ISSN No:-2456-2165

Sustainability of Black Soldier Fly Cultivation in Port Harcourt, Rivers State Nigeria: Expert Opinion

[1]Agbogunleri, B., [2]Deekae, S.N. [3]Ngah, S.A. [4]Otene, B. B. [5]Ogan, H. I.
[1]PhD Student, Rivers State University, Nigeria.
[2]Prof and HOD Fisheries and Aquaculture Environment, Rivers State University. Nigeria.
[3]Prof, Institute of Geoscience and Environmental Management, Rivers State University, Nigeria
[4]Senior Lecturer, Fisheries and Aquaculture Environment, Rivers State University. Nigeria.
[5]CEO, Ibiteinye Integrated Farms and Senior Lecturer, Department of Marketing, Rivers State University.

Abstract:- This study evaluated the environmental, social, economic and technical dimensions of sustainability of black soldier fly (*Hermetiaillucens*) larvae (BSFL) using expert opinion in Port Harcourt. Rivers State. Using questionnaire to elicit responses from agricultural practitioners, academia and regulators. The environmental sustainability index was 59.02% with utilization of different waste as the most influencing attributes (9.11%) of this dimension. The social sustainability however was 42.86% with potential for job creation as most influencing attribute with 10.71%. Economic sustainability recorded an index of 47.77% with efficiency of produced raw materials (8.04%) as most influencing attribute. Technical sustainability on the other hand recorded an index of 46.43% of which technical improvement represents 12.5% of the attributes. Overall, the sustainability index of BSFL in Port Harcourt, Rivers State Nigeria was 38.39%. This index value is low owning to the fact that small-scale cultivation of the larvae in Rivers State. It is recommended further awareness training by international organisation in collaboration with Animal Science Association of Nigeria, fisheries and aquaculture institutions and other agricultural institution can go along way to improve on sustainability of BSFL in Nigeria.

I. INTRODUCTION

Sustainability as a concept has been discussed widely in several fields[1,2,3]. It has been applied to energy, resources, entertainment, economy, education, social, public policy and cultural [3]. A significant factor affecting Nigerian fish farmer gains is the high cost of fish feed. Smallholder farmers are responsible for the basic global food production and their farms are less than 2ha of land [4]. In order to reduce fish feed cost, fish farmers often replace animal protein with grains, which can be used to produce food for direct human consumption, also affecting food security. The current supply of good quality seed is inadequate, unsustainable, and costly for the everyday small-scale fish farmer. The search for affordable and sustainable fish feed led to farmers switching to insect feed such as black soldier fly (Hermetiaillucens) otherwise known as black soldier fly larvae (BSFL). The BSFL is an insect which can feed on organic matter up to 2 times of its body mass [5,6,7]. The adult stage insects measure about 16 millimeters[7,8,9]. This species is found where there is decaying matter where one female fly lays around 500 eggs [7,8,9]. Once the eggs are laid it takes 18 days for it to form larva and stays in this stage for 18-21 days [7,8,9]. After the larva stage it transforms into the pupa stage (14 days) and then to the adult stage (4-9 days) [7,8,9]. Each larva weighs around 0.1grams [7].

There are growing awareness in the use of BSFL to the extent that the U.S. Government's Global Hunger and Food Security Initiative of "Feed the Future" is targeted at training farmers to adopt BSFL [10]. In 2021, Nigerian Institute of Animal Science in conjunction with Animal Science Association of Nigeria held a symposium titled "Livestock Resilience in the Post-Covid Era [11] called on investor after her presentation owning to the advantages of BSFL in sustaining livestock and fish feed supply. General concern rest on the use of insect as feed especially when they fall into the category of 'flies' [12]. This is as a result of public knowledge that society has about the health risks of house flies, which may have an effect on perception of other harmless flies like BSF [12]. Furthermore, several factors favoured the production of black soldier fly larvae (BSFL) in Nigeria, such as large population, waste availability, favourable climate, and high demand for livestock feeds [13]. Some of the challenges to the development of this insect included limited formal waste collection, low product awareness, insufficient local research and development (R&D) on the value chain, uncertainty regarding potential policies or government standards; lack of accessible and affordable finance and limited access to stable power [13]. Sustainability of BSFL has been studied in Indonesia [14] while information on sustainability in Nigeria is lacking. It is in view of this that this study draws on the perception of experts on the sustainability of BSFL in order to evaluate environmental, social, economic and technical dimensions of this study.

II. MATERIAL AND METHODS

A. Study Area

Port Harcourt is located on latitude 04º45'N to 04060'N and longitude 060 50'E to 0800'E and situated 15.0 metre above sea level; it is a relatively low land area [15]. It is the only city or mega city in Rivers State (with the idea of greater Port Harcourt ([15]). Port Harcourt has a humid semi hot equatorial climate ([16,17]). The mean temperature is about 28ºC ([16,17]). The mean relative humidity is about 85%, but in the wet months, especially July and September it stood at over 95% [17]. During the few dry months, especially December and January relative humidity is about 80% ([16,17]). The highest monthly rainfall is July and August are 3,496.1mm and 3,578.4mm respectively[16,17].

