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Reproductive performance of flies as a function of substrate

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Abstract
The use of maggots in poultry feed makes it possible to better overcome the problems faced by poultry farmers. Although the production cost of the latter is not substantial, it is essential to control the production parameters. This study, performed in Senegal, more precisely in the commune of Gossas, aimed to evaluate the productivity of locally available substrates. To do this, four substrates were used, namely cattle leaning, mango, sheep liver and fish viscera. As for the size, 10 maggots were taken per production to make the measurements. Regarding the duration of larva development, it was the difference between the hatching of the eggs and the onset of pupal. The results obtained reveal that the leaning substrate is more productive with an average of 900.9 larvae, followed by mango with an average of 447.6 larvae, followed by viscera with an average of 235.5 larvae and finally the liver with 159.8 larvae. Regarding the larval duration, it was slower for the viscera and mango with values of 5.7 days and 5.4 days respectively, and faster for the leaning and the liver with values of 3.6 days and 4.6 days respectively. Concerning the fly family, three were present; the Muscidae largely followed by the Calliphoridae and the Sarcophagidae in last place. The measurement of the larval size of these families reveals that they are more important at the viscera level as far as the Muscidae are concerned, with an average value of 1.26cm (±0.051). On the other hand, in the Calliphoridae, the average value is more consistent in the liver, with 1.22cm (±0.042) as the. The Sarcophagidae are only found in the viscera.

Keywords: Maggots, substrate, productivity, Gossas

Introduction
The worldwide population is growing at an exponential rate, which is estimated to increase food demand by 70-100% by 2050 [1]. World meat production in 2018 is estimated at 336.4 million tonnes, 1.2% more than in 2017 thanks to the contribution of the European Union, the United States and Brazil. As for the different types of meat, beef production recorded the strongest growth (+2.1%), followed by poultry meat (+1.3%) [2]. In addition, in developing countries and in sub-Saharan Africa, livestock is responsible for a third of agricultural GDP. According to some forecasts, the consumption of meat products could increase by 60 to 70% by 2050 [3]. The turnover of Senegal's poultry sector increased from 72.2 billion CFA francs in 2006 to 201 billion CFA francs in 2013. In 2016, the poultry sector generated a turnover of 160 billion CFA francs [2]. Poultry feed is the most important input in mass farming in terms of cost. Poultry needs a constant supply of energy, protein, essential amino acids, minerals, vitamins, and water [4]. The main raw materials used in livestock feed are currently fish and soybean meal [1]. In the face of the ever-increasing prices of these foods on the market, it is of great interest to find a substitute that is so nutrient-rich, cheaper and locally available [5]. Maggots are bio-degraders of household waste, the management of which is a major environmental concern in Africa [6, 7]. The use of larvae as a food supplement for birds has shown better results on their reproduction [8]. The present work has set itself the objective of contributing to the improvement of animal production and limiting competition between humans and animals in relation to basic protein-rich ingredients through the valorization of maggots. Specifically, it was a question of identifying the flies whose larval development takes place on local substrates, and of comparing the yield of maggots obtained per unit mass of these substrates.

Materials and Methods
Study website: The study took place in the commune of Gossas (14°27'33" North, 16°3'58"

West) located 160 km from Dakar, 74 km from Touba, 27 km from Diourbel, 47 km from Kaolack and 40 km from Fatick (Figure 1). The city of Gossas is characterized by a dry and hot semi-arid climate and has a dry season (October to May) and a rainy season (June to September). The dry season includes a cool period from December to February and a hot period from March to May. Climate has a decisive role in the life and development of flies and their larvae through humidity, temperature and winds.

