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COMPARATIVE APPRAISAL OF THE REPRODUCTION AND GROWTH PERFORMANCES OF THREE GENERA OF FLIES (*MUSCA* LINNAEUS, 1758; *LUCILIA* ROBINEAU-DESVOIDY, 1830; AND *SARCOPHAGA* MEIGEN, 1826) FOR THEIR USE IN POULTRY FEED IN SENEGAL

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ABSTRACT

The context of this study is defined by the shortage of accessible protein sources in sub-Saharan Africa, a major constraint on local poultry farming. Hence, the main objective of our study is to identify the fly species with the greatest potential to produce maggots for poultry feed. The experiment, conducted in Gossas (Senegal) from 1 August to 30 September 2023, involved breeding three genera of flies (*Musca*, *Lucilia* and *Sarcophaga*) on specific substrates. Our methodology is based on measuring embryonic, larval, and pupal development durations, as well as evaluating larval biometrics, sex ratio, and larval viability. The results indicate that *Musca* exhibits rapid maturation, *Lucilia* produces a high number of larvae, while Sarcophaga is distinguished by larger larval size and limited egg-laying. Statistical analyses, including tests of normality, the Kruskal-Wallis test, linear regression, and principal component analysis, confirm the significance of the observed differences. Linear regression shows that larval diameter, which significantly influences development duration, is more influential than size. These results can be seen as a distinct reproductive strategy, adapted to specific environmental conditions. Finally, the targeted exploitation of different kinds of flies appears to be a promising local alternative to imported inputs for poultry feed, with better performance noted for the genus *Sarcophaga*.

***Keywords*:** Fly, Genera, Performance, Poultry, Senegal.

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1. INTRODUCTION

In sub-Saharan Africa, development of poultry farming is impeded by several constraints, the main one being access to protein-rich foods (Ouattara et al. 2015; Pousga et al. 2019; Chibanda et al. 2024). Indeed, protein-rich ingredients (fish meal, cotton and soy cake) are mostly imported products, making their acquisition difficult, especially in rural areas (Pousga et al. 2007; Ouattara et al. 2015; Sajjad et al. 2024). Consequently, local poultry, which performs poorly, is raised in precarious feeding conditions (Ouattara et al. 2015; Pousga et al. 2019; Osuch et al. 2024). Identification of a new animal protein source at lower cost appears to be essential to overcome this problem whose impact on poultry production is considerable (Traoré et al. 2020a; Novodworski et al. 2022). Fly larvae have proven in recent years to be an alternative to imported proteins (Van Huis et al. 2013; Kenis et al. 2018; Dalmoro et al. 2023). These insects, present in almost all ecosystems, are naturally ingested by free-ranging poultry, highlighting their importance for poultry farming (Van Huis et al. 2013; Sajid et al. 2023). Several studies have validated the use of fly larvae as a dietary supplement for poultry (Kenis et al. 2014; Pomalegni et al. 2016; Sanou 2019; Traoré et al. 2020a, 2020b; Kiendrébéogo et al. 2019 and Sankara et al. 2021). Some species of flies can be used for this purpose: *Fannia canicularis*, *Calliphora sp.* (Meat flies), *Musca domestica* (housefly), and *Hermetia illucens* (black soldier fly) (Bloukounon et al. 2019a; Sanou 2019; Elahi et al. 2022). Among them, M. domestica seems to be the most appropriate due to its proximity to humans and the speed of production of its larvae (less than a week) (Koné et al. 2017; Sanou 2019; Khan et al. 2024). In West Africa, the maggots of *H. illucens* and *M. domestica* are most used for animal feed, mainly poultry (Bloukounon et al. 2019b). M. domestica is often preferred due to its abundance in various habitats, rapid development cycle and the possibility of obtaining maggots naturally on various substrates without raising adult flies for laying (Kenis et al. 2018; Dublecz et al. 2025). In addition, *Lucilia sericata* has high potential due to its high protein and lipid content as well as its relatively short life cycle, which makes it a candidate species for industrial larval production as an alternative to conventional nutrient sources (Fagbohoun 2018).

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Thus, this study aims to determine the most efficient fly species in terms of maggot production for poultry feed.