B. Data Collection Method

The data collection consisted of structured questionnaire to elicit responses from experts as noted by [18]. Furthermore, questionnaire was retrieved from academia, regulators and agriculturalist particularly those in livestock and aquaculture. The questionnaire wasdivided into environmental, social, economic and technical dimensions of sustainability[14]. Each dimension consisted of attributes that were scored 0, 1, and 2 for bad, moderate, and good [14].

Environmental dimension attributes were coded as E1= Material efficiency of BSFL, E2= Efficiency use of chemical for BSFL, E3= Efficiency use of energy for BSFL, E4= Efficiency of water use for BSFL, E5= Potential for air pollution during BSFL, E6= Potential for water pollution, E7= Utilization of different wastes, E8= Exploitation of natural resources, E9= Potential for biodiversity damage, E10= Potential for spread of disease.

Social dimension attributes were coded as S1= BSFL educational level, S2= Cultivar staff/family involvement, S3= Cultivar level of business motivation, S4= Possible unrest from BSF, S5= Knowledge of conservation, S6= Potential for accident, S7= Potential for job creation.

Economic dimension attributes were coded as EC1= Larvae cultivation productivity, EC2= Production management level, E3= Potential for increased business, EC4= Potential for welfare of cultivar, EC5= Efficiency of produced raw materials, EC6= Level of market absorption, EC7= Absorption rate of frass, EC8= Success rate production system.

Technical dimension attributes were coded as T1= Level of Larvae production system, T2= Level of skill specialization, T3= Level of production facility, T4= Technological improvement, T5= Level of technical sensitivity

C. Sustainability Assessment Method

According to [3], internationally accepted standard for sustainable assessment is not available. The sustainability assessment method involves multidimensional scaling (MDS) using SPSS Version 21[19]. The MDS is a procedure used to describe perceptions with stimuli that are carried out geometrically between points into dimensional space. [19] noted that the smaller the Euclidean distance, the closer each object is, and the higher the level of attributes competition.In addition, square correlation (RSQ) in multidimensional scaling indicates the proportion of input data variance that can be explained by the MDS model. Hence, the MDS model is accepted if RSQ $\geq$0.6 and Stress $\leq$ 0.25[19]. [18]provided index values as indicated in Table 1.

Table 1: Categorizing Sustainability Index

Index Values and Sustainability Categories	Index Value	Category
1	0% to 25%	Bad
2	26% to 50%	Less
3	51% to 75%	Enough
4	76% to 100%	Good

D. Data Analysis

Sustainability Index analysis was computed as follows:

$$A = \frac{t}{E} * 100 \text{.......} Eqn1$$

A= Attribute scores, $t = total\ score$, E= Expected Score

Sustainable Dimension Index(D)

$$D = \frac{T}{E} * 100 \text{.......} Eqn\ 2$$

D = Sustainable Dimension index, $T = total\ attribute\ scores$, E = Expected Score

Sustainability index (S).

$$S = \frac{d}{n} * 100 \text{.......} Eqn\ 3$$

S = Sustainable index, $d = total\ dimensions$, n = number of dimensions

III. RESULTS AND DISCUSSIONS

A. Expert Responses

The results of experts' response are presented in Table 2 The academic sector represents 17.9%, regulatory sector 25% while the agricultural sectors 57.1%.

Table 2: Experts Responses

Respondent Specialty	Number	% Respondents
Academic Sector	5	17.9
Regulatory Sector	7	25.0
Agricultural Sector	16	57.1
Total	28	100.0

B. Multidimensional Scaling Solution

The validations of multidimensional scaling (MDS) model for environmental, social, economic and technical dimensionsrevealed Stress and Square Correlation (RSQ) as (0.09895) and (0.94543); (0.13305) and (0.87140); (0.21664) and (0.69767); and (0.20224) and (0.74077) respectively. These models indicated Stress of 9.8%; 13.3%; 21.6% and 20.2% for environmental, social, economic and technical dimensions respectively. Hence, the model has good feasibility. The RSQs values are very good, majorly for environmental and social dimensions while the economic and technical dimensions are good. Figures 1-4 showed the Euclidean distance model.

