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Sustainable Bioconversion of Food Waste by Utilizing Black Soldier Fly

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Abstract: ***As the global population increases, the volume of food waste is projected to rise significantly. Black Soldier Fly (Hermetia illucens) is a highly efficient organic decomposer for organic waste management. Its larvae bio-convert organic wastes into a nutrient-rich material high in proteins and lipids. This versatility makes Black soldier fly (BSF) a valuable resource for producing sustainable animal feed, biofuel, and organic fertilizer. Additionally, BSF farming reduces environmental pollution, mitigates greenhouse gas emissions, and supports circular economy principles. This paper explores the biological characteristics, applications, and potential benefits of BSF larvae in food waste recycling, and resource recovery. Utilizing black soldier fly larvae for food waste bioconversion is highly effective, achieving a 70 % reduction over 15 days. This process simultaneously generates valuable products: fresh larval biomass and nutrient-rich poultry feed. Their high protein (40%) and fat content (30%) make them a promising alternative to conventional animal feed, particularly in culture of fish, poultry, and livestock industries. In this work, an attempt was taken to compute and compared various growth parameters of poultry which were feed on conventional diet and also with BSF mixed diet.***

Keywords: Black Soldier Fly, Bioconversion, Food waste, Poultry feed, Wastes recycling.

I. INTRODUCTION

Globally, 19% of all food available for consumption in 2022 was wasted, amounting to approximately 1.05 billion tonnes lost across various stages. Food waste is a significant environmental issue, contributing to greenhouse gas emissions, when improperly managed. Food and agricultural wastes are major threats to the environment. As estimated by the Food Waste Index Report 2024, the total food waste generated in India amounts to a staggering 78.2 million tonnes. To reduce such waste in bulk each year conserve resources, novel approaches to recycling agro food waste are required (Hack et al. 2020). Conventional disposal methods, such as landfilling and incineration, are unsustainable. Unregulated food disposal methods—notably open dumping without segregation—cause extensive environmental damage, including pollution, emissions, and ecosystem degradation (A. Suryadi, 2020).Leveraging black soldier fly larvae for bioconversion offers an efficient and cost-effective method to reduce food waste using simple, low-cost facilities (Lalander, C. et al. 2015) .*Black Soldier Fly* larvae (BSFL) are emerging as a sustainable biological agent for organic waste treatment (Diener et al. 2009). BSFL consume a wide range of organic substrates, growing rapidly, and convert waste into high-value larval by-product, which can be processed into protein meal for poultry. Their frass (larval feed residue) can also be used as an organic fertilizer thus increasing the yield of the crop.

In this context, the major objectives including by utilizing BSFL for managing canteen waste effectively, assessment poultry growth performance feeding on BSFL, (Dörper et al. 2021) and exploring the potential of BSFL biomass as a protein feed ingredient. Thus, the most important source of proteins is the life stages of insects, particularly the larval stages (Capanoglu et al. 2022). Insect life stages are sustained and provide a high nutritional value to the food. Insect life stages, particularly larval ones, are high in protein (about 50–70%), lipids (30–33%), and fiber (5–12%) (Barragan-Fonseca et al. 2017).This study aims to utilize black soldier fly larvae (BSFL) to bio-convert food waste, promoting sustainable waste management. The cultured BSF larvae may be used as a source of oil for industrial usage, and feeding residue i.e frass can be used as organic compound fertilizer (Cai et al. 2018)

II. MATERIAL AND METHODOLOGY

A. Material

The materials used in this study for the bioconversion process included food wastes collected from GIFT college canteen, Bhubaneswar, Odisha, 0.5 g of black soldier fly (BSF) eggs. The weight of larvae obtained after 14 days of bioconversion was measured using a digital balance.

B. Methodology

The bio conversion procedure followed in experiment is shown in Figure 1.All the equipment's used for preparation was washed and sanitized .Birds were fed from 4 to 8 weeks of age. Feed and water were provided to poultry birds aslabium. Data collected were subjected to a two-sample design using T-test. They require the least amount of water and inexpensive feed sources.