2. MATERIALS AND METHODS

2.1. Study Area

The present study was conducted in the commune of Gossas, located in Fatick region, in the centre-west of Senegal. The map of the study area (Fig. 1) illustrates the spatial delimitation of the commune as well as the position of the sampling site. Gossas is represented in light blue and fits into a territorial unit including the bordering communes of Patar Lia to the west, Ndiene Lagane to the north and Ouadiour to the south. The sampling site, symbolized by a red dot, is located in the southern part of the commune territory.

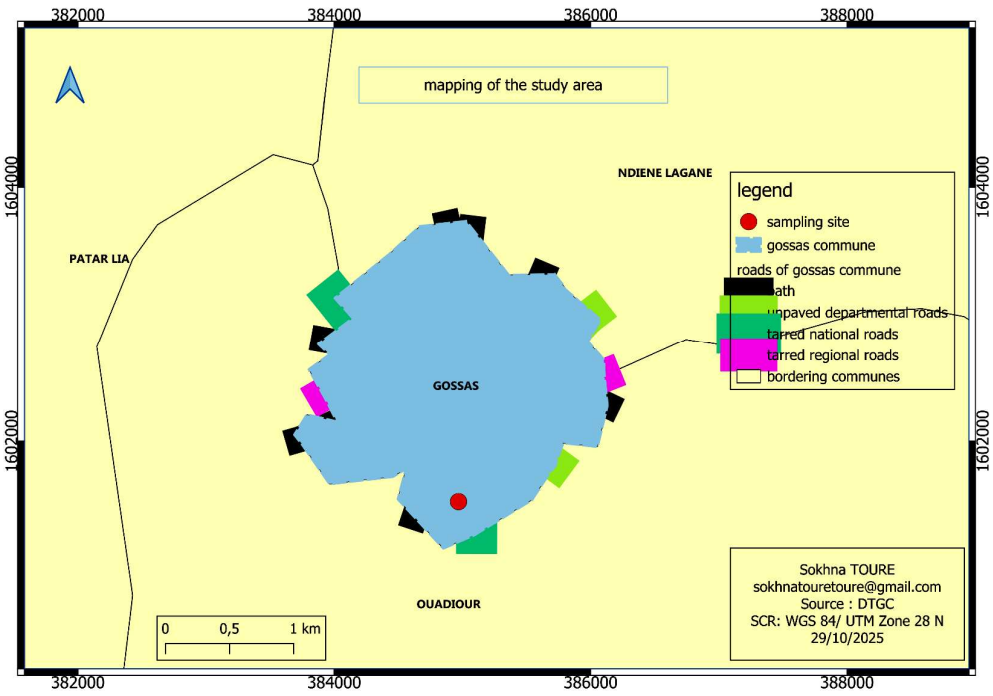

Fig. 1: Mapping and location of the study area.

2.2. Study Period

This study took place between the months of August and September 2023, more precisely from August 1st to September 30th.

2.3. Substrate Choice

The substrates were selected following the preliminary results obtained during the first manipulations. For reproduction, each genus of fly was placed on its specific substrate (Touré et al. 2024).

2.4. Flies Breeding

Adults were classified in cages according to their gender. Flies reproductive cycle was dealt with in each of these cages.

2.4.1. Duration of embryonic development: After laying, eggs were incubated in tanks at ambient medium until they hatched. This process was monitored daily in order to determine the exact embryonic life span, which corresponds to the time between egg laying and hatching.

***2.4.2. Duration of larval development*:** The duration of larval development corresponds to the time that the eggs hatch to their transformation into pupae. To properly identify this period, we had carried out daily monitoring.

***2.4.3. Duration of nymphal development*:** The nymph duration is the time that separates the pupae formation at the emergence of the adult. To be able to put a value on this period, we had incubated each pupa in a tray, which we followed daily until it emerged.

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2.4.4. Biometry of larvae: To evaluate the larval biometry, we had collected the larvae by sifting the contents of the bins to separate the larvae from the residues and subsequently sampled 10 larvae then measured their length and width using a graph paper.

2.4.5. Sex-ratio of the first generation flies: The sex ratio or the index of reproduction and numerical distribution of the sexes was calculated using the following formula: Sex-ratio = (Σ♀/Σ♂+Σ♀).This formula describes the calculation of the sex ratio, expressed as the proportion of females in a population relative to the total number of individuals (males + females). This type of formula is often used in biological studies to assess population dynamics, including in insects, for which the proportion of sexes can impact reproduction or other population behaviours (Lo 2020).

