The efficiency of wire nets in enhancing the biosecurity of poultry in Brazil

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Summary

The aim of this study was to evaluate the efficiency of the use of wire nets of various mesh sizes to enhance biosecurity in the poultry industry in Brazil by preventing other bird species from entering chicken houses. The Brazilian poultry industry is technologically advanced and employs updated technology. The current Brazilian guidelines recommend the use of 25.40 mm mesh. However, scientific evidence of the efficiency of the nets recommended by these guidelines is lacking. In this study, a bird biometric methodology was developed to evaluate bird species. The methodology was based on the body dimensions of the animal, and it employed a new statistical design to analyse the data. Three groups of bird species were designated according to their importance. The value of this criterion (the importance of the species) was estimated by assessing the ability of birds to pass through the net. The paradigm was used to study 23

wild avian species that are naturally present in Brazil. The best results were observed for nets with a mesh size ≤ 19.11 mm. This mesh size was able to efficiently restrain all of the species studied. However, in the same test, the net with 25.40 mm mesh could not restrain 11 bird species, one of which was *Passer domesticus*, which is found worldwide. On the basis of these results, the use of 19.1 mm mesh should be strongly recommended in order to achieve biosecurity of poultry houses.

Keywords

Biosecurity – Chicken – Poultry – Wire net.

Introduction

Chicken meat, a major source of animal protein, is steadily increasing in importance and demand. Brazil is the third largest broiler producer worldwide and exports chicken meat to 141 countries (1, 2, 3). The Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) have recommended biosecurity strategies for poultry houses to reduce the risk of disease, in connection with mandatory controls for international trade (4, 5, 6). In Brazil, the National Program for Poultry Health (PNSA) Acts have defined procedures for disease control, disease prevention and biosecurity with which the national poultry industry must comply (7, 8, 9, 10).

The FAO and OIE have recently recommended that nets should be used around poultry houses to isolate the poultry (11). This recommendation was made in the interest of biosecurity and reflects concerns about the pandemic, highly pathogenic disease avian influenza. This disease has been especially prevalent in certain countries, such as Cambodia (12, 13), Kenya (14), Indonesia (15), Vietnam (16, 17) and Egypt (18). International agencies have considered low-cost strategies to ensure biosecurity among small-village poultry farmers in developing countries (4, 19, 20).

To ensure the biosecurity of poultry houses in Brazil, a 2007 regulation (*Instrução Normativa* [IN] 56 of 4 December 2007) recommended the use of a 20.00 mm wire net mesh; the regulation was later modified by IN 59 of 2 December 2009 to recommend a 25.40 mm wire net mesh (21). However, no scientific evidence is available to judge the efficiency of nets of various mesh sizes in terms of their ability to exclude the bird species that are found in proximity to the industrial system of indoor chicken houses (Fig. 1). The aim of this study was to assess a methodology for evaluating birds and for analysing data in the context of this problem. The study examined 23 species of native and invasive free-living wild species and determined their ability to pass through wire nets of various mesh sizes.

Insert Figure 1

Materials and methods

The animal studies were in conformity with, and approved by, the System for Authorisation and Information in Biodiversity (*Sistema de Autorização e Informação em Biodiversidade*) SISBIO 22639-1, which determines the best experimental procedures. The studies on captive birds were carried out at a rescue and health screening centre for wild animals in Belo Horizonte in the state of Minas Gerais (*Centro de Triagem de Animais Silvestres* [CETAS-BH]). The Centre, which is one of several similar centres around the country, forms part of the Brazilian Institute of the Environment and Natural Resources (IBAMA). The studies on industrial chickens were carried out at the Professor Hélio Barbosa Experimental Farm in Igarapé, which is part of the Veterinary College at the Universidade Federal de Minas Gerais [UFMG]). The statistical analyses were performed in the Biostatistics Laboratory at the UFMG Veterinary College.

Two experiments were set up; the first examined the captive birds and the second examined free-living birds that are observed around chicken houses.

Seven net sizes were tested (Table I), including three below and three above the current standard, plus the mandatory 25.40 mm mesh net

(17). The nets were attached to the sides of the experimental cages (Figs. 2 and 3).