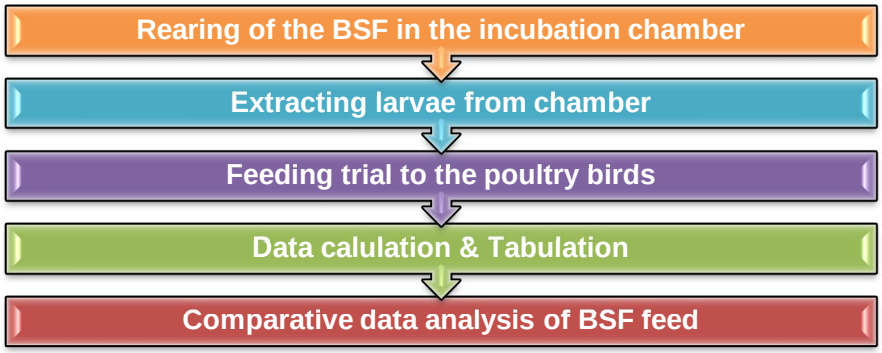

Figure 1:Flow chart showing the bioconversion procedure

The whole life cycle of the BSF is nearly about 45-50 days, with larval stage lasting up to 16-20 days. The larval stage is divided into 5 instars stages. However, 3rd instars larvae is observed in our experiment. The complete lifecycle of the BSF is shown in Figure 2. Adult BSF feed on food waste in the adult breeding chamber as shown in Figure 3. During adult stage, the fly has a lifespan of about 5-6 days, during which it reproduces through mating. It lays egg on 4th day after successful mating in controlled climatic conditions. Adult flies lay eggs in clusters in dark & moist environments on corrugated surface area. The larvae hatch from eggs quickly after a few days. The required temperature for successfully hatching is between 27°C to 32°C. The larvae stage has 16-20 day of developmental period, they consume wide range of organic waste materials, converting them into protein and fat. The larvae grow rapidly and almost reaching up to 2 cm in length. The larvae being high protein content is used as feed to various poultry and fishery. Larval density maintained was 1,000 larvae per kg of waste in plastic crates. Larvae at the late larval or pre-pupal phase for optimal nutritional benefits. BSF larvae under controlled conditions (temperature: 25–30°C, humidity: 60–70%) are found substantial growth. Canteen food waste was evaluated by the weighing method. (K. Schanes et al. 2018) In spite of time constraints, the weighing of food waste was carried out directly on site for accuracy in measurement. The actual weight of the food waste was obtained by subtracting by weight of empty bucket from the bucket with food waste. The readings were taken for three consecutive weeks.

