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Chemical Composition of the *Neochetina eichhorniae* and *Neochetina bruchi* and Their Potential for Use as Livestock Feed

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Abstract

Neochetina eichhorniae and *Neochetina bruchi* have been used for over four decades as *Eichhorniae crassipes* classical biological control agents globally. Despite the success of bio-control against the water hyacinth globally at different levels and environmental sustainability, biological control against water hyacinth seems to have overlooked the socio-economic sustainability in assisting the ravaged communities, gain resilience and adapt to the challenges of the invasive alien species. This manuscript evaluates the potential to draw out more from biological control of the water hyacinth by evaluating the potential to utilize *Neochetina eichhorniae* and *Neochetina bruchi* as feed. The live insects of the two species were collected from the water hyacinth marts in the nearby L. Victoria in Siaya county, Kenya. Where they were then transferred for semi-cultivation in localized ponds for reproduction and closer monitoring. The ponds having been set up in completely randomized design while in the open within the same climatic region mimicked the water quality and most abiotic conditions of the lake necessary for the insects' and host plant acclimatization and reproduction. The samples for proximate analysis were collected from these ponds as per the research and experimental design. The chemical compositions of the *Neochetina bruchi*, *N. eichhorniae* and their larvae composite, satisfactorily compared to basic fish feed requirements, specifically as a protein source having crude protein (CP) percentage per DM of 55.0350 ± 0.025, 54.4350 ± 0.035 and 62.2750 ± 0.025 respectively.

Keywords

Bio-Control, *Eichhornia crassipes*, Entomophagy, *Neochetina bruchi*, *Neochetina eichorniae*, Proximate

1. Introduction

Insects are poised to be the most sustainable alternative protein especially as livestock feed and aquaculture as well as cheaper protein source for humans. The task at hand is therefore to find as many as possible sustainable and adaptive local alternatives and utilize them sustainably. The emerging entomophagy is quite promising compared to conventional systems. In connection to achieving Zero Hunger as outlined by the United Nations' Sustainable Development Goal #2, insects have a great potential of contributing to making this a reality especially through sustainable agriculture [1] and environmental management [2]. This can be seen by the facts that, research has proven that: insect production has far less green house gases (GHG) emissions compared to conventional livestock [3], insect production compared to conventional livestock is far more sustainable and efficient on land and water use with high feed conversion rates. This can be maximized by using the available biodiversity of insects that can be produced on organic side streams and weeds [4]. To add, there is a wide variety of insect species to be utilized and most insects can be consumed 80% - 100% of their body weight with higher efficacy and sustainability unlike conventional livestock [5], which only less than 60% of their body weight can be consumed [6]. As sustainable food and feed resources, there are approximately 2111 edible insects already being utilized globally. This list can be said to be tentative given the increasing research and efforts going into entomophagy.

Insects can be utilized in various forms; as human food, as pets' food and as livestock and aquaculture feed. As feed components (protein) insects are capable of replacing soybean and fishmeal within a range of 25% - 100% in livestock diets depending on the species [4]. Some of the most successful insects to be used in feed include the black soldier fly *Hermetia illucens*, the domestic house fly *Musca domestica*, crickets; *Gryllodus sigillatus* and *Acheta domesticus*, mealworms; *Alphitobius diaperinus* and *Tenebrio molitor*, cockroaches, grasshoppers, termites and caterpillars. These insects' success can be attributed to their ability to utilize organic side streams and natural feed sources e.g., trees, shrubs, flowers etc. as well as the all-year round availability of their host plants such as aquatic weeds. As highlighted earlier a large number of insects are known to utilize weeds as their food and through such knowledge, highly specific insects which utilize one plant throughout their lifecycle have been used as bio-control agents [7].

There has been a lot of research going into utilizing insects as bio-control agents globally, but very little research has gone into using these insects for alternative purposes. Case in specific when we look at the control of the water hyacinth in sub-Saharan Africa. Invasive Alien Species (IAS) such as *E. crassipes* have adverse effects on ecosystems and livelihoods. However, in their control and management biological control measures prove most appropriate. Despite bio-control remedies being environmentally sustainable, the social and economic aspects of these remedies are often undermined and this has often led to unenthusiastic and inconsistent efforts in controlling the IAS (Invasive Alien Species) especially by developing economies, where financial constraints are greatly felt and are more affected. This has been demonstrated in other IAS and their control methods as highlighted by Burner *et al.* [8]. Bio-control needs to be economically and socially rewarding if not restoring especially to the affected communities. By this it's important that researchers and practitioners appreciate that the socio-economic livelihoods of the communities affected by the IAS are greatly disrupted and upset by the menace. Therefore, in pursuit of controlling and managing the IAS the practitioners should not only aim at restoring the ecosystem but also ensure they offer valid options for adaptation and resilience of the communities against IAS and climate change.