Insert Table I and Figures 2 and 3

Twenty-three bird species that are potentially capable of entering chicken houses were chosen for this study. The choice of the wild species for study was based on the following criteria: presence in the Brazilian fauna, habitual feeding on seeds, and synanthropy (association with humans). For the preliminary study, wild birds in captivity were used (CETAS-BH, IBAMA), and their status as free-living species was verified on the experimental farm (Veterinary College Experimental Farm) during an official inventory of wild bird species that was performed for this purpose.

The male and female birds were evaluated by measuring six biometric dimensions chosen for the species studied and comparing the dimensions with information in the literature (22, 23). Three types of passage through the net were evaluated. A captive manual passage (CMP) (Fig. 4) describes an attempt to pass a bird though the mesh net in the hands of a researcher. A captive voluntary passage (CVP) (Fig. 5) describes an attempt by a bird to pass though the mesh net by itself (i.e. voluntarily) inside the aviary in CETAS-BH. A wild voluntary passage (WVP) (Fig. 6) describes an attempt by a bird to pass through the mesh net in the Brazilian field setting. The captive passage tests were performed in Belo Horizonte (CETAS-BH). The wild voluntary passage tests were performed in industrial chicken houses in the Veterinary College Experimental Farm (Igarapé, Minas Gerais, Brazil). For the WVP, new, cleaned and disinfected test cages containing seeds (24) were placed beside a chicken house (Fig. 7).

Insert Figures 4 to 7

The CMP tests were initially conducted with the smallest mesh, and subsequently the mesh size was successively increased until the largest mesh had been tested. For the CVP tests, a cage containing seeds was placed inside the aviary as a single source of food (Fig. 8). Photographic and video images were collected using Olympus SP-510

UZ and Canon 40 D digital cameras with a 70–200 mm F/4 lens. To capture images of the exact moment of entry, the digital cameras were set up for remote control. The cameras were placed 3 m in front of the test cages. Images were collected to register the exact moment of passage through the mesh net, including the details of approach, perch and entry. To avoid interference, no people were present close to the experimental site (Fig. 9). The wild birds in each test were counted by reviewing the movie.

Insert Figures 8 and 9

The statistical analyses were performed using Stata 10 software (http://www.stata.com). Analyses of variance were conducted for each bird species and mesh size (25, 26). Birds of similar biotypes, which were defined by the success or lack of success in passing through the 25.35 mm mesh net, were grouped to form three archetypical categories. These categories were established in reference to the results of the three experimental paradigms used in the study (CMP, CVP, WVP). Based on the results, a criterion for the classification of species was defined according to the ability to pass through the wire nets in the three experimental setups. The classes were defined as high, medium and low importance.

Results

Analyses of variation were performed for the six biometric dimensions observed (Table II) and indicated that the body weight and the chest diameter were the most important characteristics determining the capacity of a given bird to pass through the mesh of a given size. Using the CVP test, the bird species and biometry were defined and evaluated with regard to the potential ability of that bird to pass through the net (Fig. 10). The CMP results (Table III) demonstrate which species had the ability to pass through the net, scoring 1 for yes or 0 for no. The birds that did not pass through the 25.35 mm net in the CMP test were also unable to pass through the net in the subsequent CVP and WVP tests (Tables IV and V). The CMP test results were therefore a sensitive indicator of the voluntary and natural behaviour of birds that will not be able to pass. During the WVP test,

10 out of the 23 local species selected for the study visited the test cages and attempted to pass through the nets. However, only five species succeeded in passing through the 25.35 mm net in all three of the tests: CMP (Table III), CVP (Table IV) and WVP (Table V). The CVP test results were used to determine the optimal number of individuals of each species required for statistical evaluation in a free-will experiment. The results of the CVP test also confirmed the value of the limits established from the biometric values of body weight and chest diameter in the CMP test. Furthermore, they revealed the strategies used by the birds to pass through the net. These strategies included a tendency of the birds to perch while they examined the net and made the appropriate postural adjustments.