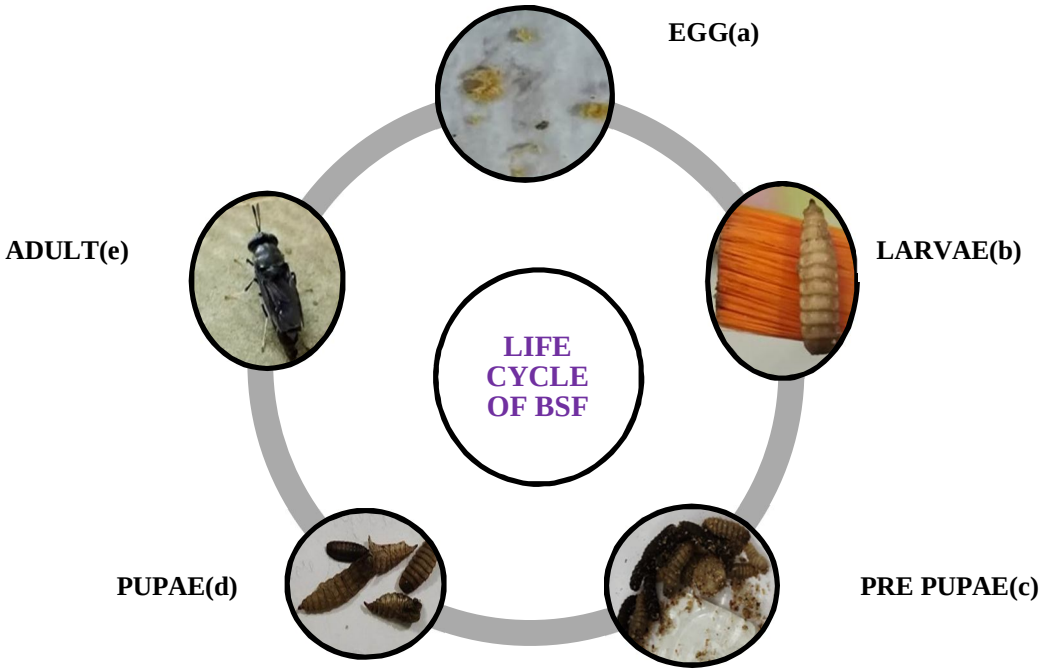

Figure2: Lifecycle of the Black Soldier Fly

The pre pupae stage last up to 10 days in which the BSF stops eating and in pupae stage which last up to 15 days the molding and conversion from larvae to fly occurs. The wings of the fly are to be attached .The adult flies are transferred to the breeding chamber for mating purpose.

For broilers feed, BSF meal can be included at a rate of 5%–20% of the total feed, serving as a substitute for fish meal or soybean meal. For layers, the inclusion level ranges from 5%–15%, depending on the bird's age and production stage. The BSF meal can be incorporated into either mash or pellet feed. During formulation, it should be thoroughly blended with grains, vitamins, minerals, and other protein sources to ensure a balanced and nutritionally complete diet (Wang & Shelomi 2017). Chicks aged two months were used for this sampling study. Feeding was carried out regularly following standard poultry schedules, with necessary precautions to prevent disease and feed spoilage (Diener et al. 2009). Fresh or moist BSF larvae were also provided immediately after harvest, ensuring proper hygiene to avoid contamination. The birds' health indicators, such as skin condition and activity level, were monitored to assess the benefits of diversified nutrient intake.

III. RESULTS AND DISCUSSION

A. Characterization of food wastes

Figure 4 shows the different types of food waste collected from the canteen for BSF feed. Wet waste which almost includes 45 percentage of total waste includes dal, curry, salad and all types of liquid leftover waste.

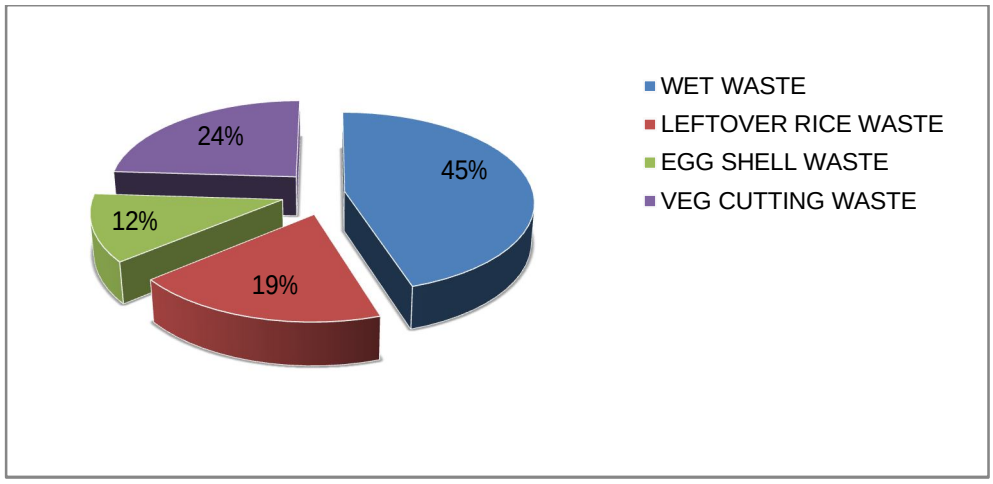

Figure 4: Food wastes collected as Sample

Left over rice waste includes all the rice waste inclusive of both leftover and plate waste. Egg shell waste included the egg shells peeled including the shell membrane before precooking and amounted almost twelve percent of total waste. Cutting waste includes all the vegetable cutting waste generated in the canteen before precooking.