This study set out:

1) To nutritionally profile of each specie to identify and document the optimal growth stages of the two species.

2) To compare the nutritional profiles of these insects to those of conventional insects' feed/meals and other common protein ingredients in feeds.

2. Materials and Methods

Though, some may be skeptical to the novel idea of utilizing and mass farming of bio-control agents due to a few concerns and gaps, that cannot be ignored, the merits and necessities to do so outweigh its demerits. The following characteristics and traits guide the methodology:

- Cheap and readily available feed for the insects throughout all metamorphic stages, *E. crassipes*, an environmental nuisance just like organic side streams utilized to raise insects such as the black soldier fly or cockroaches [4].
- Rearing insects that feed and live exclusively on water hyacinth (or any other IAS) can be considered as another form of utilizing the weed just as it has been utilized to make clothing dyes, briquettes, papers, manure or even as pig feed [9].
- Rearing the bio-control agents at home based level for feed, combines the biological and manual control efforts as it destroys/removes the plant and its seeds from the lake preventing further regrowth and the farmers can always be encouraged to release some of the insects for sustainable semi-cultivation.
- Utilizing the bio-control agents as feed does not in any way threaten the populations in the lake, on the contrary it is a form of mass production outside the lake and government labs through local grassroots efforts that can be considered Community Based Natural Resource Management.
- The insects are also easy to domesticate and handle and with the specificity of these agents, they pose no threats to other plants or ecosystems except the pervasive and deleterious water hyacinth.
- Through the promotion and utilization of these insects as feed, it's likely to prompt further research into these insects as well as their effect on the ecosystem, water hyacinth and on each other as unique species and provide governments with adequate data to encourage further investment into other integral bio-control processes such as restocking, monitoring and rehabilitation which have been often ignored. This will also create opportunities for the recommended addition, use and combination of new bio-control agents

such as the *Niphograpta albiguttalis*.

- Most of these insects have a short lifecycle and if not supported through human intervention their impact might not be as expected, for instance the *Niphograpta albiguttalis* adult only lives for about four days, laying eggs before dying. This protein can be utilized for feed.

Sample Collection and Proximate analysis.

The *Neochetina weevils* and larvae were harvested from rearing ponds that had been established by the researcher after being culture for 5 months. The samples were all lyophilized for 24 to 48 hours and preserved in a freezer at −80˚C (Biobase). The proximal analysis was performed at the University of Nairobi (UoN), Department of Animal Production, in the Animal Production Nutrition Laboratory. The instruction and methods by the Association of Official Analytical Chemist 16th edition [10] were followed. Approximately 50 gms per sample were used for the chemical analysis of the *Neochetina* samples carried out in triplicates The ash content was determined using a Muffle furnace set at 600˚C, while, the ether extraction used the using Soxhlet apparatus and as for the crude protein content was determined using Kjeldahl's mode of digestion, distillation and titration.

Data related to chemical composition and nutritive value of *Neochetina weevils* were compiled by using Microsoft Excel 2016. Independent T test was performed to analyze the data by using SPSS 20.0 [11] Statistical significance was accepted at 5% level ($P < 0.05$).

3. Results

Mean chemical composition of the Neochetina spp.

Table 1 shows the dry matter (DM) content of the insects; adult *N. bruchi* and *N. eichhorniae* and a composite larvae sample of the two was 40.5121% ± 0.0350%, 44.8377% ± 0.020%, 20.501% ± 0.0150% respectively. The larvae composite had the highest crude protein (CP) composition of 62.275% ± 0.025% as well as the highest ether extract (EE) of 24.710% ± 0.01% while *N. eichhorniae* had the highest crude fiber (CF) content of 35.145% ± 0.055% and *N. bruchi* had the highest ash content among the samples of 4.065% ± 0.035% with Ca and P levels of 1.98% ± 0.035% and 0.86% ± 0.015% respectively per 100 gm. Results in Table 2 indicate that there is significant difference in nutritive composition among all the treatment samples in Ash, EE, CP, CF, NFE, Ca and P.