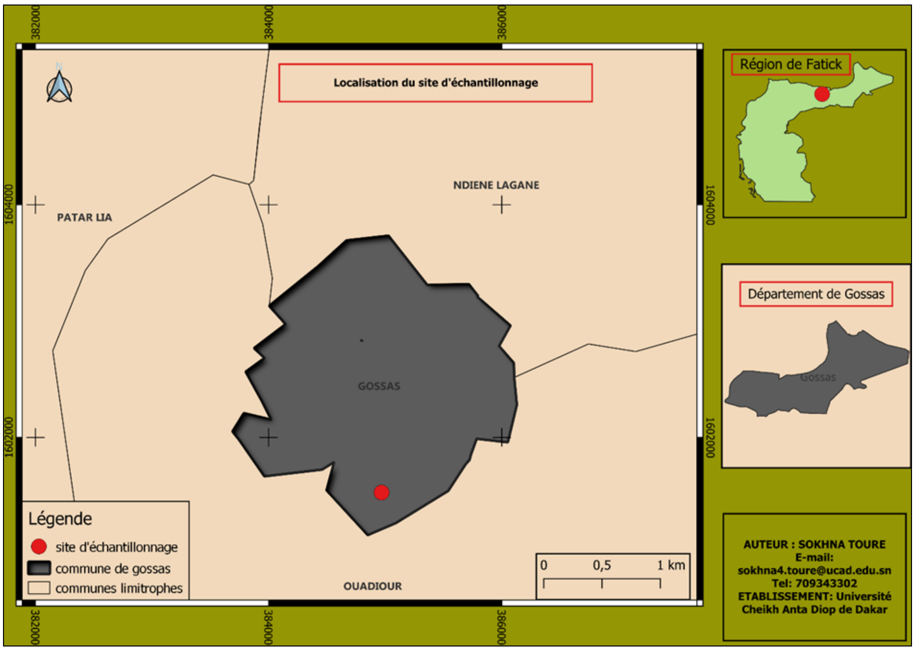

Fig 1: Geographical map of the commune of Gossas and the sampling site

Substrate Selection

Flies deposit their eggs in nature on more or less decomposed organic matter [9]. In the context of this study, sheep liver, mango, bovine leaning and fish viscera were selected because of their availability and free of charge as maggot production substrates. The fresh fish waste was collected free of charge from the women fishmongers present in the city. The cattle leaning was chosen due to its avaibility for free ou at lower cost in the slaughterhouse in Gossas town. In this same place we were able to obtain liver. mango was obtained easily since this was its period.

Experimental design

The experiment was conducted on an open tarpaulin terrace, 7 m long, 4 m wide and 3 m high. The experimental design was made in a complete random block with 4 randomized treatments corresponding to the number of substrates. Each treatment corresponds to a type of substrate contained in a tank intended for maggot breeding. This process was repeated 3 times. The third replicate was used to identify the flies that emerged from the breeding tanks. In total, on the site, 12 bins covered with fine mesh (mosquito net) were placed, well spaced between them, numbered and each containing 1kg of substrates. The opening and bottom of each tank measured 40 and 9 cm in diameter, respectively. The different substrates were kept at an average temperature that varied between 20 and 22.3 °C and exposed to the open air according to the method proposed by Bouafou *et al.* [6]. The basins were covered with mosquito nets 24 hours after exposure to reassure us of the homogeneity of the larvae and to avoid late stocking.

Monitoring of maggots development

Determining the number and size of maggots: The production parameters retained during this study are the total number of larvae, the development time and the size of the maggots. After each harvest, 10 maggots per treatment were collected and soaked for 5 seconds in boiling water to measure their average size using graph paper and a flat ruler graduated in cm.

Fly identification

The fly samples were manually captured on different substrates using a small sweep net and subsequently stored in vials containing 70% alcohol for later identification. The identification was made at the Entomology and Acarology Laboratory of the Cheikh Anta Diop University of Dakar on the basis of morphological characters using the monocular magnifying glass and identification keys [10, 11].

Statistical analyses

Excel 2019 spreadsheet was used for data processing and table representation. Statistical analyses were carried out with the R. 4.2.2 software (R Core team 2022). The Shapiro-Wilk test was performed to verify the normality of the quantitative variables. Since the latter do not follow the normal distribution, the Kruskal-Wallis test was applied to the 5% probability threshold. Not having only quantitative variables, the chi-2 test was also applied.