Formula Details:

- Σ♀: Sum of the number of females in the population.
- Σ♂: Sum of the number of males in the population.
- Σ♀+Σ♂: Total of individuals in the population.

2.4.6. Viability of larvae: Larvae viability is the number of larvae that have reached the pupa stage compared to the total larvae harvested.

2.5. Statistical Analysis

Excel Spreadsheet 2013 was used for data entry and the representation of figures and tables as well as to calculate emergence rates. The statistical analyses were carried out using R version 4.1.2. The Shapiro-Wilk test was conducted to assess the normality of the data. When the data did not follow a normal distribution, the Kruskal-Wallis test was applied at the 5% significance level.

3. RESULTS

3.1. Sex-ratio of the First Generation Flies

In our study, the sex ratio evolves differently by gender. However, it is in all cases in favour of males (Table 1).

Table 1: Sex ratio of flies according to gender

Gender	Number of adults	Number of males	Number of females	Sex-ratio
Musca	100	58	42	0.42
Lucilia	100	62	38	0.38
Sarcophaga	100	77	23	0.23

2.6. Duration of Embryonic Development

The embryonic development duration of eggs from females of Musca, Lucilia and Sarcophaga (Fig. 2) are respectively equal to 22.8, 18.1 and 0 hours, and their mean difference was very significant (P =1.92 e-06 < alpha level of significance = 0.05).

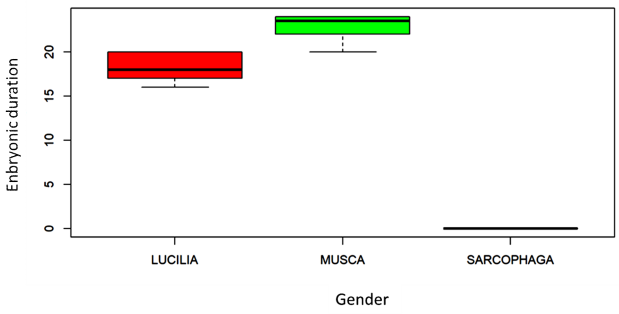

Fig. 2: Duration of embryonic development.

2.7. Duration of Larval Development

The average duration of larval development was 4.1 days for Musca; 6 days for Lucilia and 8.6 days for Sarcophaga (Fig. 3). The difference between durations was very significant (P =5.779e-06 < alpha level of significance = 0.05).

2.8. Number of Larvae

The average of larvae according to gender was 152.7 for *Lucilia*; 101 for *Musca* and 21.2 for *Sarcophaga* (Fig. 4). The difference in pupa number was highly significant (P = 1.91e-05 < alpha level of significance = 0.05).

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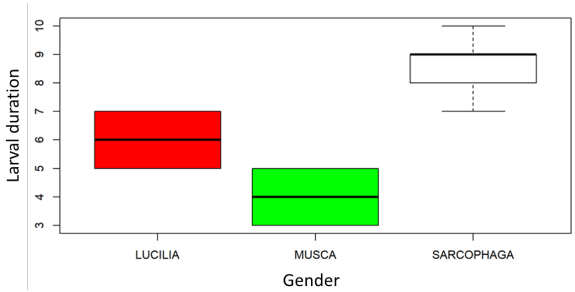

Fig. 3: Duration of larval development according to gender.

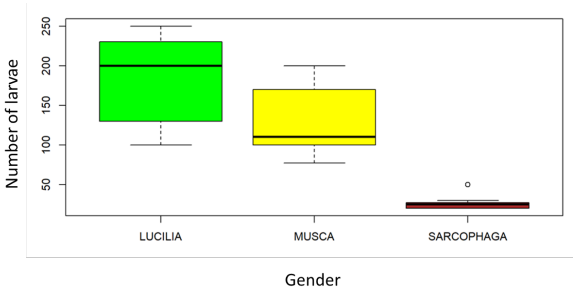

Fig. 4: Number of larvae according to gender.

2.9. Biometry of Larvae

2.9.1. Length: The average larval length was 1.21 for Lucilia; 1.033 for Musca and 1.84 for Sarcophaga (Fig. 5). The difference between these values was very significant (P = 1.33e-05 < alpha level of significance = 0.05).