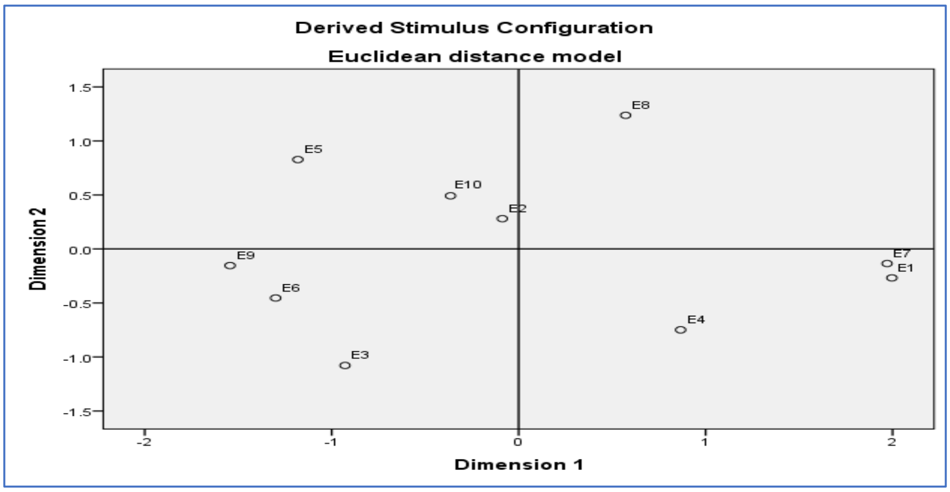

Fig. 1: MDS of Environmental Dimension

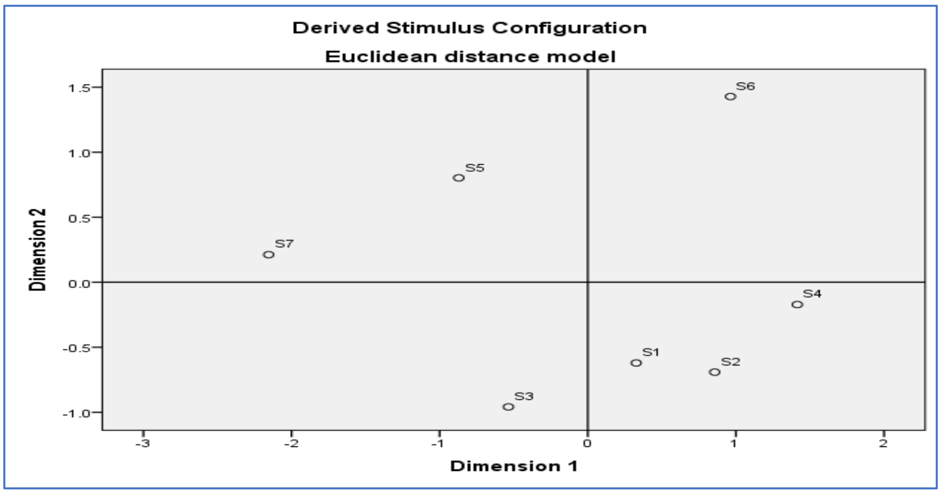

Fig. 2: MDS of Social Dimension

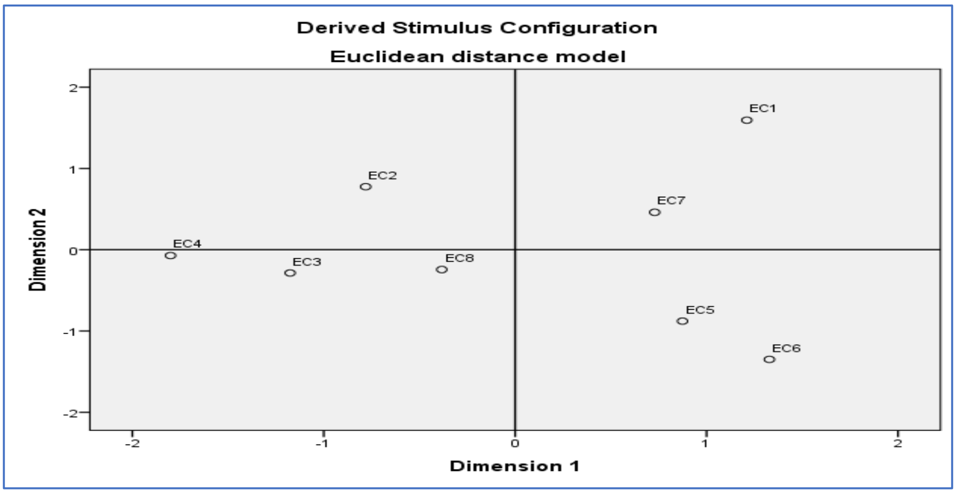

Fig. 3: MDS of Economic Dimension

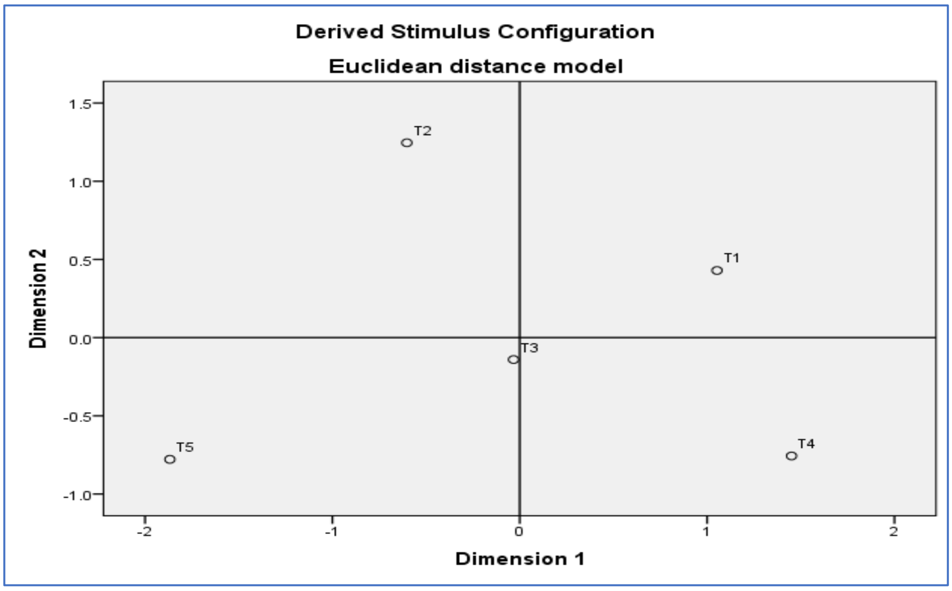

Fig. 4: MDS of Technical Dimension

C. Environmental Dimension of Sustain ability Index Analysis

The calculated environmental sustainability index is 59.82% (Table A1). This result showed index value that is categorized as enough since it falls within 51% to 75%. The valued obtained in this study (59.82%) is less than (92.02%) by Santoso et al. (2023). The processed index of the attribute scores is shown in Figure 5. From this figure, potential for spread of disease represents 5.18%, potential for biodiversity damage 3.75%, exploitation of natural resources 6.07%, utilization of different wastes 9.11%, potential for water pollution 4.11%, potential for air pollution 4.46%, efficiency of water uses7.68%, efficiency use of energy 4.82%, efficiency of chemical use 5.71%, and material efficiency 8.98%. Therefore, attribute of utilization of different wastes for BSFL (9.11%) was most significant than any other attribute while potential for biodiversity damage (3.75%) was low.