Results

Identification of substrate-associated fly families

Three families of flies (Sarcophagidae, Muscidae and Calliphoridae) all belonging to the order Diptera and the suborder Cyclorraphes were involved in the seeding of different by-products used as substrates as shown in Figure 2 below:

Fig 2: The families of flies associated with substrates: Sarcophagidae(A), Muscidae(B) and Calliphoridae(C)

Species belonging to the family Calliphoridae and those of Muscidae were in the prevailing, because they were present with fairly large numbers on almost all substrates, unlike the Sarcophagidae which were found only on one substrate, namely the viscera, but with a higher number than those of the other families (Figure 3). The visceral substrate was more important in terms of diversity because in it were present all the families listed in this study. On the other hand, the family Muscidae was more abundant in the slope and the Calliphoridae in the liver.

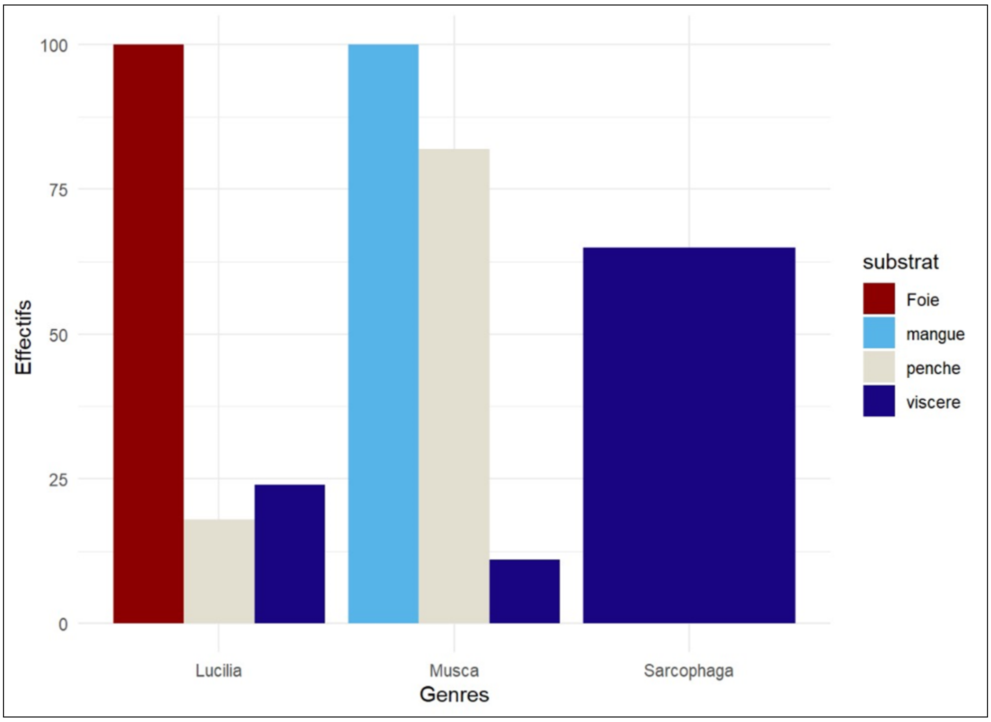

Fig 3: Diversity and abundance of flies by substrate

Number of maggots depending on the substrate

Figure 4 shows the effect of substrates on maggot abundance. A significant quantity of maggots was obtained with the penche (9009 larvae). The mango waste used had contributed to a good productivity of maggots (4476 larvae). With fish viscera, we were able to obtain an interesting number of maggots, but not greater than the first two (2355 larvae). With sheep liver, the quantity of maggots obtained was smaller compared to other substrates (1598 larvae). There was no statistically significant difference between maggot productivity from the liver and the viscera. The same applies to mango and slack. On the other hand, a statistically significant difference was observed between the maggot productivity of the liver and the swing. And between mango and viscera (P-value = 3.607e-06).