2.9.2. Larvae width: The average larval width was 0.35 for Lucilia; 0.22 for Musca and 0.66 for Sarcophaga (Fig. 6). The difference between these values was very significant (P = 3.253e-06 < alpha level of significance = 0.05).

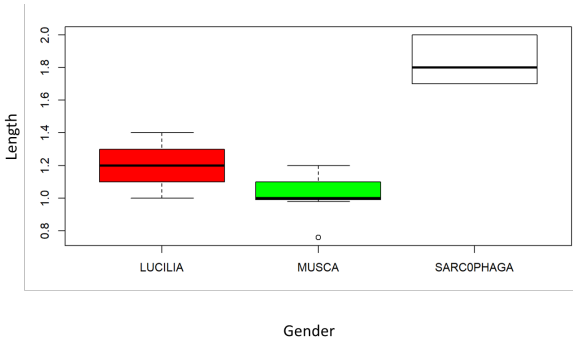

Fig. 5: Average length of larvae according to gender

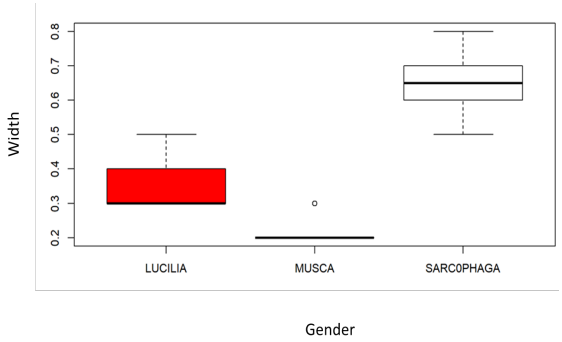

Fig. 6: Average width of larvae according to gender.

2.10. Correlation matrix Between Development Parameters

Fig. 7 represents a heat map of a correlation matrix between three variables namely: diameter, size and duration. Colours are mostly blue, indicating positive correlations between variables. However, the correlation is stronger between diameter and size, followed by the relationship between diameter and duration indicated by a high correlation, and finally the relationship between size and duration. This means that when one of the variables increases, the others also increase. The three variables are strongly related, so for a larger diameter is associated with a larger size and a longer duration.

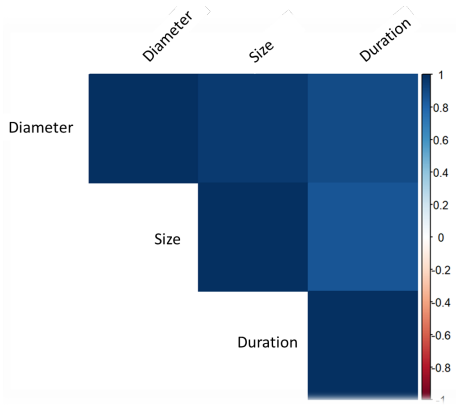

Fig. 7: Correlation matrix between development parameters.

2.11. Linear Regression

Table 2 represents a linear regression analysis, where the dependent variable is explained by two independent variables: Size and Diameter.

Table 2: Linear regression analysis

Coefficients:	Estimate	SE	P
Intercept	2.6482	1.0941	0.02251 *
Size	-0.3498	1.6187	0.83053
Diameter	9.9054	3.0260	0.00291 **

Significance: *P<0.05; **P<0.001.

R^2 = 0,802 et P = 3,193^{e-10}

Intercept (Constant = 2.6482 ; P = 0.02251)

When we set Size = 0 and Diameter = 0, the predicted value of the dependent variable is 2.6482. The P

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(0.02251) is less than 0.05, so this effect is statistically significant.

Size (Estimate = -0.3498; P = 0.83053)

A negative effect, indicating that as Size increases, the dependent variable slightly decreases. High P (0.83053) Not significant effect, so Size does not have a noticeable impact on the dependent variable.

Diameter (Estimate = 9.9054, p = 0.00291)

Important positive effect: when the Diameter increases by 1 unit (cm), the dependent variable increases on average by 9.9054 units (day). Very low P (0.00291) → highly significant effect, showing that the diameter strongly influences the dependent variable.