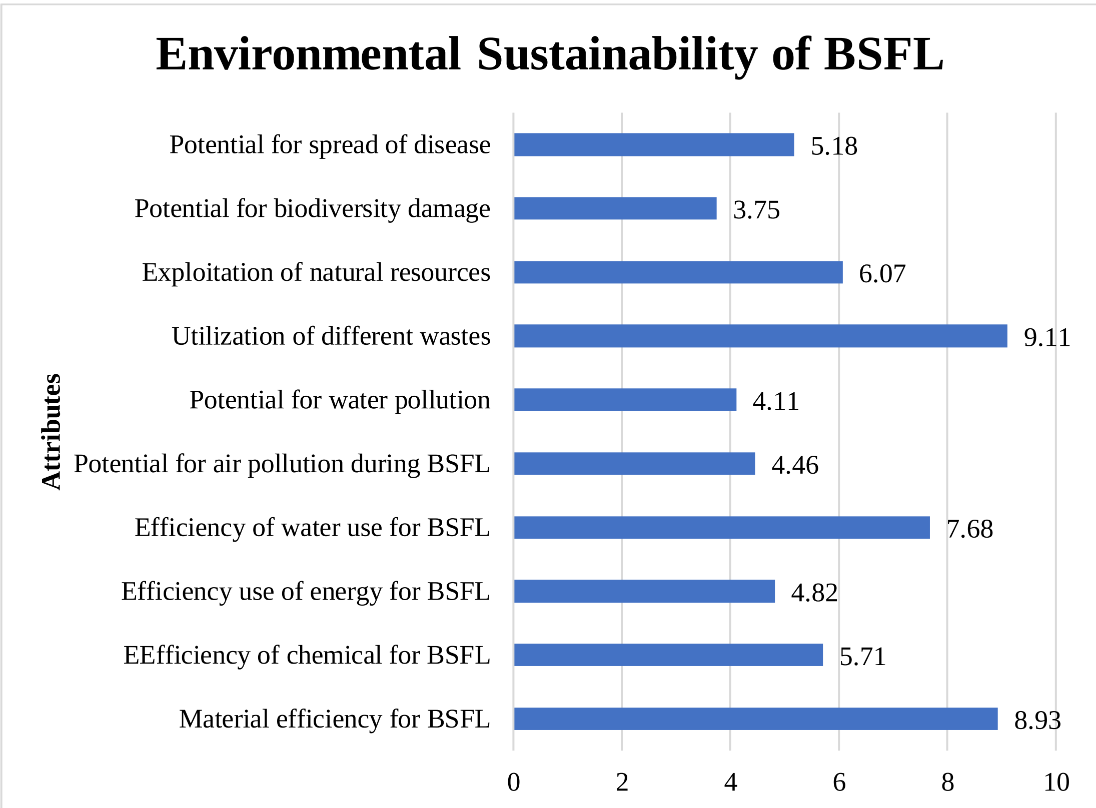

Fig. 5: Process data of Environmental Attribute Scores

D. Social Dimension of Sustainability Index Analysis

The calculated social sustainability revealed an index of 42.86% (Table B1). This result showed index value that is categorized as less since it falls within the range 25% to 50%. The valued obtained in this study (42.86%) is less than (92.2%) by Santoso et al. (2023). The processed index of the attribute scores is shown in Figure 6. From this figure, potential for job creation represents 10.71%, potential for accident 3.83%, knowledge of conservation 6.12%, possible unrest from BSF 4.59%, cultival level of business motivation 6.63%, cultival family involvement 4.08%, BSFL educational level 6.89%. Hence, potential for job creation is the most significant than any other attribute while potential for accident was lowest.

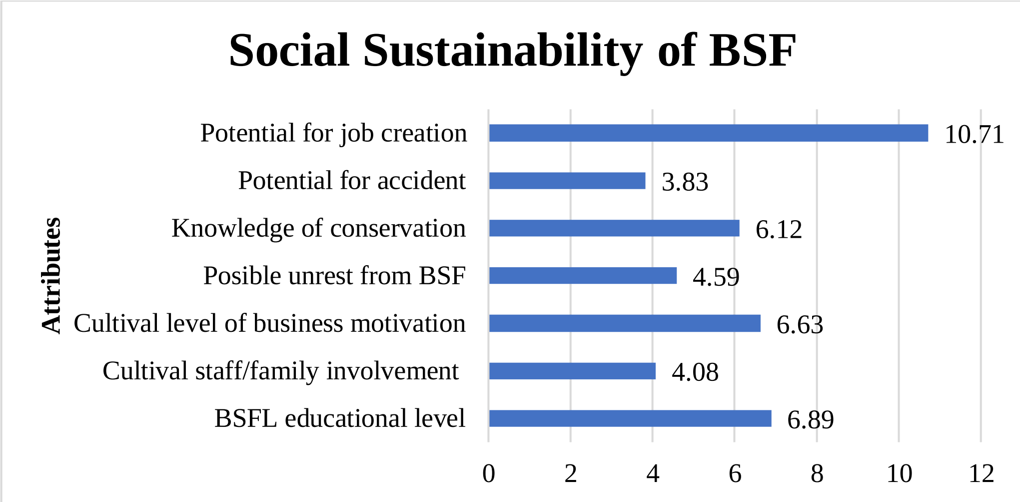

Fig. 6: Sensitivity Index of Social Attribute Scores

E. Economic Dimension of Sustainability Index Analysis

Economic sustainability revealed an index of 47.77% (Table C1). This result showed index value that is categorized as less since it falls within the range 25% to 50%. The valued obtained in this study (47.11%) is less than (100%) by Santoso et al. (2023). The processed index of the attribute scores is shown in Figure 7. From this figure, the attribute of success rate of production system represents 4.46%, absorption rate of frass 5.8%, level of market absorption 3.35%, efficiency of produced raw materials 8.04%, potential for welfare of cultival 6.7%, potential for increased business 6.92%, production management level 6.92%, and larvae cultivation productivity 5.58%. Therefore, efficiency of produced raw materials was most significant than any other attribute while level of market absorption was lowest.