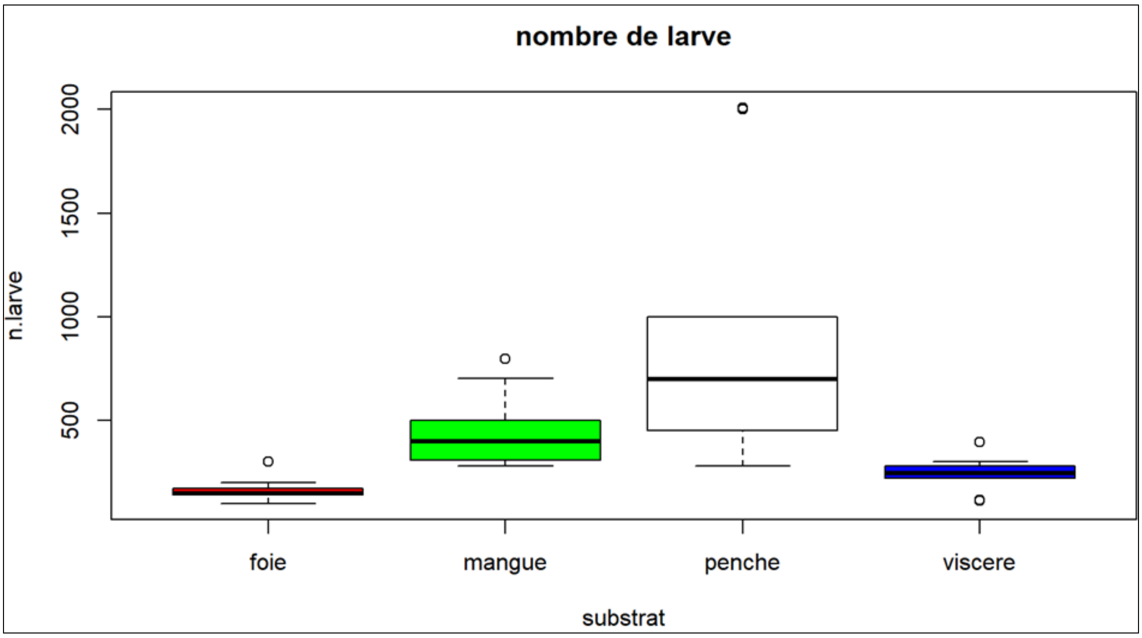

Fig 4: Number of maggots as a function of substrates

Duration of larval development as a function of substrate
Generally, the duration of larval development varies considerably depending on the substrate. The production cycle was thus more significant in certain substrates than in others (Figure 5). The duration was slower for the intestine and the mango with respective values of 5.7 days and 5.4 days, and faster for the stomach and liver with respective values of 3.6 days and 4.6 days (p-value = 2.214e-06).

