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Minerals and vitamins Composition of Unprocessed and heat Processed Maggots from different substrates

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ABSTRACT

This study investigates the mineral and vitamin composition of maggots derived from Musca domestica, focusing on the influence of substrate type and heat processing duration. Maggots were cultured using three organic substrate: cow manure with cow blood (CMM), swine manure with cow blood (SMM), and poultry manure with cow blood (PMM). Larvae were harvested at day 4 and subjected to varying drying times (35, 45, and 55 minutes) at a constant temperature of 90°C. The mineral and vitamin content of both unprocessed and processed maggot samples were quantified using standard methods, including Atomic Absorption Spectroscopy (AAS) for minerals and UV spectroscopy for vitamins. Statistical analysis was conducted using R software, employing Analysis of Variance (ANOVA) to assess differences among groups, with Tukey's Significant Difference (HSD) for mean separation. Results revealed significant differences in mineral concentrations across manure sources, with cow maggot meal exhibiting the highest levels of calcium, sodium, potassium, and phosphorus. Processing duration positively influenced mineral content, particularly calcium and phosphorus, with p-values less than 2.0 × 10-16 indicating highly significant differences. In terms of vitamins, substantial variations were observed, particularly in vitamin A and E levels, with poultry maggots displaying the highest vitamin A concentrations (445.32 ± 0.00 mg/100g), while overall vitamin E levels remained low.

This research plays a critical role of substrate selection and processing methods in optimizing the nutritional profile of maggot. The findings highlight the potential of maggots as a sustainable protein source, providing valuable insights for enhancing animal feed formulations and promoting improved livestock health and productivity. Further investigations are warranted to explore the long-term effects of maggot meal incorporation into livestock diets and its implications for sustainable food systems.

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Introduction

Minerals and vitamins play crucial roles in various physiological processes and are essential for maintaining optimal health in both humans and animals. The composition of these micronutrients in food sources can be significantly affected by processing methods, particularly heat treatment.

In recent years, there has been growing interest in alternative protein sources, including insects and their larvae, such as maggots, due to their potential nutritional value and sustainability [1].

Maggots, which are the larval stage of flies, can be reared on different substrates, potentially influencing their nutritional composition. The mineral and vitamin content of maggots may vary depending on the substrate they are raised on, as well as the processing methods applied to them [2].

The utilization of insects as a food source has garnered significant interest due to their high protein content, rapid growth rates, and lower environmental impact compared to traditional livestock [3]. Maggots, particularly those from the Black Soldier Fly (Hermetia illucens), have shown promise in a variety of applications, including waste management and animal feed [4].

The nutritional composition of maggots is heavily influenced by their rearing substrate, particularly the type of manure from which they derive sustenance. Studies have shown that maggots reared on different types of manure exhibit varied levels of protein, fat, vitamins, and minerals, which are crucial for their overall health and growth, as well as for their use as animal feed [5,6]. For instance, maggots fed on poultry manure have been found to have higher protein content in comparison to those fed on cow or swine manure, which can be attributed to the nutrient profile inherent in the substrate.

Heat processing, such as boiling and roasting, is commonly used to prepare insects for consumption and can have significant effects on their nutrient composition. Studies on other insect species have shown that heat treatment can lead to changes in mineral content, often resulting in increased concentrations of certain elements due to moisture loss. For instance, research on *Ruspolia differens* demonstrated that boiling and roasting led to significant increases in iron, zinc, copper, manganese, and calcium content. However, heat processing can also negatively impact certain nutrients, such as vitamin B12, which was found to decrease significantly after boiling in R. *differens* .The effects of processing on mineral and vitamin composition have been observed in various food sources. For example, studies on plant-based foods have shown that heat treatment can lead to reductions in mineral content due to leaching, as seen in the case of phosphorus, potassium, and sodium in processed R. *differens* [2]. Similarly, research on *Icacina* senegalensis seeds revealed a general decline in mineral concentration after processing [7].