B. Rearing and Harvesting BSF

BSF can survive a wide range of temperature; however, maintaining an optimal temperature is crucial to ensure efficient mating of adult flies. The ideal temperature range for larval growth lies between 27 °C and 35 °C. Previous studies report that protein content in this feedstock varied from 19-32 % on a dry matter basis (Eggwink et al.,2022) However the nutritional composition of the BSFwas found through proximate analysis. The protein content was found by using Kjedhal apparatus using concentrated H_2SO_4 as catalyst. The fat content of BSF was found by using Soxhlet apparatus using diethyl ether as solvent. The percentage composition of nutrients obtained from BSF larvae is shown in Table 1.

Table 1: Nutrients constituent of BSF larvae

Nutrient	Percentage (dry matter)
Protein	41% - 46%
Carbohydrates	2% - 4%
Fat	28% - 35%
Ash	08% - 10%

C. Growth Performance Analysis

The substitution of regular feed given to poultry with Black Soldier Fly (BSF) larvae meal showed noticeable effects on the growth performance on various poultry birds and depicted in Table 2. From Table 2 , it is found that both the 75% BSF + 25% Regular Feed group and the 100% BSF Feed group exhibited satisfactory growth, but with notable differences in feed efficiency and weight gain. It is observed that 100% BSF feed group showed slightly higher weight gain compared to the 75% BSF group. This suggests that a partial inclusion of conventional feed may enhance palatability and nutrient balance, thereby optimizing growth .

Table 2: Comparative study of Batch wise growth

Feed Type	Initial Weight (gm)	Final Weight (gm)	Weight Gain (gm)	Weight Gain (%)
Control (Regular feed)	1200	1800	600	50.00
25% BSF + 75% Regular Feed	1180	1850	670	54.80
50% BSF + 50% Regular Feed	1195	1920	725	59.70
75% BSF + 25% Regular Feed	1210	1985	775	62.50
100% BSF Larvae Feed	1205	2000	795	65.00

The 75% BSF group demonstrated a better *Feed Conversion Ratio (FCR),* indicating more efficient feed utilization compared to the 100% BSF group, which showed a slightly higher FCR likely due to limitations in amino acid profile or digestibility when used as the sole protein source. Feed intake was also higher in the 75% BSF group, possibly because the presence of regular feed improved texture and palatability, while the 100% BSF group consumed less feed, potentially due to lower palatability or higher fat content. The third instar of BSF larvae was used in this experiment . No mortality was observed in either group, confirming the safety of BSF larvae as a feed ingredient. However, the 75% BSF group exhibited slightly better health indicators such as skin condition and activity level, suggesting the advantage of a balanced and diversified nutrient intake. Economically, both BSF-based feeds were more cost-effective than conventional commercial feeds, with the 100% BSF option being the most economical. Nevertheless, the 75% BSF inclusion appeared to offer the best balance between performance, health, and cost efficiency, making it the optimal formulation for practical application.These results indicate that BSFL can significantly reduce canteen waste volume within a short period while generating protein-rich biomass suitable for animal feed (Van Huis 2013).

IV. CONCLUSION

Black Soldier Fly (BSF) larvae serve as a sustainable, protein-rich alternative to traditional poultry feed, offering high nutritional value and effective waste management. A 75% BSF + 25% regular feed ratio provides optimal growth, feed intake, and health, while 100% BSF remains a cost-effective option with potential for improvement through nutrient optimization. BSF bioconversion efficiently transforms canteen waste into valuable protein feed which provides more protein to the poultry birds and organic fertilizer, operating faster and more cleanly than conventional composting.