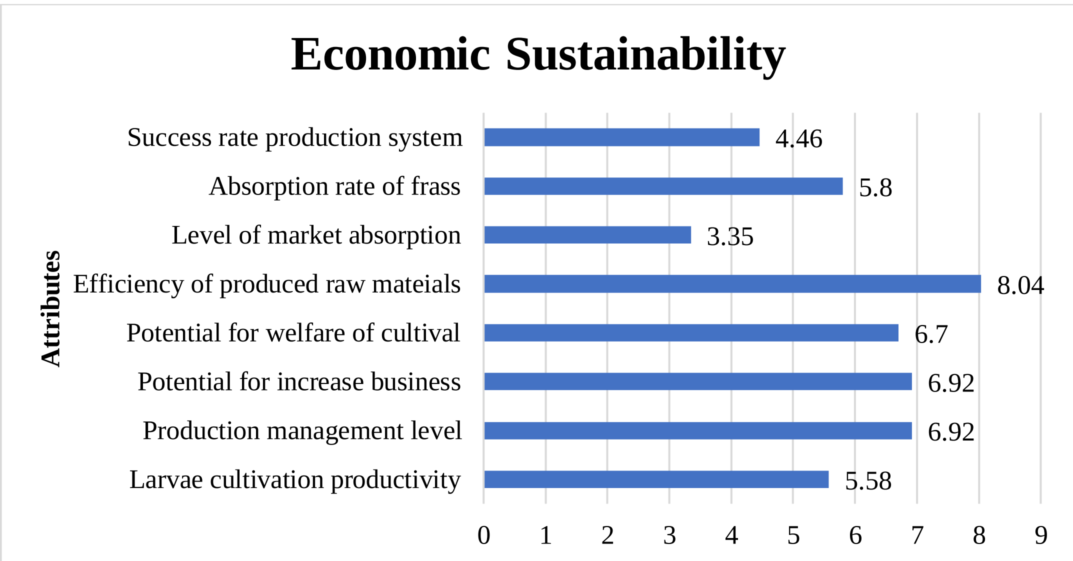

Fig. 7: Processed Index of Economic Attribute Scores

F. Technical Dimension of Sustainability Index Analysis

Technical sustainability revealed an index of 46.43% (Table D1). This result showed index value that was categorized as less since it falls within the range 25% to 50%. The valued obtained in this study (46.43%) is less than (74.74%) by Santoso et al. (2023). The processed index of the attribute scores is shown in Figure 8. From this figure, the attribute of level of technical sensitivity represents 6.43%, technological improvement 12.5%, level of production facility 7.86%, level of skill specialization 8.57%, and level of larvae production system 11.07%. Therefore, technical improvement is most significant than any other attribute while level of technical sensitivity was lowest.

ISSN No:-2456-2165

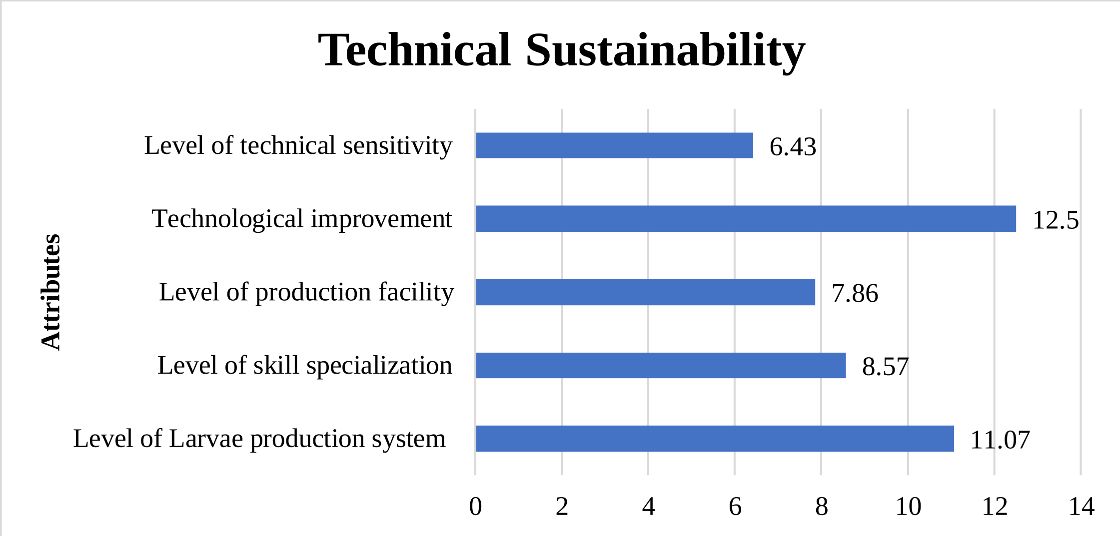

Fig. 8: Processed Index of Technical Attribute Scores

The various sustainability index is depicted in Figure 9. Overall, the sustainability of black soldier fly larvae was 38.39%.