The processing of maggots through heat treatment is a crucial step in enhancing their food safety and digestibility. Heat processing can effectively reduce microbial loads and inactivate potential pathogens present in the maggots, thereby improving their safety for consumption by livestock and humans [5]. However, the impact of heat processing on the retention or alteration of essential nutrients specifically vitamins and minerals remains an area requiring further investigation. It is hypothesized that while heat may enhance the safety of maggots, it could also lead to the degradation of sensitive nutrients, particularly certain vitamins, necessitating a careful consideration of processing conditions [8]. Given the potential of maggots as a sustainable protein source and the importance of understanding their nutritional value, it is crucial to investigate the mineral and vitamin composition of unprocessed and heat-processed maggots from different substrates. This knowledge will contribute to optimizing rearing conditions and processing methods to maximize the nutritional benefits of maggots as a food or feed ingredient.

Materials and Methods

Maggot Production and Processing

Maggots used for this study were grown on three organic substrate mixtures comprising cow manure + cow blood (CMM), swine manure + cow blood (SMM) and poultry manure + cow blood(PMM). The cow blood was used as fly attractant. The substrate beds were made wet with water daily. The manure was exposed for the housefly (Musca domestica) to lay eggs and was later kept under shade to allow for the development of larvae. Larvae were harvested on day 4 of larval formation using the floatation method. The manure and larvae were first immersed in water causing the larvae to float. The floating larvae were collected by sieving through a 3mm-mesh size net [9]. The larvae collected were rinsed several times until they attained their characteristic white colour. After the rinsing process, they were blanched in hot water and then exposed to the sun in trays followed by oven drying at a temperature (90oC) at different time regimes (35 minutes, 45 minutes, and 55minutes). Processed larvae were milled using a blender to yield maggot meal. Each treatment was named according to the substrate source: CMM35, CMM45, CMM55, SMM35, SMM45, SMM55, PMM35, PMM45, PMM55, CMMunp, PMMunp and PMMunp.

Laboratory Analysis

The Mineral and vitamin composition of the unprocessed (raw) and variously processed maggot samples were determined by standard methods as described in [10]. Minerals were determined using AAS. For vitamin analysis, UV spectroscopy was utilized to quantify the vitamins in the samples.

Determination of Vitamin A

One gram, of the sample was weighed and macerated with 20mls of n- hexane in a test tube for 10 minutes. Then 3mls of the upper hexane extract was transferred into a dry test tube in duplicates and evaporated to dryness. Following this, 0.2ml of acetic anhydride chloroform reagent was added and 2ml of 50% trichloroacetic acid (TCA) in chloroform was also added. The absorbance was taken at 15 seconds and 30 seconds intervals at 620nm.

Determination of Vitamin E

One gram (1g) of the original sample was weighed, macerated with 20mls of n- hexane in a test tube for 10 minutes and centrifuged for 10 minutes. The solution was filtered, 3mls of the filtrate was transferred into a dry test tube in duplicates and evaporated to dryness in a boiling water bath. Following this, 2mls of 0.5N alcoholic potassium hydroxide was added and boiled for 30 minutes in a water bath. Then 3mls of n-hexane was added and was shaken vigorously. The n-hexane was transferred into another set of test tubes and evaporated to dryness. Two (2)mls, of ethanol was added to the residue. Another volume, 1ml of 0.2% ferric chloride in ethanol was added. Then 1ml of 0.5% 1 1 -dipyridyl in ethanol was added followed by the addition of 1ml of ethanol to make it up to 5mls. The solution was mixed and absorbance taken at 520nm against the blank.

Statistical Analysis

Data were analysed using R v. 4.0.0. Descriptive statistics were obtained using Rmisc package in R as well as reshape. Analysis of Variance (ANOVA) was conducted using agricolae package, emmeans package and multiple comparisons were made using multcomp and viewed using multcompView. Mean separation was done using Tukey's Honestly Significant Difference (HSD) as implemented in multcomp and emmeans.

