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Research Article
Seasonal and Harvest Effects on Maggot Composition from Ruminal Contents With or Without Bovine Blood

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Abstract
Background and Objective: Livestock productivity in Sub-Saharan Africa is often limited by inadequate nutrition, particularly during varying seasons. Understanding how seasonal changes and harvest times affect the chemical composition of feed is crucial for improving livestock nutrition and sustainability. This study investigates the effects of season and harvest time on the chemical composition of animal feed, focusing on ruminal contents alone or in combination with bovine blood. **Materials and Methods:** A total of 48 containers were used in the production of maggots. 6 treatments made up of 1, 1.5, and 2 kg of ruminal contents, either alone or associated to 10% of bovine blood. Each substrate was repeated 8 times, and maggots were separately harvested as follows: 4 repetitions were harvested on the 5th day, and the 4 others on the 10th day. Data on the chemical composition of the substrates were analyzed using a four-factor analysis of variance with SPSS 20.0 to identify significant differences among treatments Data were analyzed using ANOVA and Duncan's test (5%), with t-test for seasonal and harvest-day comparisons in SPSS 20.0. **Results:** On the 5th or the 10th day, the dry matter contents and ash contents of the maggot meal obtained in the dry season were higher than those obtained during the rainy season. In the dry season, the highest protein content (59.13%) was obtained on the 10th day, and the lowest protein content (55.62%) on the 5th day. During the rainy season, the highest protein content (57.78%) was also obtained on the 10th day and the lowest on the 5th day. The mineral content (calcium, potassium and sodium) of maggot meal on the 5th day of harvest was higher than the mineral content on the 10th day in the rainy season in all substrates. No matter the season, the potassium content recorded the highest. **Conclusion:** The result of this study demonstrates that the season and harvest time significantly influence the chemical composition of maggot meal, particularly in terms of protein and mineral content, highlighting the potential of using ruminal contents and bovine blood for maggot production in animal nutrition

Key words: Bovine blood, maggots, chemical composition, ruminal contents, season

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In Sub-Saharan Africa, the development of livestock is significantly hindered by inadequate protein in animal feed, which often fails to meet their nutritional needs[1]. This deficiency in protein in the animals' diets can lead to low productivity, preventing them from reaching their full potential[2]. The dietary proteins that are available are expensive and difficult to access by the small breeder. However, the physiology of ruminant and non-ruminant animals requires the presence of proteins in their diet, to compensate for the impossibility of synthesis of certain amino acids[3]. To resolve this problem of low animal productivity, Parisi *et al.*[4] showed the need to search for new sources of animal proteins, easily accessible, not consumed by humans but capable of enriching livestock feed. Edenakpo *et al.*[5] reported that cockroaches and termites can replace meat meal in broiler diets. Noumbissi *et al.*[6] obtained better weight growth of Muscovy ducklings which reached 1.3 kg in 8 weeks of age and a reduction in their mortality rate (less than 6%) using fly maggot meal as a source of protein in the ration. Bouafou[7] reported that maggot meal can validly replace fish meal in animal feed. Among the insects that have hitherto been used in the production of animal meal, maggots have the advantage that in Sub-Saharan Africa, they can be produced in large quantities from a wide range of household waste, under -industrial products, animal excrement and slaughterhouse waste[1,4,7,8]. Concerning household waste and slaughterhouse waste, their management constitutes an environmental concern in Africa[7]. According to Odjo *et al.*[1] various practice are implemented for the recovery of this waste, notably the production of maggots for animal feed. This same author used ruminal contents in plastic bags to produce maggots.

However, the maggot production performances obtained were much lower than those obtained by Odjo *et al.*[9] using fresh brewers' grains as a substrate, or by Babatunde *et al.*[10] with chicken droppings. Resolving this problem could therefore be done by researching ways and means to increase the maggot productivity of ruminal contents. The work of Bouafou *et al.*[8] reported that proteins of animal origin such as raw meat, fish remains and blood are good attractive substrates for flies to produce maggots. Enriching ruminal contents with bovine blood could therefore improve maggot production. This work was initiated in order to contribute to the diversification of alternative sources of animal proteins that can be used in animal feed. This study aimed to investigate the effects of season and harvesting conditions on the composition of maggots produced from ruminal contents with or without the addition of bovine blood, in order to assess variations in their nutritional profile and potential utilization.