Insert Tables II to V and Figure 10

The WVP best represented the natural situation in chicken houses because this paradigm required the smallest amount of interference by the researchers. Ten out of the 23 species of birds present in the area visited the cages for feeding. Five of these species were able to pass through the 25.35 mm mesh net (the mandatory net); these species were present around the chicken houses and succeeded in passing through the net in all of the tests. Six of the species that were examined in the captive tests (CVP and CMP) were not detected in the WVP. Three groups were defined as archetypes for subsequent analysis. The high-importance group was associated with a higher risk of passage. This group consisted of 11 species of birds, all of which passed through the 25.35 mm net in two of the tests (CMP and CVP). The medium-importance group consisted of six species of birds that passed only through the 25.35 mm net in the CMP test. The low-importance group consisted of six species of birds that did not pass through the 25.35 mm net in any of the tests. The analyses of the bird data involved the archetypes defined according to importance and the biometric measurements of the birds (Table VI). The analysis of the biometric values revealed that the heaviest species also had the widest chest diameters ($r = 0.844$; $p < 0.001$).

Insert Table VI

In an analysis of the importance parameter, the chest diameter (Table VI) and body weight (Table VII) exhibited highly significant differences among the three importance groups ($p < 0.001$). These results served to further characterise meaningful groupings of the species. In the low-importance group, the six species that proved unable to pass through the 25.35 mm net in any of the tests (CMP, CVP and WVP) were: *Agelaius ruficapillus*, *Aratinga aurea*, *Columbina talpacoti*, *Paroaria dominicana*, *Gnorimopsar chopi* and *Saltator similis*. The six medium-importance species that only passed through the 25.35 mm net in the CMP test were: *Coryphospingus pileatus*, *Forpus xanthopterygius*, *Passerina brissonii*, *Sicalis flaveola*, *Sporophila frontalis* and *Zonotrichia capensis*. The 11 high-importance species that passed through the 25.35 mm net in the CMP and CVP tests were: *Passer domesticus*, *Carduelis magellanicus*, *Sporophila caerulescens*, *Sporophila lineola*, *Sporophila nigricollis*, *Volatinia jacarina*, *Sporophila plumbea*, *Sporophila leucoptera*, *Sporophila collaris*, *Sporophila bouvreuil* and *Sporophila* (*Oryzoborus*) *angolensis*. Five species of the high-importance group visited the test cages and were also able to pass through the 25.35 mm net in the WVP test (*Passer domesticus*, *Sporophila caerulescens*, *Sporophila lineola*, *Sporophila nigricollis*, *Volatinia jacarina*).

Insert Table VII

Discussion

The highest efficiency with regard to biosecurity was achieved using the 19.11 mm chain-link net. This net did not allow bird passage in the CVP and WVP tests.

The CMP test allowed the evaluation of involuntary passage through the nets by all of the captive individuals. It was considered to represent a reference methodology. Its results corresponded to the biometric dimensions of each species and predicted the results obtained from the voluntary CVP and WVP tests. These voluntary tests were considered useful for simulating natural conditions, and they allowed the evaluation of naturally occurring species.

Eight species of wild birds could pass through the 19.11 mm mesh net in the CMP test. However, this same group of birds could only pass through the 20.78 mm net in the CVP.

In the WVP test, the minimum mesh net diameter that allowed passage was 25.35 mm. Although feed was present as an incentive in this test, the minimum net size was large relative to the minima found in the CMP and CVP tests. One possible explanation for this difference is that the individuals in their natural environment had access to their usual food sources and did not depend on the test cages for food.

Passer domesticus, the house sparrow, was able to pass through the 25.35 mm net in the CVP and WVP tests. This species is considered important because of its prevalence, synanthropic habits and cosmopolitan distribution. The house sparrow is present on all continents, and study of this species may allow comparisons to be made among diverse environments worldwide. The sparrow nests in small holes under the roofs of houses and barns. Its resulting proximity to humans and domestic animals could increase the risk of disease transmission.

