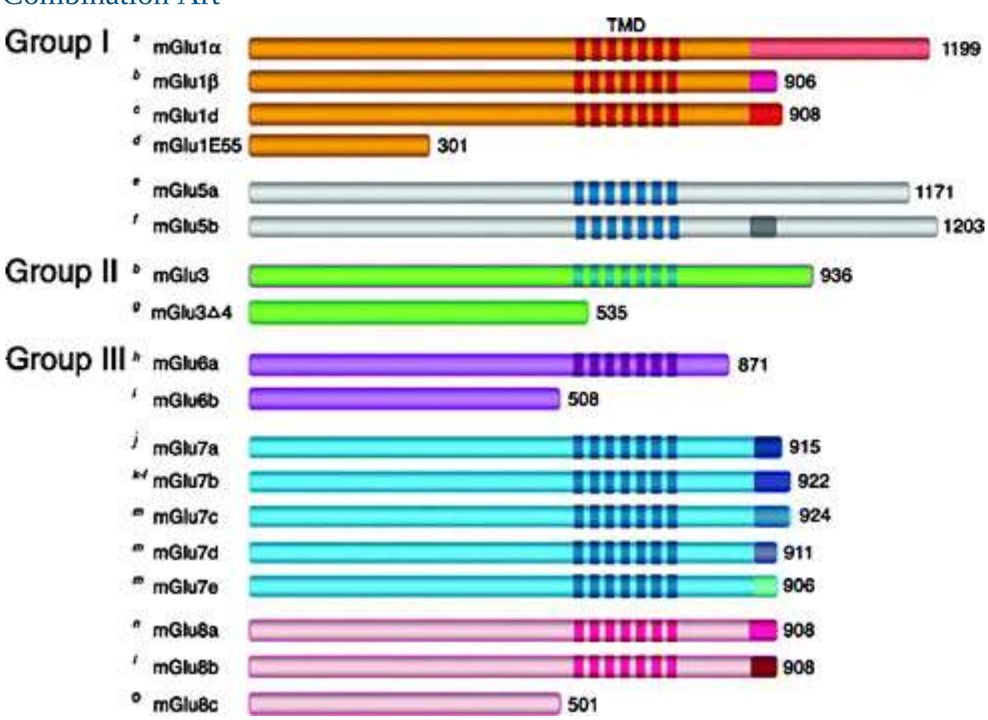

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