MATERIALS AND METHODS

Study area: The present study was conducted in September (rainy season test) and January (dry season test) in 2023 at the Application and Research Farm (ARF) and the analyses were carried out at the Laboratories of Nutrition and Animal Feed (LANAA) and soil sciences from the University of Dschang (Uds). The FAR is located between 05°26' North Latitude and 10°26' East Longitude and at an altitude of 1420 m. The climate of the region is equatorial, Cameroonian, modified by altitude. Temperatures range between 10°C (July-August) and 25°C (February) with an annual insolation of 1800 hrs and relative humidity varying between 40 and 97%. Precipitation varies between 1500 and 2000 mm per year. The dry season is from mid-November to mid-March, and the rainy season is from mid-March to mid-November. This last period corresponds to the growing season. The original vegetation is a shrubby savannah with gallery forests in places.

Breeding environment: A rectangular breeding environment on stilts was built on an ARF with local equipment. The enclosure measured 6 m long and 3 m wide; the height of the walls was 30 cm. The floor was covered with braces, and the roof was covered with a transparent plastic sheet. The edges of the enclosure were slightly open to allow good ventilation and fly circulation. The basins containing the breeding substrate rested on the braces of the floor.

Origin of substrates: The ruminal contents of cattle were collected early in the morning (6 a.m.) at the municipal slaughterhouse of Dschang with their approval. As soon as the animal was slaughtered and eviscerated, the contents of its rumen were poured directly into the bag lined with plastic to prevent ruminal juice from leaking out. The bag was tied with a rope and then transported to the FAR. The blood from the same cattle was collected immediately after slaughter in a 10-liter bucket, which was then hermetically sealed and transported to the Teaching and Research Farm (FAR) for testing.

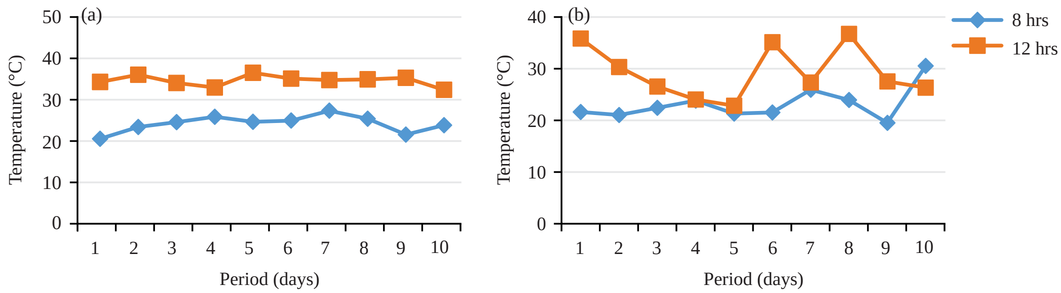

Fig. 1(a-b): Evolution of ambient temperature during the test, (a) Dry season and (b) Rainy season

Experimental design: For this study, repeated over two seasons, we used for each season 48 maggot rearing devices distributed in a 2×3×2 factorial design (2 types of substrates, 3 quantities, and 2 collection periods) with 4 repetitions per harvest period. During each harvest day, 4 replicates per treatment were destroyed, and their maggots were collected.

Breeding management: Each rearing device included a plastic strainer with a diameter of 26 cm at the opening, 13 cm at the base, and a depth of 10.5 cm, containing the substrate. This colander rested on a basin also made of plastic with a diameter of 28 cm at the opening, 21.5 cm at the base, and a depth of 11 cm. This basin was intended to receive the maggots that passed through the mesh of the strainer.