The grouping of the analytical results by species' importance enabled the categorisation of native bird species according to risk. This categorisation describes the ability of various bird species to pass through the mandated net in one or more of the three test paradigms.

The importance of segregating poultry is emphasised in several international publications (12, 14, 15, 16, 17, 18, 19, 20). However, the only technical information available regarding the evaluation of wire net mesh sizes was the recommendation for a 20.00 mm mesh made by a Canadian consulting firm (5).

Conclusion

The research reported here found that none of the bird species tested could voluntarily pass through the 19.11 mm mesh. This finding justifies the recommendation that a 19.11 mm mesh should be used to

ensure the greatest biosecurity for poultry. In contrast, the current standard 25.40 mm net was unable to retain six wild bird species in a test that allowed voluntary passage through the mesh. Therefore, on the basis of these results, a 19.11 mm mesh size is strongly recommended to ensure the biosecurity of poultry houses.

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Table I
Hexagonal and chain-link wire net sizes evaluated, as standardised by the Brazilian Association of Technical Standards (ABNT)

Net	Mesh net size (mm)	Mesh net area (mm²)
Hexagonal*	17.65	270
Hexagonal*	27.65	663
Chain-link**	19.11	365
Chain-link**	20.78	432
Chain-link**	25.35	643
Chain-link**	27.05	732
Chain-link**	30.15	909

*ABNT No. 10122

**ABNT No. 10118

Table II
Bird species and their average biometric dimensions
These species are free-living birds that are found in the region where the study was conducted

Bird species	Number of birds analysed	Average weight (g)	Average head length (mm)	Average head diameter (mm)	Average wing span (mm)	Average chest diameter (mm)	Average total length (without tail) (mm)
Aratinga aurea	22	82	40	22	144	31	141
Gnorimopsar chopi	22	62	47	19	120	26	129
Columbina talpacoti	22	52	33	14	84	26	94
Agelaius ruficapillus	22	39	38	16	85	24	103
Paroaria dominicana	22	34	32	16	87	25	105
Saltator similis	22	29	40	17	97	21	129
Zonotrichia capensis	22	19	31	14	64	16	88
Forpus xanthopterygius	22	27	27	16	81	19	91
Passerina brissonii	22	22	33	15	74	21	98
Sicalis flaveola	22	22	25	13	70	22	100
Coryphospingus pileatus	22	15	29	13	61	15	83
Sporophila frontalis	22	21	27	13	64	23	99
Passer domesticus	22	27	31	15	73	19	86
Sporophila angolensis	22	14	26	13	57	16	76
Volatinia jacarina	22	11	25	12	47	15	60
Carduelis magellanicus	22	13	25	12	65	15	71
Sporophila leucoptera	22	16	26	14	59	15	80
Sporophila plumbea	22	12	23	12	60	14	72
Sporophila lineola	22	11	21	12	52	15	68
Sporophila collaris	22	13	25	13	58	15	75
Sporophila caerulescens	22	10	23	12	55	14	75
Sporophila nigricollis	22	11	23	12	55	16	78
Sporophila bouvreuil	22	9	21	11	52	13	65

Table III
Results of captive manual passage tests according to net model and size of the mesh
Scores indicate the birds' ability to pass through the net (0 = no; 1 = yes)

Bird species	Hexagonal 17.65 mm	Chain-link 19.11 mm	Chain-link 20.78 mm	Chain-link 25.35 mm	Chain-link 27.05 mm	Hexagonal 27.65 mm	Chain-link 30.15 mm
Aratinga aurea	0	0	0	0	0	0	0
Gnorimopsar chopi	0	0	0	0	0	0	0
Columbina talpacoti	0	0	0	0	0	0	0
Agelaius ruficapillus	0	0	0	0	0	0	1
Paroaria dominicana	0	0	0	0	0	0	1
Saltator similis	0	0	0	0	0	0	1
Forpus xanthopterygius	0	0	0	1	1	1	1
Passer domesticus	0	0	0	1	1	1	1
Passerina brissonii	0	0	0	1	1	1	1
Sicalis flaveola	0	0	0	1	1	1	1
Sporophila frontalis	0	0	0	1	1	1	1
Zonotrichia capensis	0	0	1	1	1	1	1
Coryphospingus pileatus	0	0	1	1	1	1	1
Sporophila angolensis	0	0	1	1	1	1	1
Carduelis magellanicus	0	0	1	1	1	1	1
Volatinia jacarina	0	1	1	1	1	1	1
Sporophila leucoptera	0	1	1	1	1	1	1
Sporophila collaris	0	1	1	1	1	1	1
Sporophila plumbea	0	1	1	1	1	1	1
Sporophila lineola	0	1	1	1	1	1	1
Sporophila nigricollis	0	1	1	1	1	1	1
Sporophila caerulescens	0	1	1	1	1	1	1
Sporophila bouvreuil	0	1	1	1	1	1	1