Results

The minerals composition of maggots processed at a constant temperature of 90°C for varying durations (35, 45, and 55 minutes) was evaluated, revealing significant differences across different manure sources. The results, presented in Table 5, demonstrate the concentrations of calcium (Ca), sodium (Na), potassium (K), and phosphorus (P) in milligrams per 100 grams of sample. For cow maggot meal (CMM), the calcium content increased with drying time, from 378.34 ± 0.01 mg/100g at 35 minutes (CMM35) to 465.35 ± 0.00 mg/100g at 55 minutes (CMM55), with significant differences observed between the time regimes ($p < 2.0 \times 10^{-16}$). Sodium levels also rose from 258.65 ± 0.00 mg/100g (CMM35) to 296.35 ± 0.01 mg/100g (CMM55), while potassium remained relatively stable, fluctuating between 843.54 ± 0.01 mg/100g (CMM35) and 986.35 ± 0.01 mg/100g (CMM55). Phosphorus content exhibited a similar trend, increasing from 695.66 ± 0.01 mg/100g (CMM35) to 796.36 ± 0.01 mg/100g (CMM55). In swine maggot meal (SMM), calcium levels were significantly lower than those of cow maggot meal, ranging from 285.43 ± 0.01 mg/100g (SMM35) to 312.46 ± 0.01 mg/100g (SMM55). Sodium values ranged from 221.46 ± 0.01 mg/100g (SMM35) to 244.66 ± 0.00 mg/100g (SMM55), with potassium concentrations showing an increase from 624.54 ± 0.01 mg/100g (SMM35) to 794.06 ± 0.01 mg/100g (SMM55). The phosphorus content varied from 503.15 ± 0.01 mg/100g (SMM35) to 585.65 ± 0.01 mg/100g (SMM55). Poultry maggot meal (PMM) exhibited the lowest mineral concentrations among the three manure types. Calcium content ranged from 268.60 ± 0.01 mg/100g (PMM35) to 300.16 ± 0.01 mg/100g (PMM55). Sodium levels varied from 215.76 ± 0.01 mg/100g (PMM35) to 224.16 ± 0.00 mg/100g (PMM55). Potassium levels were consistently the lowest, from 545.86 ± 0.00 mg/100g (PMM35) to 511.12 ± 0.00 mg/100g (PMM55). Phosphorus content increased slightly from 452.26 ± 0.01 mg/100g (PMM35) to 472.15 ± 0.00 mg/100g (PMM55). Unprocessed maggots from the three manure types (CMMunp, SMMunp, PMMunp) displayed distinct mineral profiles. Calcium levels were lowest in unprocessed cow maggot meal (257.34 ± 0.82 mg/100g), while sodium was highest in unprocessed swine maggot meal (223.46 ± 0.60 mg/100g). Potassium content was highest in unprocessed cow maggot meal (603.25 ± 0.69 mg/100g), and phosphorus levels were highest in unprocessed cow maggot meal as well (591.08 ± 2.01 mg/100g). Overall, the analysis shows that processing time significantly influences the mineral composition of maggots, with differences noted among various manure sources. All p-values were found to be less than 2.0 × 10-16, indicating highly significant differences in mineral concentrations across the samples. The means in each column followed by different superscripts differ significantly at $p < 0.05$, emphasizing the impact of both manure source and processing duration on mineral content. The vitamin composition of maggots processed at a constant temperature of 90°C for varying durations (25, 35, and 55 minutes) was analyzed, focusing on vitamin A and vitamin E levels, as detailed in Table 6. The findings highlight significant differences in vitamin content across different manure sources and processing times. For cow maggot meal (CMM), vitamin A levels varied significantly among processing durations. The highest concentration was observed in CMM25 at 192.80 ± 50.00 mg/100g, which was significantly greater than that of CMM35 (126.88 ± 0.00 mg/100g) and CMM55 (117.64 ± 0.00 mg/100g). The substantial decrease in vitamin A content with increased drying time was statistically significant ($p = 5.46 \times 10^{-9}$). In terms of vitamin E, CMM samples exhibited relatively low concentrations, ranging from 0.62 ± 0.00 mg/100g (CMM25) to 0.66 ± 0.00 mg/100g (CMM55), but these values were not significantly different from one another. Swine maggot meal (SMM) displayed a different trend for vitamin A, with values increasing from 218.31 ± 0.01 mg/100g at SMM25 to 242.26 ± 0.01 mg/100g at SMM55. This increase was not only notable but also statistically significant (p = 5.46 × 10-9). Vitamin E levels in SMM ranged from 0.57 ± 0.00 mg/100g (SMM25) to 0.68 ± 0.00 mg/100g (SMM55), also reflecting a significant improvement with processing time. Poultry maggot meal (PMM) had the highest vitamin A concentrations among all treatments, peaking at 445.32 ± 0.00 mg/100g for PMM25, which significantly differed from the other treatments. However, vitamin E levels in PMM were notably low, starting at 0.22 ± 0.00 mg/100g (PMM25) and increasing slightly to 0.32 ± 0.01 mg/100g (PMM55), yet remaining significantly lower compared to SMM samples. Unprocessed maggots showed lower vitamin concentrations overall, with cow maggot meal (CMMunp) containing 378.91 ± 0.01 mg/100g of vitamin A and 0.41 ± 0.01 mg/100g of vitamin E. Swine maggot meal (SMMunp) had 343.48 ± 1.42 mg/100g of vitamin A and 0.29 ± 0.01 mg/100g of vitamin E, while poultry maggot meal (PMMunp) showed the lowest values at 283.65 ± 3.01 mg/100g for vitamin A and 0.26 ± 0.02 mg/100g for vitamin E. Overall, the analysis reveals significant differences in vitamin content among processed and unprocessed maggots, with p-values indicating highly significant differences for both vitamin A ($p = 5.46 \times 10^{-9}$) and vitamin E ($p = 2.17 \times 10^{-14}$). The means in each column followed by different superscripts differ significantly at $p < 0.05$, underscoring the importance of processing time and manure source in affecting the nutritional profile of maggot meals.