During the two tests (dry season and rainy season), the quantities of ruminal contents used were 1 kg, 1.5 kg, and 2 kg with or without bovine blood. 6 treatments were therefore constituted and placed in a 2×3×2 factorial device (2 types of substrates, 3 quantities, and 2 collection periods) with 4 repetitions per treatment for each collection day. These treatments were as follows:

- **CR1:** 1 kg of rumen content
- **CR2:** 1.5 kg of rumen content
- **CR3:** 2 kg of rumen content
- **CRS1:** 1 kg of rumen content+10% blood
- **CRS2:** 1.5 kg of rumen content+10% blood
- **CRS3:** 2 kg of rumen content+10% blood

The substrates thus formed were placed in the open air for 5 hrs before being introduced into the breeding building, protected from bad weather. The harvests took place on the 5th and 10th days during the rainy season and the dry season. For this, the production device containing the substrate was exposed to the sun and the maggots escaped the heat by going to the bottom of the substrate and they passed through the mesh of the strainer to fall into the collection basin. The maggots that remained in the substrate were collected by manual sorting after spreading the said substrate on plastic. This substrate was no longer reused afterwards. Ambient temperatures were taken every day around 8 a.m. and 12 p.m. using an electronic thermometer (Fig. 1a-b).

Data collected and parameters studied

Chemical and mineral composition of maggot meal: The collected maggots were dried in an oven at 60°C until constant weight and then ground in a grinding machine. The chemical composition of the maggot meal obtained was determined at the FASA Animal Nutrition and Feeding Laboratory. Thus, dry matter (DM), crude protein content and ash were determined[11]. The minerals Na and K were measured by flame spectrophotometry, while Ca was determined by complexometry using EDTA (ethylene diamine tetra acetate).

Data analysis: The data on the chemical composition were subjected to the analysis of variance with four factors (type of substrate and quantity of substrate). When there were significant differences between treatments, the means were separated by the Duncan test at the 5% significance level. The Student t-test was used to compare the averages of the seasons and harvest day. The statistical software SPSS 20.0 (Statistical Package for Social Sciences) was used for these analyses.

RESULTS

Effect of bovine blood in the substrate on the chemical composition of maggot meal depending on the harvest day: It appears from this table that the dry matter, organic matter, protein and ash content of the maggot flour produced on the 5th day with the substrates without was comparable to that of the substrates with blood. Potassium and sodium contents were significantly ($p<0.05$) higher in maggot meal from bloodless substrates during the same period. On the 10th day, the crude protein content of maggots from substrates having received bovine blood was significantly ($p<0.05$) higher than

Table 1: Effect of the substrate with blood and without blood on the chemical composition of the maggot flour obtained in the rainy season

	Day 5			Day 10		
Chemical composition (%MS)	CR	CRS	p-value	CR	CRS	p-value
MS	91.28±0.89[a]	90.51±0.53[a]	0.41	92.00±0.22[a]	91.56±0.36[a]	0.64
MO	91.03±0.96[a]	92.65±1.15[a]	0.65	93.62±0.49[a]	93.56±1.12[a]	0.87
PB	57.02±6.82[a]	57.32±5.57[a]	0.93	51.01±3.26[a]	55.33±9.39[a]	0.47
C	8.96±0.96[a]	7.34±1.15[a]	0.29	6.37±0.49[a]	6.43±1.12[a]	0.70
Minerals (g/kg)						
Ca	3.16±3.18[a]	3.54±1.56[a]	0.32	0.82±0.36[a]	1.03±0.37[a]	0.69
K	9.10±1.19[a]	6.73±0.47[b]	0.00	2.87±1.12[b]	5.87±1.62[a]	0.00
Na	1.46±0.25[a]	1.07±0.09[b]	0.00	0.65±0.32[a]	0.99±0.29[a]	0.58

[a,b]The means bearing the same letter on the line are not significantly different at the 5% threshold CR: Ruminal content, CRS: Ruminal content+10% blood, MS: Dry matter, MO: Organic matter, PB: Crude protein and C: Ash