Table IV
Results of captive voluntary passage tests according to net model and size of the mesh
Scores indicate the birds' ability to pass through the net (0 = no; 1 = yes)

Bird species	Hexagonal 17.65 mm	Chain-link 19.11 mm	Chain-link 20.78 mm	Chain-link 25.35 mm	Chain-link 27.05 mm	Hexagonal 27.65 mm	Chain-link 30.15 mm
Aratinga aurea	0	0	0	0	0	0	0
Gnorimopsar chopi	0	0	0	0	0	0	0
Columbina talpacoti	0	0	0	0	0	0	0
Agelaius ruficapillus	0	0	0	0	0	0	0
Paroaria dominicana	0	0	0	0	0	0	0
Saltator similis	0	0	0	0	0	0	0
Zonotrichia capensis	0	0	0	0	0	0	0
Forpus xanthopterygius	0	0	0	0	0	0	1
Passerina brissonii	0	0	0	0	0	0	1
Sicalis flaveola	0	0	0	0	0	0	1
Coryphospingus pileatus	0	0	0	0	0	1	1
Sporophila frontalis	0	0	0	0	1	1	1
Passer domesticus	0	0	0	1	1	1	1
Sporophila angolensis	0	0	0	1	1	1	1
Volatinia jacarina	0	0	0	1	1	1	1
Carduelis magellanicus	0	0	0	1	1	1	1
Sporophila leucoptera	0	0	0	1	1	1	1
Sporophila plumbea	0	0	0	1	1	1	1
Sporophila lineola	0	0	1	1	1	1	1
Sporophila collaris	0	0	1	1	1	1	1
Sporophila caerulescens	0	0	1	1	1	1	1
Sporophila nigricollis	0	0	1	1	1	1	1
Sporophila bouvreuil	0	0	1	1	1	1	1

Table V
Results of wild voluntary passage tests according to net model and size of the mesh
Scores indicate the birds' ability to pass through the net (0 = no; 1 = yes)

Bird species	Hexagonal 17.65 mm	Chain-link 19.11 mm	Chain-link 20.78 mm	Chain-link 25.35 mm	Chain-link 27.05 mm	Hexagonal 27.65 mm	Chain-link 30.15 mm
Columbina talpacoti	0	0	0	0	0	0	0
Zonotrichia capensis	0	0	0	0	0	0	0
Agelaius ruficapillus	0	0	0	0	0	0	1
Sicalis flaveola	0	0	0	0	0	0	1
Coryphospingus pileatus	0	0	0	0	0	0	1
Passer domesticus	0	0	0	1	1	1	1
Volatinia jacarina	0	0	0	1	1	1	1
Sporophila lineola	0	0	0	1	1	1	1
Sporophila caerulescens	0	0	0	1	1	1	1
Sporophila nigricollis	0	0	0	1	1	1	1