2.12. Analysis in Main Components

Fig. 8 represents a Principal Component Analysis (PCA) of individuals belonging to three groups: *Lucilia* (red dots), *Musca* (green triangles), *Sarcophaga* (blue squares). The two main axes: Dim1 (93.4%) explains 93.4% of total variance. Dim2 (5.3%) explains 5.3% of total variance. The individuals are projected according to their first two main components (Dim1 and Dim2), allowing them to visualize their similarities and differences. The individuals of the genus *Musca* (green - on the left, green circle), are mostly located in the negative zone of Dim1; this group is well separated from the others. Weakly dispersed, with homogeneous individuals, the genus *Lucilia* (red - in the centre, red circle), is placed around Dim1 0, with a vertical distribution; its individuals are slightly scattered but remain close to the centre. It is noticed a partial overlap with *Musca*, indicating similarities. Individuals of the genus *Sarcophaga* (blue - right, blue circle), located in the positive zone of Dim1, are well distinct from those of other groups; they are highly dispersed with more variability between individuals. Ultimately, we can say that the genus *Lucilia* shares similarities with *Musca*, while *Sarcophaga* is quite distinct.

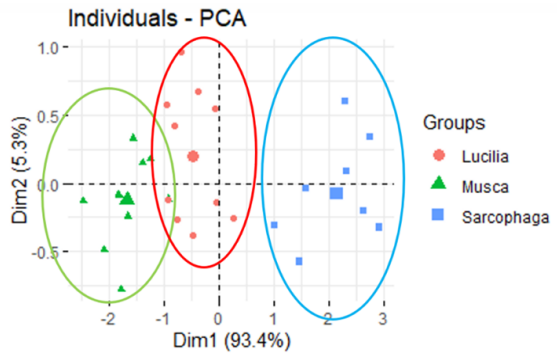

Fig. 8: Analysis in Main Components.

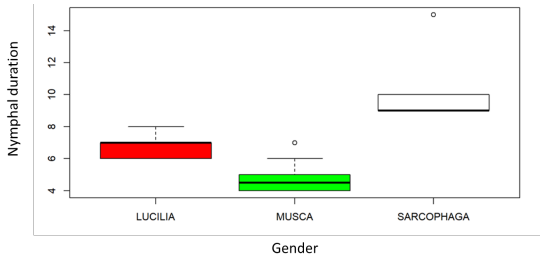

Fig. 9: Duration of nymph development based on gender.

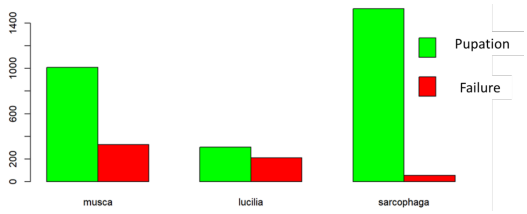

Fig. 10: Proportion of pupae.

2.13. Nymphal Duration

The average duration of nymph development was 4.8 days for *Musca*; 6.8 days for *Lucilia* and 10.4 days for *Sarcophaga* (Fig. 9). The difference between these durations was very significant (P =4.876e-06 < alpha level of significance = 0.05).

2.14. Viability of Larvae

Larval viability is the number of larvae that have reached the pupa stage compared to the total larvae harvested. Our results show 82.37% success out of 17.63% failure for the genus *Lucilia*, 76.79% success out of 23.21% failure for the genus *Musca* and 79.44% success out of 20.56% failure for the genus *Sarcophaga* (Fig. 10).

4. DISCUSSION

The study of embryonic development in diptera is crucial to a better understanding of their bioecology. This study highlights the embryonic duration of three distinct genera (*Lucilia*, *Musca* and *Sarcophaga*), revealing significant disparities that reflect their own reproductive strategies. For the genus Lucilia, an embryonic duration of between 16 and 20 hours was observed, with a median of around 18 hours. The low dispersion of values reflects a certain homogeneity in development, which is consistent with the observations of Grassberger and Reiter (2002), who estimated the embryonic duration of Lucilia sericata at 25°C to be within this range.

As for the Musca genus, its embryonic period is slightly longer, with a median of approximately 22 hours. This may be due to the characteristics of the local population, as some naturally have a slower embryonic period than others. Low temperatures also

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slow the embryonic period. These results are consistent with those of Denlinger and Zdarek (1994), who reported an incubation period of 20 to 24 hours at 25°C for Musca domestica. In contrast, in Sarcophaga, the embryonic period is estimated at 0 hours, suggesting viviparity. This interpretation is confirmed by Rivers et al. (2010), who showed that Sarcophaga carnaria releases larvae directly at the moment of expulsion, thus explaining this zero value.