Table1: Minerals Composition of Unprocessed Maggots and Processed Maggots at constant Temperature (90oc) at Different Time Regimes.

Samples	Ca(mg/100g)	Na(mg/100g)	K(mg/100g)	P(mg/100g)
CMM_{35}	378.34 ± 0.01^h	258.65 ± 0.00^h	843.54 ± 0.01^g	695.66 ± 0.01^h
CMM_{45}	385.32 ± 0.01^i	277.65 ± 0.01^i	844.53 ± 0.01^g	731.65 ± 0.01^i
CMM_{55}	465.35 ± 0.00^j	296.35 ± 0.01^j	986.35 ± 0.01^h	796.36 ± 0.01^j
SMM_{35}	285.43 ± 0.01^d	221.46 ± 0.01^c	624.54 ± 0.01^d	503.15 ± 0.01^c
SMM_{45}	294.13 ± 0.01^e	238.51 ± 0.00^f	652.38 ± 0.00^e	542.12 ± 0.01^e
SMM_{55}	312.46 ± 0.01^g	244.66 ± 0.00^g	794.06 ± 0.01^f	585.65 ± 0.01^f
PMM_{35}	268.60 ± 0.01^b	215.76 ± 0.01^a	545.86 ± 0.00^b	452.26 ± 0.01^a
PMM_{45}	285.64 ± 0.01^d	226.53 ± 0.01^e	594.36 ± 0.01^c	456.75 ± 0.00^a
PMM_{55}	300.16 ± 0.01^f	224.16 ± 0.00^d	511.12 ± 0.00^a	472.15 ± 0.00^b
CMM_{unp}	257.34 ± 0.82^a	220.16 ± 0.02^b	603.25 ± 0.69^c	591.08 ± 2.01^g
SMM_{unp}	276.16 ± 0.03^c	223.46 ± 0.60^d	626.06 ± 2.02^d	526.02 ± 0.22^d
PMM_{unp}	295.12 ± 1.00^e	220.67 ± 0.19^{bc}	538.06 ± 5.61^b	504.58 ± 1.90^c
p-value	$<2.0 \times 10^{-16}$	$<2.0 \times 10^{-16}$	$<2.0 \times 10^{-16}$	$<2.0 \times 10^{-16}$

Means in the same column followed by different superscripts differ significantly ($p<0.05$)