Table 2: Chemical composition of maggot obtained in the dry season depending on the substrates

	Day 5			Day 10		
Chemical composition (%MS)	CR	CRS	p-value	CR	CRS	p-value
MS	92.71±0.23[a]	91.52±0.86[a]	0.67	92.12±1.10[a]	94.04±0.81[a]	0.36
MO	87.19±1.34[a]	84.33±0.26[a]	0.79	86.27±0.44[a]	85.19±0.84[a]	0.96
PB	55.62±2.60[a]	56.83±1.50[a]	0.50	59.13±5.80[a]	57.78±1.20[a]	0.83
C	12.80±1.34[a]	15.66±0.26[a]	0.32	13.71±0.44[a]	14.80±0.84[a]	0.17
Minerals (g/kg)						
Ca	0.96±0.60[b]	2.05±1.64[a]	0.00	1.34±0.46[a]	0.90±0.45[a]	0.44
K	7.60±2.80[b]	9.67±2.50[a]	0.00	7.21±3.31[a]	7.59±1.09[a]	0.59
Na	1.38±0.62[a]	1.29±0.86[a]	0.22	1.31±0.81[a]	0.88±0.72[a]	0.18

[a,b]Averages with the same letter on the line are not significantly different at the 5% threshold. CR: Ruminal content, CRS: Ruminal content+10% blood, MS: Dry matter, MO: Organic matter, PB: Crude protein and C: Ash

that of maggots produced with substrates without blood. Furthermore, no significant difference ($p>0.05$) was observed between the two types of substrates in terms of dry matter, organic matter, ash, calcium and sodium content (Table 1).

Table 2 presents the effect of the substrate with blood and without blood on the chemical composition of the maggot flour obtained in the dry season. It appears from this table that on the 5th and 10th day the content of dry matter, organic matter, protein and ash of the maggot flour obtained with the substrates without blood was comparable to that obtained with the substrates having received the blood.

The Ca and K mineral content of maggot meal from the 5th day of harvest was significantly higher with the substrates associated with bovine blood.

It appears that the ash content of maggot flour from the 5th day of harvest in the dry season was significantly ($p<0.05$) higher than that of the rainy season, regardless of the substrate. On the other hand, the organic matter content of maggot meal from the rainy season was significantly ($p<0.05$) higher than that from the dry season, regardless of the substrate. The crude protein and dry matter contents of the two seasons were comparable.

The calcium content of maggots from the rainy season was significantly ($p<0.05$) higher than that from the dry season, regardless of the substrates. On the other hand, the potassium content of maggots produced in the dry season with the substrate containing bovine blood was significantly ($p<0.05$) higher than that of maggots from the rainy season.

The ash content of maggot flour from the 10th day of harvest in the dry season was significantly ($p<0.05$) higher than that of the rainy season regardless of the substrate. On the other hand, the organic matter content of maggot meal from the rainy season was significantly ($p<0.05$) higher than that from the dry season regardless of the substrate. The crude protein content of the dry season was comparable to that of the rainy season for both bloodless and blooded substrates.

It appears that the calcium, potassium and sodium content of maggot meal from the rainy season was significantly ($p<0.05$) higher than that from the dry season with substrates without blood. On the other hand, for the substrates with blood these contents were comparable during the two seasons.

DISCUSSION

Chemical composition shows that on the 5th and 10th day, the dry matter and ash contents of the maggot flour obtained in the dry season were higher than the contents obtained in the rainy season. This observation suggests that the chemical composition of the maggot flour would be indirectly affected by the season which will act on the organic matter of the substrate. The crude protein contents of these same days were higher in the dry season for all substrates except CR2 and CRS1 on day 5 and CRS3 on day 10. The protein content of the maggot meal obtained varied from 51.01 to 59.13% MS. These observations confirm the high crude protein contents in maggot flour. Which is consistent with the results of Fashakin *et al.*[12], Sogbesan *et al.*[13] and Hwangbo *et al.*[14] who respectively obtained 45% MS, 50.4% MS and 63.9% MS.