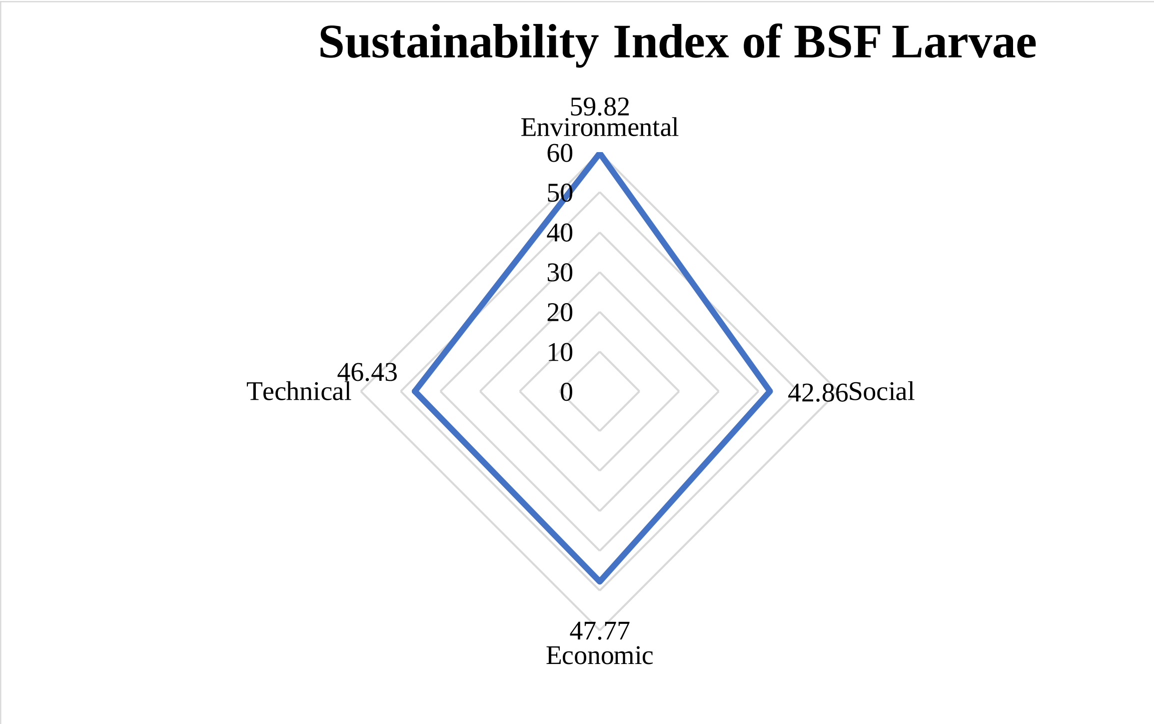

Fig. 9: Overall Sustainability of BSFL

IV. CONCLUSION AND RECOMMENDATIONS

Insects constitute a promising opportunity to overcome the threat of food insecurity in livestock farming through feeds alternatives. The cultivation of BSFL is on the increase, yet its evaluation for sustainability has not been reported in Port Harcourt, Rivers State Nigeria. This study evaluated the environmental, social, economic and technical dimensions of sustainability of BSFL. The environmental sustainability index was 59.02% with utilization of different waste as the most influencing attributes (9.11%) of this dimension. The social sustainability however was 42.86% with potential for job creation as most influencing attribute with 10.71%. Economic sustainability recorded an index of 47.77% with efficiency of produced raw materials (8.04%) as most influencing attribute. Technical sustainability on the other hand recorded an index of 46.43% of which technical improvement represents 12.5% of the attributes. Overall, the sustainability index of BSFL in Port Harcourt, Rivers State Nigeria was 38.39%. This index value is low owning to the fact that small-scale cultivation of the larvae in Rivers State. In all the evaluations conducted the values obtained were low compared the works of Santoso et al. (2023).

It is recommended further awareness training by international organisation in collaboration with Animal Science Association of Nigeria, fisheries and aquaculture institutions and other agricultural institution can go a long way to improve on sustainability of BSFL in Nigeria.

Table 3: The Various Scope of the Environmental Attributes

Material efficiency of BSFL	Efficiency use of chemical for BSFL	Efficiency use of energy for BSFL	Efficiency of water use for BSFL	Potential for air pollution during BSFL	Potential for water pollution	Utilization of different wastes	Exploitation of natural resources	Potential for biodiversity damage	Potential for spread of disease	Total
2	1	1	2	1	2	2	1	1	2	15
1	1	2	2	0	1	2	1	1	1	12
1	1	0	1	2	0	2	2	0	1	10
2	1	1	1	1	1	1	1	1	1	11
2	2	1	1	1	1	2	1	1	1	13
2	1	1	2	1	1	2	1	1	2	14
1	1	1	2	2	2	2	1	1	1	14
2	1	1	2	1	1	2	1	0	0	11
2	1	2	2	1	1	1	1	1	1	13
2	1	1	2	1	1	2	1	1	1	13
2	1	1	2	1	1	2	1	1	2	14
1	1	1	2	2	1	2	1	1	1	13
2	1	0	1	0	0	1	2	0	1	8
2	1	2	1	1	1	2	1	1	1	13
1	2	1	1	1	1	2	1	1	1	12
2	1	0	1	0	0	2	2	0	1	9
2	1	1	2	1	1	2	1	1	1	13
2	1	2	2	1	1	2	1	0	0	12
2	2	1	2	1	1	1	1	1	1	13
2	1	1	2	1	1	2	1	1	1	13
2	1	0	1	0	0	2	2	0	1	9
1	1	0	1	1	0	1	2	0	1	8
2	1	2	1	0	1	2	1	1	1	12
2	2	1	1	1	1	2	1	1	1	13
2	1	0	1	1	0	2	2	0	1	10
2	1	1	2	1	1	2	1	1	1	13
2	1	1	1	1	0	2	1	2	1	12
2	1	1	2	0	1	2	1	1	1	12
50	32	27	43	25	23	51	34	21	29	335
8.93	5.71	4.82	7.68	4.46	4.11	9.11	6.07	3.75	5.18	59.82