Key:
CMM_{35}= cow maggot meal oven dried for 35minutes
CMM_{45}= cow maggot meal oven dried for 45minutes
CMM_{55}= cow maggot meal oven dried for 55minutes
SMM_{35}= swine maggot meal oven dried for 35minutes
SMM_{45}= swine maggot meal oven dried for 45minutes
SMM_{55}= swine maggot meal oven dried for 55minutes
PMM_{35}= Poultry maggot meal oven dried for 35minutes
PMM_{45}= Poultry maggot meal oven dried for 45minutes
PMM_{55}= Poultry maggot meal oven dried for 55minutes
CMM_{unp}= Unprocessed maggots from cow manure
SMM_{unp}= Unprocessed maggots from swine manure
PMM_{unp}= Unprocessed maggots from poultry manure

Table2: Vitamins Composition of Unprocessed Maggots and Processed Maggots at constant Temperature (90oc) at Different Time Regimes.

Samples	Vitamin A(mg/100g)	Vitamin E(mg/100g)
CMM_{35}	192.80 ± 50.00^{ab}	0.62 ± 0.00^{f}
CMM_{45}	126.88 ± 0.00^{a}	0.65 ± 0.00^{fg}
CMM_{55}	117.64 ± 0.00^{a}	0.66 ± 0.00^{fg}
SMM_{35}	218.31 ± 0.01^{bc}	0.57 ± 0.00^{e}
SMM_{45}	219.68 ± 0.01^{bc}	0.66 ± 0.00^{fg}
SMM_{55}	242.26 ± 0.01^{bc}	0.68 ± 0.00^{g}
PMM_{35}	445.32 ± 0.00^{f}	0.22 ± 0.00^{a}
PMM_{45}	443.63 ± 0.00^{f}	0.25 ± 0.00^{ab}
PMM_{55}	415.25 ± 0.01^{ef}	0.32 ± 0.01^{c}
CMM_{unp}	378.91 ± 0.01^{ef}	0.41 ± 0.01^{d}
SMM_{unp}	343.48 ± 1.42^{de}	0.29 ± 0.01^{bc}
PMM_{unp}	283.65 ± 3.01^{cd}	0.26 ± 0.02^{ab}
p-value	5.46×10^{-9}	2.17×10^{-14}

Means in the same column followed by different superscripts differ significantly ($p<0.05$)

Key:
CMM_{35}= cow manure maggot oven dried for 35minutes
CMM_{45}= cow manure maggot oven dried for 45minutes
CMM_{55}= cow manure maggot oven dried for 55minutes
SMM_{35}= swine manure maggot oven dried for 35minutes
SMM_{45}= swine manure maggot oven dried for 45minutes
SMM_{55}= swine manure maggot oven dried for 55minutes
PMM_{35}= Poultry manure maggot oven dried for 35minutes
PMM_{45}= Poultry manure maggot oven dried for 45minutes
PMM_{55}= Poultry manure maggot oven dried for 55minutes
CMM_{unp}= Unprocessed maggots from cow manure
SMM_{unp}= Unprocessed maggots from swine manure
PMM_{unp}= Unprocessed maggots from poultry manure

Discussion

The mineral composition of processed and unprocessed maggots, evaluated at a constant temperature of 90°C across varying time regimes, reveals substantial differences attributable to both processing duration and manure source. In this study, the calcium content in cow maggot meal (CMM) increased significantly with drying time, reaching 465.35 ± 0.00 mg/100g after 55 minutes (CMM55). This result aligns with the findings of who noted that processing can enhance the availability of minerals in insect-based feeds[11]. Food processing can have both positive and negative impacts on mineral bioavailability. On the positive side, processing can lead to the separation or partitioning of minerals (enrichment), destruction of inhibitors, or beneficial complex formation between food components and metal ions, thereby enhancing their availability [12]. For instance, fermentation during the production of certain foods can affect the bioavailability of zinc and iron [13]. However, processing can also negatively impact mineral availability by deactivating enzymes that degrade inhibitors or by generating insoluble metal compounds through oxidation or precipitation [12]. The result obtained in the present study was consistent with the observation of who reported similar results for sun dried maggot meal [14]. However, contrary to the findings of, who reported higher calcium levels in certain insect larvae, our results suggest that cow maggot meal specifically benefits from extended drying processes to enhance mineral concentrations.. The differences suggested that appropriate drying method for the maggots is crucial for the nutritional content of the maggot's meal. In contrast, swine maggot meal (SMM) demonstrated lower calcium levels compared to CMM, with a maximum of 312.46 ± 0.01 mg/100g at 55 minutes. These results are consistent with the work of [1,15]. who indicated that mineral concentrations can vary significantly among different insect species and substrates, emphasizing the need for targeted research in this area.