Integrating BSF technology in institutional systems supports zero-waste initiatives and promotes circular economy goals, making BSF a promising solution for sustainable livestock production.

V. ACKNOWLEDGEMENT

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Conflict of Interest

"The authors declare that they have no conflict of interest."

REFERENCES

[1] Abd El-Hack, M. E., Shafi, M. E., Alghamdi, W. Y., Abdelnour, S. A., Shehata, A. M., Noreldin, A. E., &Ragni, M. (2020). Black soldier fly (Hermetiaillucens) meal as a promising feed ingredient for poultry: A comprehensive review. Agriculture, 10(8), 339.
[2] A. Suryadi, F. E. Islami, H. Kausarian, and D. B. E. Putra, "Geophysical Survey on Open Dumping Landfill for Monitoring Spread of Leachate: A Case Study in Pekanbaru, Riau, Indonesia," Journal of Geoscience Engineering Environment and Technology, vol. 5, no. 2, pp. 104-107, June 2020.
[3] Barragan-Fonseca, K. B., Dicke, M., & van Loon, J. J. (2017).Nutritional value of the black soldier fly (Hermetiaillucens L.) and its suitability as animal feed–a review. Journal of Insects as Food and Feed, 3(2), 105-120.
[4] Cai, M., Hu, R., Zhang, K., Ma, S., Zheng, L., Yu, Z., & Zhang, J. (2018). Resistance of black soldier fly (Diptera: Stratiomyidae) larvae to combined heavy metals and potential application in municipal sewage sludge treatment. Environmental Science and Pollution Research, 25(2), 1559-1567.
[5] Capanoglu, E., Nemli, E., & Tomas-Barberan, F. (2022). Novel approaches in the valorization of agricultural wastes and their applications. Journal of Agricultural and Food Chemistry, 70(23), 6787-6804.
[6] Diener, S., Zurbrügg, C., &Tockner, K. (2009). Conversion of organic material by black soldier fly larvae: establishing optimal feeding rates. Waste Management & Research, 27(6), 603–610.
[7] Dörper, A., Veldkamp, T., &Dicke, M. (2021). Use of black soldier fly and house fly in feed to promote sustainable poultry production. Journal of Insects as Food and Feed, 7(5), 761-780.
[8] Eggink, K. M., Lund, I., Pedersen, P. B., Hansen, B. W., &Dalsgaard, J. (2022).Biowaste and by-products as rearing substrates for black soldier fly (Hermetiaillucens) larvae: Effects on larval body composition and performance. PLoS One, 17(9).
[9] K. Schanes, K. Dobernig, and B. Gozet, "Food Waste Matters - A Systematic Review of Household Food Waste Practices and Their Policy Implications," Journal of Cleaner Production, vol. 182, pp. 978-991, May 2018.
[10] Lalander, C., Fidjeland, J., Diener, S., Eriksson, S., & Vinnerås, B. (2015). High waste-to-biomass conversion and efficient Salmonella spp. reduction using black soldier fly for waste recycling. Agronomy for Sustainable development, 35(1).
[11] Van Huis, A. (2013).Potential of insects as food and feed in assuring food security.Annual Review of Entomology, 58, 563–583.
[12] Wang, Y. S., &Shelomi, M. (2017). Review of black soldier fly (Hermetiaillucens) as animal feed and human food. Foods, 6(10), 91.

Declaration

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This is not applicable

Authors' Contributions

Rakesh Kumar Behera: general investigation, experimentation, data collection and manuscript writing Amar Kumar Das: data analysis, editing and validation, Md Khalid Khan: conceptualization and overall review of the manuscript, Narayan Gouda: experimentation and overall review of the manuscript.

Ethical Approval

Ethical approval was not required for this study as it did not involve human .Our research involved only insects.