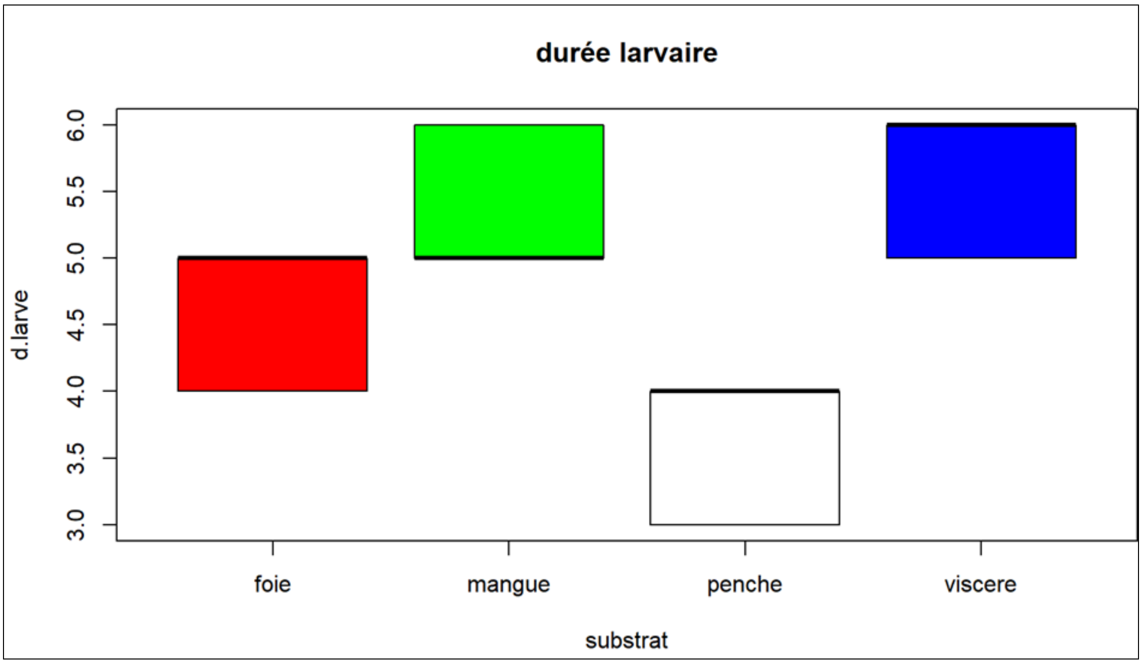

Fig 5: Duration of larval development as a function of substrates

Size of larvae depending on the substrate
In general, the average size of maggots increases depending on the substrate and the production cycle; some substrates produced larger maggots than others. For all substrates, the most significant average sizes of maggots were obtained during their final production stage. During our study, we were able to compare the average size of Musca larvae and that of Lucilia because they were the only ones found in several substrates.

Size of Musca larvae depending on the substrate
The analysis of our results has shown that the average size of Musca larvae was greater in the viscera, where they reached a value of 1.26cm. Following this were the maggots produced on the slope, which reached an average length of 1.067 cm, and finally the larvae produced on the mango, which had developed to an average of 0.613 cm. Statistical analysis of this difference between the sizes of the musca larvae showed a high significance translated by a p-value that is equal to 3.162e-06 (Figure 6).

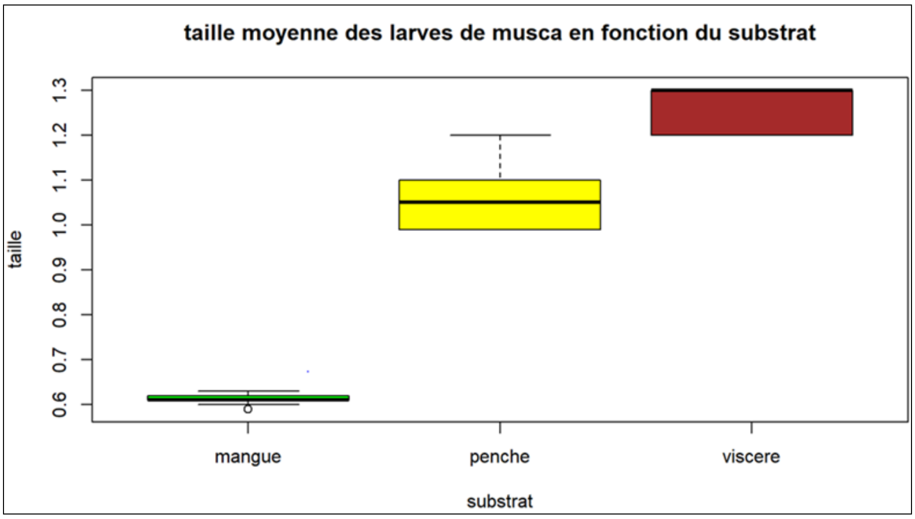

Fig 6: Average size of Musca maggots according to substrates

Average size of Lucilia larvae based on substrate.

Our analysis of the results has shown that the average size of Lucilia larvae was larger in the liver, where they reached a value of 1.22cm. Following this were the maggots produced on the slope, which had reached an average length of 1.15cm, and finally the larvae produced in the viscera, which had developed up to an average of 1.04cm. The statistical analysis of this difference between the sizes of Lucilia larvae had shown strong significance, as indicated by a p-value equal to 2.366e-05 (Figure 7).