Sodium levels exhibited a significant increase in CMM and SMM with longer drying times. Specifically, CMM showed sodium levels rising from 258.65 ± 0.00 mg/100g (CMM35) to 296.35 ± 0.01 mg/100g (CMM55), reflecting findings by Udo et al. (2016) [16], who also observed similar trends in sodium content as a result of processing. However, the lower sodium concentrations in poultry maggot meal (PMM) highlight a disparity, suggesting that the substrate used in feeding affects sodium retention.

Potassium levels were notably higher in CMM and SMM compared to PMM, which is consistent with the observations of that indicated variations in potassium levels among insect larvae depending on their diet and growth conditions. The relatively stable potassium levels in PMM raise questions about the nutritional strategies employed in poultry manure feeding, which may be less conducive to potassium retention compared to other substrates [17].

The phosphorus content in CMM also increased significantly with processing, paralleling the findings of regarding the importance of processing conditions on mineral bioavailability [18]. In contrast, the phosphorus levels in PMM were lower, which supports the findings of, who reported that phosphorus concentrations in insect meals are influenced by the type of manure substrate [12].

Unprocessed maggots showed distinct profiles, with unprocessed cow maggot meal (CMMunp) exhibiting the highest phosphorus levels (591.08 ± 2.01 mg/100g). This finding is in line with the assertion by that unprocessed insect larvae often retain higher nutrient concentrations, suggesting that some processing methods may inadvertently lead to nutrient loss [13] .

Overall, the significant differences in mineral concentrations across the manure types highlight the impact of the substrate on the nutritional profile of the resulting maggot meals. The lower mineral concentrations found in PMM, particularly potassium and sodium, suggest that poultry manure may not be as nutritionally rich as its counterparts, reinforcing the findings of regarding the importance of substrate selection in optimizing the nutritional value of insect meals [17] .

The analysis of vitamin composition in processed and unprocessed maggots highlights significant variations attributable to manure source and processing duration. The results, particularly regarding vitamin A and vitamin E concentrations, provide valuable insights into the nutritional potential of maggot meals as alternative feed sources [19,20].

The study found that cow maggot meal (CMM) exhibited a marked decrease in vitamin A levels with increased drying time, with CMM25 showing 192.80 ± 50.00 mg/100g compared to 126.88 ± 0.00 mg/100g in CMM35 and 117.64 ± 0.00 mg/100g in CMM55. This trend aligns with the findings of who reported that prolonged heat exposure could degrade sensitive vitamins, including vitamin A. Conversely, Swine maggot meal (SMM) presented an opposite trend, with vitamin A content increasing from 218.31 ± 0.01 mg/100g at SMM25 to 242.26 ± 0.01 mg/100g at SMM55 [19]. This unexpected outcome may relate to the specific nutrient profiles of the swine manure substrate, which appears to support higher retention of vitamin A during processing. Processing durations also play a critical role in the vitamin content of maggot meals. Several methods exist for processing maggots, including drying, blanching, and milling, each yielding different nutritional outcomes. Research by illustrates that extended drying periods could lead to a deterioration of heat-sensitive vitamins, notably vitamin E. Conversely, minimally processed maggot meals (lightly dried) maintain higher concentrations of both vitamin A and E compared to those subjected to prolonged heat exposure. [21] It is vital for producers to optimize processing techniques, as the efficiency of nutrient retention has direct implications for feed formulation.