4. Discussion

Feed insecurity is a major challenge to the livestock sector in Sub-Saharan Africa, especially in ASALs and riparian low lands, particularly for monogastric livestock. The main concern in regard to feed insecurity other than feed availability is the matter of feed quality. An important indicator of feed quality is the CP content of the feed often readily available in the right quantities in fish, insects, legumes and young green grasses. However, CP becomes very scarce during

Table 1. Proximate composition of *Neochetina bruchi*, *Neochetina eichhorniae* and the composite larvae sample.

Sample	%Ash	%EE	%CP	%CF	%NFE	%Ca	%P
Composite Larvae	2.90 ± 0.01	24.710 ± 0.01	62.275 ± 0.025	9.575 ± 0.015	0.540 + 0.01	0.635 ± 0.12	0.455 ± 0.01
N. bruchi	4.065 ± 0.035	6.710 ± 0.03	55.035 ± 0.025	34.03 ± 0.01	0.1600 + 0.035	1.98 ± 0.035	0.86 ± 0.015
N. eichhorniae	4.03 ± 0.020	6.335 ± 0.025	54.435 ± 0.035	35.145 ± 0.055	0.055 ± 0.015	1.915 ± 0.015	0.825 ± 0.025

Table 2. Statistical analysis of the proximate.

Sample		DM	Ash	EE	CP	CF	NFE	Ca	P
N. bruchi	Mean	95.4350	4.0650	6.7100	55.0350	34.0300	0.1600	1.9800	0.8600
	Std. Deviation	0.04950	0.04950	0.04243	0.03536	0.02828	0.01414	0.16971	0.01414
	Std. Error of Mean	0.03500	0.03500	0.03000	0.02500	0.02000	0.01000	0.12000	0.01000
N. eichhorniae	Mean	93.9600	4.0300	6.3350	54.4350	35.1450	0.0550	1.9150	0.8250
	Std. Deviation	0.02828	0.02828	0.03536	0.04950	0.07778	0.02121	0.04950	0.02121
	Std. Error of Mean	0.02000	0.02000	0.02500	0.03500	0.05500	0.01500	0.03500	0.01500
Larvae	Mean	84.6450	2.9000	24.7100	62.2750	9.5750	0.5400	0.6350	0.4550
	Std. Deviation	0.02121	0.01414	0.01414	0.03536	0.02121	0.01414	0.02121	0.03536
	Std. Error of Mean	0.01500	0.01000	0.01000	0.02500	0.01500	0.01000	0.01500	0.02500

dry spells as plants and grasses dry out converting available plant proteins into silicate fiber for their survival. With fewer producers in the ecosystems during dry seasons, primary consumers such as insects also become scarce and competition for remaining protein sources such as fish for human competition leaves the livestock feed sector greatly deprived of reliable CP ingredients, pushing the prices even higher and making the venture unsustainable. It is therefore imperative to find sustainable alternatives that are tenacious enough to withstand changes in weather and climate for sustainable livestock feed of better quality. Insects stand out as a suitable and sustainable source of feed particularly as CP ingredients. *Neochetina weevils* as established by this study have the potential to be utilized as feed once factors of legislation, mass production and management have been streamlined. With the *Eichhorniae crassipes* as their only substrate it is important to understand its composition, gaps as well as challenges to its utilization as feed that maybe passed to the weevils and the food chain at large. Table 3 indicates the proximate analysis carried out by various researchers. The water hyacinth has been utilized as livestock feed for ruminants in Bangladesh and other countries with records of its proximate analysis being provided by a number of researchers [12] [13] [14] [15] [16].

Concerns have been raised over the possibility of heavy metals residues in the water hyacinth as well as its predators due to the ability of water hyacinth to be used in bioremediation. However, this is dependent on the levels of contamination in the specific water bodies. In a study carried by Adeyemi & Osubor [14] in Ijana River, Nigeria the heavy metal contamination content in water hyacinth

Table 3. Proximate compositions of *Eichhorniae crassipes*.

Source	DM%	CP%	CF%	Ash%	EE%	NFE%
Hossain *et al.* [12]	9.3	10.5	26.9	12.4	1.5	48.7
WHLPC Oyeyemi and Osubor [14]		56.38 ± 2.15	33.61 ± 1.55	4.88 ± 0.24	4.11 ± 0.55	

Table 4. Comparing *Neochetina weevils*' chemical composition to FAO Fish feed standards.

Content	FAO Tilapia feed standards	*Neochetina* Larvae	*Neochetina bruchi*	*Neochetina eichhorniae*
CP%	40	62.2750	55.0350	54.4350
CF%	5	9.5750	34.0300	35.1450
Ash%	19	2.9000	4.0650	4.0300
EE%	6	24.7100	6.7100	6.3350
NFE%		0.5400	0.1600	0.0550
Ca%	2.5	0.635	1.98	1.915
P%	3.75	0.455	0.86	0.825

leaves were well below WHO (World Health Organisation) 1998 heavy metal limits.