Consent to Participate*

This is not applicable

Consent to Publish*

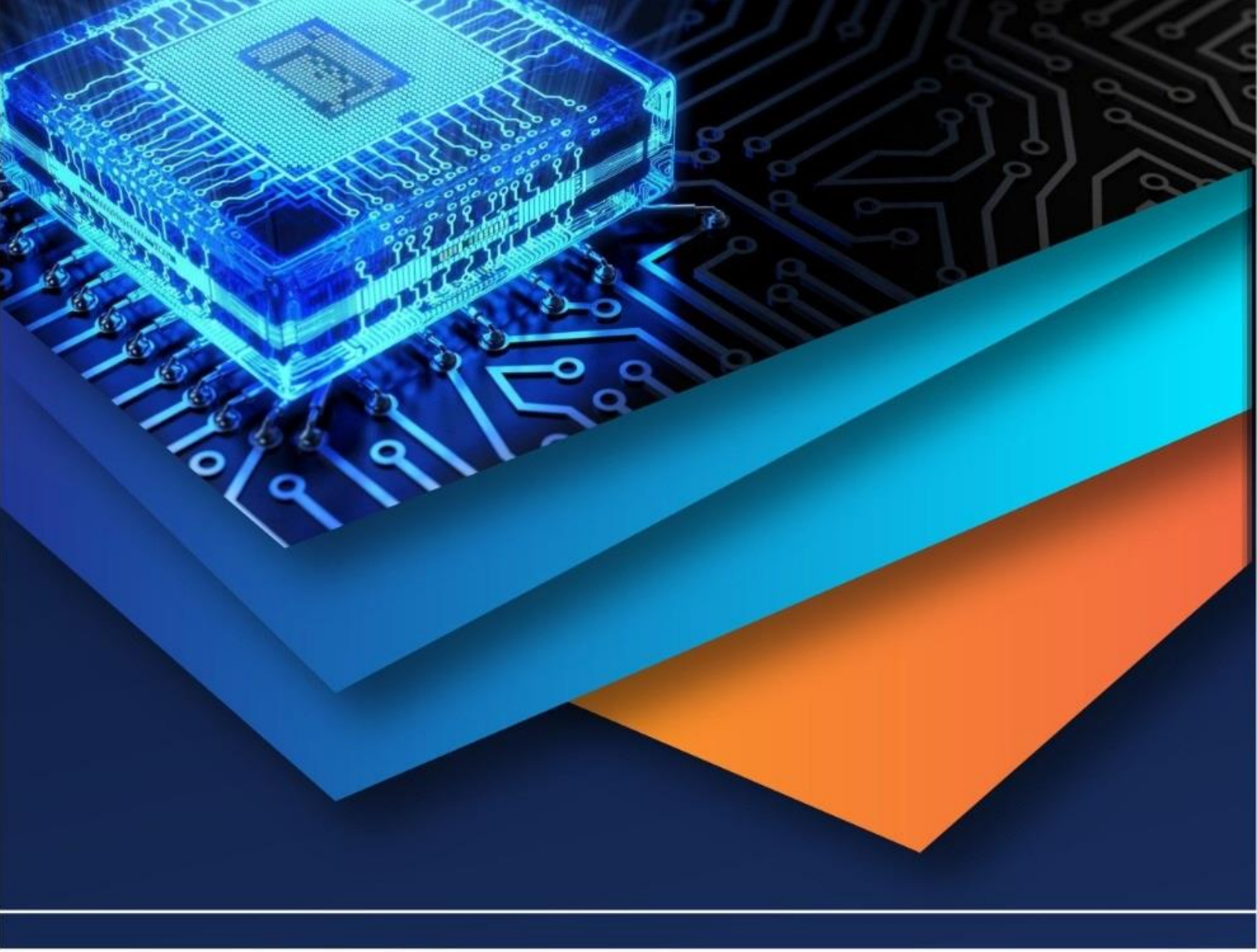
This is not applicable

Conflict of Interest

"The authors declare that they have no conflict of interest."

Data Availability Statement

The corresponding author may be requested for the data availability.



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