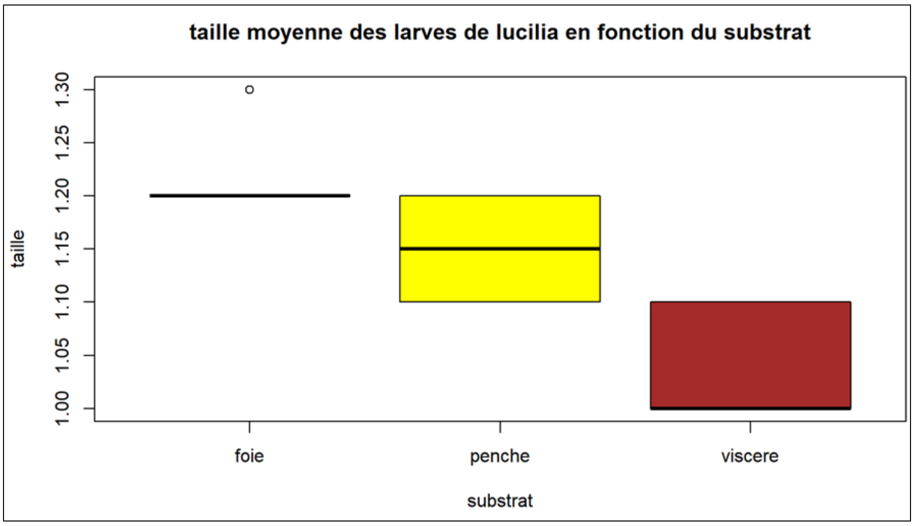

Fig 7: Average size of Lucilia maggots based on substrate

Discussion

The morphological identification of flies revealed three families of flies colonizing substrates, namely Muscidae, Calliphoridae, and Sarcophagidae. This result differs from the one obtained by Agodokpessiv *et al.* [12], who confirm that only the Muscidae family is capable of colonizing all substrates. Furthermore, Bouafou *et al.* [13] identified Muscidae and Calliphoridae in their study on the potential of maggot production from by-products in Côte d'Ivoire. Similarly, Sankara *et al.* [14] also only found Calliphoridae and Muscidae. These differences can be explained by the fact that these studies were conducted in different environments and time periods, therefore under different conditions. The factors responsible for attracting flies to production substrates include climatic factors. However, the results of Akilimali *et al.* [3] confirm ours. As for the production of maggots, it varies depending on the substrates. This result is consistent with those of Ganda *et al.* [15], Sankara *et al.* [16], and Sankara *et al.* [14], which suggest that maggot yield is related to the nature of the substrates. This can be explained by the fact that the characteristics of the substrates differ from each other in terms of protein content, smell, texture, state, and decomposition rate. The best substrate for producing maggots is manure. This result contradicts the findings of Koné *et al.* [17], Sanou *et al.* [18], and Sankara *et al.* [16], who declare poultry droppings as the better substrate. This difference may be attributed to the fac that they did not use the same substrates as us, but also by the impact of the agroecological zone. The development of maggots as well as their lifespan is directly influenced by the moisture content of the substrate. These results obtained corroborate those of Sanou *et al.* [18] and Sankara *et al.* [14] who reveal that the wetter the substrate, the longer the duration. The optimum substrate humidity range is between 52 and 70%; below 50%, there is high mortality, and above 70%, growth is very slow [19]. At the end of their development, apart from their shape, the maggots differ in size. These variations can be explained by the difference in substrate composition, as there may be an element that promotes the mass gain of maggots as well as their length. The fact is also that the characterization of the fly species colonizing the substrate must be taken into account as they have their own morphology. However, the impact of the agroecological zone should not be overlooked, as each location is colonized by specific species.

Conclusion

The level of using maggots as an alternative source of protein in animal feed remains practically nonexistent among farmers in Senegal. This is due to a lack of information and popularization about the virtues of larvae. Our study has shown that maggot production is a sustainable and economical protein production system. This work has enabled us to identify three main families of flies associated with maggot-developing substrates: Muscidae (the majority), followed by Calliphoridae and Sarcophagidae (rarely found). It also determined the level of production of these different substrates and the biometry of the larvae they produced. In short, this study shows that the sloping substrate should be chosen for the possible use of bio-organic residues as poultry feed, thereby helping to protect the environment.

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