Table 4: The Various Scope of the Social Attributes

BSFL educational level	Cultivar staff/family involvement	Cultivar level of business motivation	Possible unrest from BSF	Knowledge of conservatio n	Potential for accident	Potential for job creation	Total
1	0	0	1	0	1	1	4
0	0	1	0	1	0	2	4
2	1	2	1	2	1	2	11
1	1	1	0	1	0	1	5
1	1	1	1	0	0	1	5
1	1	1	1	1	1	1	7
1	0	1	1	0	0	1	4
1	0	0	1	0	1	1	4
0	0	1	0	1	0	2	4
2	1	2	1	2	1	2	11
1	1	1	0	1	0	1	5
1	1	1	1	0	0	1	5
1	1	1	1	1	1	1	7
0	0	0	0	2	2	2	6
1	0	0	1	2	2	2	8
1	1	1	1	1	0	1	6
1	0	0	1	0	1	1	4

0	0	1	0	1	0	2	4
2	1	2	1	2	1	2	11
1	1	1	0	1	0	2	6
1	1	1	1	0	0	2	6
1	1	1	1	1	1	1	7
1	0	1	0	0	0	1	3
1	0	0	1	0	1	1	4
0	0	1	0	1	0	2	4
2	1	2	1	2	1	2	11
1	1	1	0	1	0	2	6
1	1	1	1	0	0	2	6
27	16	26	18	24	15	42	168
6.89	4.08	6.63	4.59	6.12	3.83	10.71	42.86

Table 5: The Various Scope of the Economic Attributes

Larvae cultivation productivity	Production management level	Potential for increase business	Potential for welfare of cultivar	Efficiency of produced raw materials	Level of market absorption	Absorption rate of frass	Success rate production system	Total
0	1	2	2	1	0	1	1	8
1	1	1	1	1	0	1	1	7
2	1	0	0	1	0	1	0	5
1	2	1	2	1	0	1	1	9
1	2	2	1	2	1	2	1	12
0	1	1	1	2	1	1	1	8
1	0	1	0	0	1	0	0	3
2	2	2	2	1	1	1	1	12
1	1	1	1	1	1	2	1	9
0	0	0	1	1	1	0	0	3
0	1	2	2	1	0	1	1	8
1	1	1	1	1	0	1	1	7
2	1	0	0	1	0	1	0	5
1	2	1	2	1	0	0	1	8
1	2	2	1	2	1	2	1	12
0	1	1	1	2	1	0	1	7
1	0	1	0	2	1	0	0	5
2	2	2	2	1	1	1	1	12
1	1	1	1	1	1	2	1	9
0	0	0	1	1	1	2	0	5
1	1	1	1	2	0	1	1	8
2	1	0	0	1	0	1	0	5
1	2	1	2	1	0	0	1	8
1	2	2	1	2	1	2	1	12
0	1	1	1	2	1	0	1	7
1	0	1	0	1	1	0	0	4
0	1	2	2	1	0	1	1	8
1	1	1	1	2	0	1	1	8
25	31	31	30	36	15	26	20	214
5.58	6.92	6.92	6.70	8.04	3.35	5.80	4.46	47.77

Table 6: The Various Scope of the Technical Attributes

Level of Larvae production system	Level of skill specialization	Level of production facility	Technological improvement	Level of technical sensitivity	Total
1	2	1	2	0	6
1	0	0	1	0	2
2	0	2	2	0	6
1	1	1	1	1	5
2	2	1	1	1	7
1	1	1	1	1	5
0	0	0	2	1	3
1	1	1	1	1	5
1	1	0	2	0	4
1	1	1	1	2	6
1	2	1	2	0	6
1	0	0	1	0	2
2	0	2	2	0	6
1	1	1	1	1	5
2	2	1	1	1	7
1	1	1	1	1	5
0	0	0	1	1	2
1	1	1	1	1	5
1	1	0	1	0	3
1	1	1	1	2	6
1	0	0	1	0	2
2	0	2	1	0	5
1	1	1	1	1	5
2	2	1	1	1	7
1	1	1	1	1	5
0	0	0	1	1	2
1	2	1	2	0	6
1	0	0	1	0	2
31	24	22	35	18	130
11.07	8.57	7.86	12.50	6.43	46.43

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