The duration of the larval stage is also a determining factor in the biological cycle of diptera, influencing both their development and dispersal. In Lucilia, the larval phase lasts from 5 to 7 days, with a median of 6 days, which is consistent with the findings of Grassberger and Reiter (2002), who reported an average duration of 5.7±0.5 days at 25°C. Polat et al. (2025) also confirm a duration of 6 days, while emphasising that the availability of nutrient substrate can accelerate or slow down development.

The genus Musca has the shortest larval period, ranging from 3 to 5 days, with a median of 4 days. These results corroborate the work of Liu et al. (2016), who reported an average duration of 4 days for Musca domestica at 26°C. However, Casey et al. (2025) observed slightly longer durations (5 to 6 days) at 20°C, confirming the importance of temperature as a determinant of larval development speed. Conversely, Sarcophaga has a significantly longer larval stage, lasting between 7 and 10 days (median: 8 days). These data are consistent with those of Rivers et al. (2010), who showed that Sarcophaga bullata larvae require 7 to 9 days before pupation at moderate temperatures. However, Denlinger and Zdarek (1994) noted that this duration could be reduced to 6 days when the temperature exceeds 30°C, illustrating the adaptability of this genus to environmental fluctuations.

The analysis of fertility also highlights marked contrasts. Lucilia produces an exceptionally high number of larvae, with a median of around 200 and a maximum of close to 250. These observations are consistent with data from Yang et al. (2021), who report an average egg-laying rate of 180 to 250 eggs per female in *Lucilia sericata*. Polat et al. (2025) also point out that this genus adopts a reproductive strategy based on mass egg-laying, with each female capable of laying several hundred eggs at a time, which promotes rapid colonisation of substrates rich in organic matter.

The Musca genus has an average yield, with a median number of larvae between 100 and 150, but a more marked dispersion of values is observed. These results are consistent with those of Scott et al. (2014), who report an average egg-laying rate of 120 to 150 eggs in Musca domestica, and that these variations are correlated with environmental conditions. Berta et al. (2011) also showed that Musca domestica could lay up to 500 eggs during its lifetime, but in several successive cycles, which explains the more variable distribution of larvae per clutch.

In Sarcophaga, production is much more modest, with generally less than 25 larvae. These results are consistent with the work of Rivers and Dahlem (2014), who explain that Sarcophagidae lay larvae directly rather than eggs. This biological characteristic has a detrimental effect on their reproductive capacity, which is only around 40, sometimes even 20, per clutch. This minimal number of larvae, combined with the low percentage of females observed throughout this study, underscores the negligible value of Sarcophaga. Despite all this, it can be proud of the impressive size of its larvae, which could well represent a significant nutritional asset.

5. CONCLUSION

When comparing the three species of flies, there are striking differences in their reproductive capacity. Sarcophaga, although it gives birth to live larvae, is less productive with relatively slow development. Musca, on the other hand, reproduces constantly, but without really excelling. Lucilia, on the other hand, stands out for its rapid growth and remarkable larval abundance, demonstrating clear biological superiority. These observations are confirmed by linear regression, which underscores the crucial importance of development speed and the number of larvae produced, especially since multivariate analysis clearly places Lucilia at the top in performance. Ultimately, whether from a biological or statistical perspective, Lucilia stands out as the most efficient fly species for the intensive production of larvae for animal feed.

Declarations

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Conflict of Interest: The authors declare no conflict of interest.

Data Availability: The data used to make this article possible are available upon request.

Ethics Statement: The samples used in this study were collected exclusively from animals that had already been slaughtered for human consumption in commercial abattoirs. No animal was sacrificed for this research. The

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sampling procedure was strictly limited to the collection of parasitic worms from the abomasum post-mortem. Therefore, according to the national and institutional guidelines, this study did not require specific approval from an animal ethics committee.

Author's Contribution: Sokhna TOURE: She was responsible for the study design, experimental execution, data collection and analysis, as well as the initial drafting of the manuscript. Toffène DIOME: He contributed to the scientific supervision, statistical analysis, and critical review of the content. Mamecor FAYE: He handled the complete translation of the manuscript into English and the linguistic and technical review. Mbacké SEMBENE: He participated in validating the results and in the final editing of the manuscript.

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