In the dry season, if we compare days 5 and 10, we see that the dry matter and organic matter contents of the maggot flour obtained with the bloodless substrates of the 5th day were higher than those of the 10th day. Conversely, for maggot flour from substrates with blood, the highest dry matter and organic matter contents were obtained on the 10th day. This variation observed in the chemical composition of maggots may be linked to the type of production substrate[13,15] and the age of the maggot at harvest[15,16]. In the rainy season, the dry matter and organic matter of the maggots from the 10th day of collection were higher than those of the maggots from the 5th day whatever the substrate. This could be explained by the fact that when the maggot approaches the pupa stage during its metamorphosis, it begins to store energy in the form of lipid[17]. This lipid accumulation on the 10th day would have led to an increase in the dry matter and organic matter content of the maggots.

In the dry season, the crude protein content of maggot meal from the 5th day was higher than that from the 10th day in all substrates except CR2 and CRS3. This drop in crude protein content on the 10th day could be due to the fact that when the maggot approaches the pupal phase of its metamorphosis it begins to use its proteins in enzymatic reactions to form its chitin[18]. In the rainy season, the crude protein content was highest in the maggot meal obtained with blood-free substrates on the 5th day of collection. However, for maggot meal obtained from substrates with blood, the crude protein content was high on the 10th day. This suggests that the blood would have improved the nutritional quality of the substrates and therefore the protein content of the maggots feeding on these substrates.

In the rainy season, the ash content of the maggot flour from the 5th day of collection was higher than that from the 10th day whatever the substrate. The highest content being 10.08% DM which is comparable to that obtained by Makkar *et al.*[19] and higher than those obtained by Hwangbo *et al.*[14] and Aniebo *et al.*[15] who obtained respectively; 5.16 and 6.25%MS. However, this content was lower than that obtained by Fashakin *et al.*[12], Sogbesan *et al.*[13] which obtained 11.65 and 13.20% DM respectively. The lowest content (5.13% DM) was obtained on the 10th day. This content is comparable to that obtained by Hwangbo *et al.*[14] and Aniebo *et al.*[15]. Mineral analysis reveals that maggot meal is relatively poor in minerals compared to other animal meals. This confirms the observation of Fashakin *et al.*[12] and Makkar *et al.*[19]. The highest mineral contents were obtained on the 5th day whatever the season. This observation is in agreement with that of Amakoé et *al.*[20] and Ghosh et *al.*[21] who observed that the chemical composition of maggots was closely linked to their larval development stage. The highest Ca and K contents were higher than those obtained by Makkar *et al.*[19] (3.4g/kg for Ca content and 6.67g/kg for K).

The Na contents are lower than those obtained by Makkar *et al.*[19] who obtained a Na content of 8.64g/kg. These differences observed in the mineral composition of maggot flour result from the nature of the production substrate[22]. The K content was higher than that of Na and Ca, which is in agreement with the results of Fashakin *et al.*[12].

CONCLUSION

The study demonstrates that both season and harvest time significantly influence the chemical composition of maggots produced from ruminal contents, with or without bovine blood supplementation. Overall, dry matter and ash contents were higher during the dry season, whereas organic matter was comparatively higher in the rainy season across substrates. Protein content remained consistently high in all treatments, confirming maggot meal as a reliable alternative protein source for animal feed. The inclusion of bovine blood further modulated mineral composition, indicating its potential to enhance specific nutritional attributes depending on harvest timing. These findings highlight the importance of optimizing seasonal conditions and harvest intervals to improve the nutritional quality of maggot-based feed resources.

SIGNIFICANCE STATEMENT

This study provides important evidence that maggot production using ruminal contents, with or without bovine blood, can be strategically optimized through seasonal management and harvest timing to improve nutritional quality. It highlights a sustainable approach to converting slaughterhouse waste into high-protein animal feed, thereby supporting low-cost livestock nutrition systems. The findings are particularly relevant for improving feed resource efficiency and promoting circular bioeconomy practices in Sub-Saharan Africa.

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