Poultry maggot meal (PMM) displayed the highest vitamin A concentration among treatments, peaking at 445.32 ± 0.00 mg/100g in PMM25. This finding is consistent with the work of , who suggested that poultry manure is particularly rich in certain nutrients, including vitamin A precursors. However, the low levels of vitamin E in PMM challenge the conclusions of, who reported that nutrient concentrations in maggot meals could generally be favorable, pointing to a potential need for specific dietary adjustments in poultry-based maggot feeding [13,19].

Vitamin E levels were relatively low across the samples, particularly in PMM, where the maximum value reached only 0.32 ± 0.01 mg/100g after 55 minutes of processing. This is in agreement with the findings of, who also noted low vitamin E concentrations in insect larvae meals [21]. The slight increase in vitamin E levels with processing time in SMM, ranging from 0.57 ± 0.00 mg/100g to 0.68 ± 0.00 mg/100g, reinforces the potential for specific substrates to enhance certain vitamin profiles. The significant increase in vitamin E content with processing in SMM aligns with the observations of who posited that some processing methods can enhance the stability of fat-soluble vitamins[21,22]. The significant differences in vitamin content (p = 5.46 × 10-9 for vitamin A and p = 2.17 × 10-14 for vitamin E) highlight the critical impact of both processing duration and manure source on the nutritional composition of maggot meals. These findings underscore the need for careful consideration of processing methods to maximize the retention of beneficial nutrients in feed formulations [22,23].

Unprocessed maggots showed lower concentrations of vitamins overall, with CMMunp containing 378.91 ± 0.01 mg/100g of vitamin A and 0.41 ± 0.01 mg/100g of vitamin E. These findings are in line with the observations by who suggested that processing can enhance the nutritional profiles of insect-based feeds [21]. The lower vitamin concentrations in unprocessed samples reaffirm the notion that thermal processing can play a crucial role in nutrient availability.

The nutrient composition of maggots is heavily influenced by the type of manure from which they are reared. Studies indicate that maggots fed on different substrates can exhibit distinct nutritional profiles, particularly regarding vitamin content. For instance, maggots raised on dairy manure have been shown to obtain more vitamin E than those cultivated on poultry manure due to the higher lipid content in dairy substrates [21]. Conversely, poultry manure may yield maggots with significantly higher levels of vitamin A, attributable to the diet of the birds, which is naturally richer in carotenoids [20]. The interplay of manure composition and the maggots' ability to bioaccumulate nutrients significantly determines their vitamin profile. Insect larvae, including maggots, have shown varying nutritional profiles, with factors such as diet and processing directly impacting vitamin concentrations. Vitamins A and E are of particular interest; vitamin A is essential for vision, immune function, and skin health, while vitamin E serves primarily as an antioxidant, protecting cells from oxidative damage [22].

Furthermore, research suggests that livestock fed diets enriched with vitamin A and E demonstrate better body weight gain compared to their counterparts who received standard diets (Sujata et al.,2020)[23]. This vital correlation supports the assertion that utilizing maggot meals could lead to not only enhanced animal productivity but also improved animal health and welfare.

Conclusion

The present study provides evidence of the significant impact that substrate type and processing conditions have on the mineral and vitamin composition of maggots, particularly from the larvae of Musca domestica. Our findings reveal that maggots from different organic substrates such as cow manure, swine manure, and poultry manures exhibit distinct mineral profiles, with cow manure yielding the highest concentrations of key minerals such as calcium, sodium, potassium, and phosphorus. Processing duration also plays a critical role; longer drying times at a constant temperature of 90°C generally enhanced the mineral content of maggots, particularly for calcium and phosphorus. The vitamin composition analysis highlights significant variations in vitamin A and vitamin E levels, influenced both by the manure substrate and processing time. Notably, poultry maggot meal exhibited the highest vitamin A concentration, reinforcing the idea that dietary sources directly impact the nutritional outcomes of maggot larvae. As the demand for alternative protein sources continues to grow, insights from this study could guide future research and development efforts aimed at optimizing the use of maggot meals in animal feed, thereby enhancing livestock health, productivity, and overall sustainability in food systems. Future research should focus on exploring the long-term effects of incorporating processed maggot meals into livestock diets, assessing their impact on growth performance, health outcomes, and overall animal welfare. [25,26]

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