The proximate results of the *Neochetina weevils* as indicated in **Table 4** were measured against Food and Agricultural Organization (FAO) [17] set standard requirements of CP, CF, ash and EE for ruminants and non-ruminants as shown in **Table 4** and were found to be satisfactory. Amino acid and fatty acid profiling were not carried out in this study due to time and financial constraints.

Aquaculture is said to be one of the fastest growing food production systems because of the high demand for fish used for feed and oil productions. Arnold van Huis (2013) reports that by 2006, 5.46 and 0.95 million tons of fish meal and fish oil respectively were produced globally and of this 68% and 89% respectively were used back into aquaculture. Due to the unmatched demand, overexploitation of fisheries both marine and fresh is now a major challenge. Insects can be used to replace fish in fish meal and aquaculture, and insects such as the black soldier fly (BSF) have been used to produce biodiesel. Research by Ayieko, O Ndong'a & Tamale [18] indicates that insects such as BSF have been used whole or partly to replace fish meal in poultry and fish feed at 25% - 100% and delivered very satisfactory results paving way for further research to find more suitable alternatives to fish meal. Among the most affected areas is the fresh water biomes such as the Lake Victoria which is home to diverse insects such as the mayfly and several fish species now threatened by climate change and IAS. These threats do not spare insects too and therefore innovation in combating these challenges is of essence.

This research therefore was based on the many positive attributes of entomophagy especially on fresh water biomes and aquaculture that are most threatened and sought to add to the body of knowledge new variety of insects that can be used sustainably not just as bio-control agents but as food and feed resources for the conservation of freshwater resources as well as empowerment of communities living around these resources. Insects have been and are a naturally available food resource in the tropics that have been used in diversely and uniquely as there are many edible species as explained by Ayieko and Oriaro [19] as well as Münke-svendsen *et al.* [20].

5. Conclusions and Recommendations

From the aforementioned data, it is plausible to conclude that the *Neochetina weevils* at both metamorphous stages of adult and larvae have the potential and suitability to be used as feed or feed ingredients mainly as a protein meal. The high crude fiber content in adults is as a result of their exoskeleton, which is suspected to be high in chitin the main substance in most insects' exoskeleton. Chitin has been proposed as an important antibiotic and probiotic agent in animal nutrition that boost immunity and minimizes the use of drugs in livestock therefore mitigating antimicrobial resistance in the food systems. The rearing of these insects for bio-control as well as feed can help create more opportunities to utilize manage and hopefully control the invasive water hyacinth which is the sole substrate and host for the *Neochetina* species.

Seeing that the chemical compositions of the *Neochetina weevils* compares fairly well to the FAO recommended Tilapia fish feed standards, I would recommend that due to the small biomass of the insects as well as being a novel unexplored feed, the insects can be used as feed for fingerlings as well as organic aquarium fish feed to ease the competition for fish products in the aquaculture sector.

Invasive alien species are a huge challenge to sustainable development and agriculture especially in Sub-Saharan Africa. The water hyacinth has been identified as one of the top 100 most invasive and deleterious species in the world and hopes of eradicating it have been dashed and only controlling and managing it are left as the viable options. One way of managing this invasive species is through bio-control as well as utilization in rearing larvae for fish feeding. The researchers recommend the marrying of the two strategies by encouraging communities living around the invaded riparian lands to get involved in the mass production of *Neochetina weevils* for bio-control and livestock feed as a community based natural resource management strategy. It is also possible to use these insects as feed in nurseries to restore endemic species that have been lost to invasive species within the various fresh water bodies such as Lake Victoria and other smaller water points.

More research needs to be carried on the potential to utilize *Neochetina bruchi* and *N. eichhorniae* as feed especially on anti-nutritive contents. This is in line with the research carried out on this manuscript, it will go a long way in providing empirical evidence that supports or criticizes the utilization of the

Neochetina weevils. Further in support of this, research should also be dedicated in evaluating the microbial loads in the insects proposed for feed when produced *in-situ* or *in-vivo*. On a larger scale and with more focus on their natural habitat, the authors recommend further studies into the predation of these insects by prevailing predators in their unique habitats as well as the effect of predation on bio-control efforts.

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Conflicts of Interest

The authors declare no conflicts of interest.

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