Table VI

Analyses of variation in chest diameter according to species importance

Importance	Bird species	Samples	Chest diameter: Average (mm)	Standard average (mm)	Minimum confidence bound	Maximum confidence bound	Coefficient of variation
Low[a]	*Agelaius ruficapillus*, *Aratinga aurea*, *Columbina talpacoti*, *Gnorimopsar chopi*, *Paroaria dominicana*, *Saltator similis*	132	25.34	4.32	24.6	26.08	17.41
Medium[b]	*Coryphospingus pileatus*, *Forpus xanthopterygius*, *Passerina brissonii*, *Sicalis flaveola*, *Sporophila frontalis*, *Zonotrichia capensis*	132	19.32	3.4	18.74	19.90	17.58
High[c]	*Passer domesticus*, *Carduelis magellanicus*, *Sporophila angolensis*, *Sporophila bouvreuil*, *Sporophila caerulescens*, *Sporophila collaris*, *Sporophila lineola*, *Sporophila leucoptera*, *Sporophila nigricollis*, *Sporophila plumbea*, *Volatinia jacarina*	242	15.25	2.21	14.97	15.52	14.52

a) Low importance: birds that did not pass through the 25.3 mm mesh net in any test

b) Medium importance: birds that passed through the 25.3 mm mesh net in the captive manual passage test

c) High importance: birds that passed through the 25.3 mm mesh net in the captive manual passage and captive voluntary passage tests

Table VII

Analyses of variations in body weight according to species importance

Importance	Bird species	Sample	Body weight: Average (g)	Standard average (g)	Minimum confidence bound	Maximum confidence bound	Coefficient of variation
Low	*Agelaius ruficapillus*, *Aratinga aurea*, *Columbina talpacoti*, *Gnorimopsar chopi*, *Paroaria dominicana*, *Saltator similis*	132	49.76	19.46	46.44	53.08	39.11
Medium	*Coryphospingus pileatus*, *Forpus xanthopterygius*, *Passerina brissonii*, *Sicalis flaveola*, *Sporophila frontalis*, *Zonotrichia capensis*	132	21.02	4.24	20.3	21.74	20.17
High	*Passer domesticus*, *Carduelis magellanicus*, *Sporophila angolensis*, *Sporophila bouvreuil*, *Sporophila caerulescens*, *Sporophila collaris*, *Sporophila lineola*, *Sporophila leucoptera*, *Sporophila nigricollis*, *Sporophila plumbea*, *Volatinia jacarina*	242	13.47	5.07	12.83	14.11	37.64

Low importance: birds that did not pass through the 25.3 mm mesh net in any test

Medium importance: birds that passed through the 25.3 mm mesh net in the captive manual passage test

High importance: birds that passed through the 25.3 mm mesh net in the captive manual passage and captive voluntary passage tests

Fig. 1
Chain-link net used in industrial aviculture
(Brazilian Association of Technical Standards [ABNT] – 10118)

Fig. 2
Measurement of the chain-link net using calipers, according to the Brazilian standard
(Brazilian Association of Technical Standards [ABNT] – 10118)

CETAS: Centro de Triagem de Animais Silvestres

CMP: captive manual passage

CVP: captive voluntary passage

WVP: wild voluntary passage

Fig. 3
Flowchart for the captive manual passage, captive voluntary passage and wild voluntary passage tests

Fig. 4
Captive manual passage test of *Paroaria dominicana*
Chest diameter is the body dimension that determines the biometric limits for successful passage through the net

Fig. 5
Captive voluntary passage test
The captive voluntary passage test of *Sporophila lineola* through the 25.35 mm net is shown

Fig. 6
Wild voluntary passage test
The passage of *Sporophila lineola* through the 25.35 mm mesh net is shown. The study site is in Igarapé, MG (adjacent to the chicken house at the Veterinary School farm)

Fig. 7
Wild voluntary passage
The test cage is adjacent to the Veterinary College industrial chicken house on the Professor Hélio Barbosa Experimental Farm in Igarapé, which is part of the Universidade Federal de Minas Gerais

Fig. 8
Captive voluntary passage test
The captive voluntary passage of *Passer domesticus* through the 25.35 mm mesh net is shown

Fig. 9
The Olympus camera used during image capture for captive voluntary passage in the wild animal screening centre (*Centro de Triagem de Animais Silvestres*) in Belo Horizonte

Fig. 10
Correlations between body weight and chest diameter, and the ability to pass through the 25.35 mm chain-link mesh net during the captive voluntary passage test