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Evaluation of Macronutrient Content in Frass from Black Soldier Fly Larvae (*Hermetia Illucens* l.). (BSFL) Treatment of Plant-Dominated and Animal-Dominated Substrates in Port Harcourt. Nigeria

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Abstract:- This study was aimed at evaluating the macronutrient content in frass from black soldier fly larvae (*Hermetia Illucens* l.). (BSFL) treatment of plant-dominated and animal-dominated substrates in Port Harcourt. Nigeria. Its objectives were to determine macronutrient content found in frass from BSFL treatment of plant-dominated and animal-dominated substrates. Between-Group design was employed along with laboratory analysis. Analysis of variance indicated p = .714 for TN, p =.716 for TC, p = .690 for Na, p = .618 for Mg, p =.147 for K, and p = .444 for Ca which were higher than 0.05. and, therefore, there were no statistically significant differences in the means between plant-dominated frass and animal dominated frass for these parameters. However, p = .048 for P was below 0.05. and therefore, there is statistically significant difference in the means between plant-dominated frass and animal-dominated frass for this parameter. It is therefore recommended that depending on plant macronutrients requirements, frass with more macronutrient should be chosen from animal-dominated substrates such as pig and chicken manure.

I. INTRODUCTION

Research indicates that by 2050, there will be approximately 9.5 billion people on Earth [1]. To fulfill the demands of the expanding population in a sustainable manner, enormous agricultural production is needed. The challenge for the majority of developing nations is to raise agricultural output without endangering the environment [2]. Food is a basic human necessity, and one of the main obstacles in producing enough to feed the expanding populations of emerging nations like Nigeria is the quality of the land. The characteristics of the soil in Rivers State vary. It has been reported that there has been an observable variance between the marsh and upland areas [3]. For example, the wetlands had larger percentages of accessible phosphorus (P), total nitrogen, iron content, and cation exchange capacity than the upland areas, and the pH was often lower in the wetlands. High acidity has the potential to cause high P fixation, which limits agricultural productivity [4]. Using organic fertilizer can help solve the issue which can be derived from agricultural wastes. It was estimated that Nigeria generates between 0.65 and 0.95 kg of waste per inhabitant per day, or 42 million tonnes on average, of waste each year [5]. This amounts to almost 24% of the waste produced in sub-Saharan Africa each year, and our country faces significant challenges in determining where and how to dispose of these pollutants. It was equally noted that 52 % of wastes generated are organic waste which creates additional disposal problems [5]. For instance, pig and poultry manure only generated in Nigeria stood at 15.3 and 32.6 million tons per year respectively. The pig and poultry manure can be reduced to 59.9% and 58.8% respectively [6], when fed to black soldier fly larvae (BSFL) which produces useful biomass rich in protein and fat for livestock and aquaculture feeds while utilizing the frass for soil amendment or fertilizer. Solution to managing organic waste with minimal energy input, low cost and within the shortest possible of time, rest in using black soldier fly larvae (*Hermetia illucens* L.). BSF technologies have received considerable attention during the last five years and research, development and investments have been allocated to make the BSFL and frass products more commercially competitive in comparison to other animal feed products in terms of price and nutrient content [7]. The emerging waste treatment technology of using BSFL to convert biodegradable waste into marketable products can therefore help to contribute towards several sustainability goals and a circular economy [8]. The use of BSF frass as organic fertilizer is relatively new to farmers. Before adopting frass as fertilizer, information on its properties is required. This is because potential revenue may be loss from BSFL frass due to variability of frass originating from the substrates used to feed BSFL. To avoid revenue losses on BSFL frass, studies on the properties of BSFL frass are needed to guide informed decision-making. The aim of this study is to evaluate the properties of frass from the management of different organic waste using BSFL in Port Harcourt, River State, Nigeria. The objectives are to determine macronutrient content found in frass from BSFL treatment of plant-dominated and animal-dominated substrates.

II. MATERIALS AND METHODS

➢ *Location of Farm and Extent*

The production of Black Soldier Fly Larvae (*Hermetia illucens*) and frass were carried out at Ibiteinye Integrated Farms (IIF) located in Port Harcourt metropolis based on the work of [6]. The farm covers approximately 19,590 square meters with its perimeter fence of approximately 776m. It is bounded by latitudes 4.853623ºN to 4.855295ºN and longitude 7.087622ºE to 7.089713ºE [6]. The farm (Figure 1) is located within Port Harcourt. 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. Port Harcourt is the capital of Rivers State and the entire South-South states of Nigeria [9].

Fig 1 Google Earth Map Showing Location of Ibiteinye Integrated Farms
Source: [6].

➢ *Research Design*

Between-Group design was employed which is a study design in which two or more groups subject to different experiences or treatments are compared. The purpose is to make statistical comparisons between two or more groups and demonstrate a causal relationship between the independent variable and the outcome of interest (Zubair, 2022). Hence, the researcher grouped the frass into plant and animal base. Plant-dominated (spent grain, carrot, green pepper and water melon) and animal-dominated (pig manure and chicken manure) were divided into two experiments fed to black soldier fly larvae [6]. The plant-dominated includes 100% spent grain fed to BSFL; 100% fruit waste fed to BSFL; and 50% fruit wastes combined with 25% poultry manure and 25% pig manure fed to BSFL. The animal-dominated includes 100% pig manure fed to BSFL; 100% poultry manure fed to BSFL; 50% pig manure combined with 25% poultry manure and 25% fruit wastes fed to BSFL; and 50% poultry manure combined with 25% pig manure and 25% fruit wastes fed to BSFL. Selection and sourcing of feeding substrates to BSFL; substrate preparation; source of larvae; larvae feeding and sampling was done in accordance with [6]

➢ *Sampling Frass and Procedure*

The frass from the treatment of 100% spent grain, 100% pig manure and 100% chicken manure by BSFL were sampled after the thirteenth day while the frass from the treatment of 50% fruit wastes combined with 25% poultry manure and 25% pig manure; 50% pig manure combined with 25% poultry manure and 25% fruit wastes; and 50% poultry manure combined with 25% pig manure and 25% fruit wastes were after sixteenth day. For each of these sampling, a bulk sample was thoroughly mixed together and divided into four quadrants. One part of the quadrants was collected in a transparent polyethene bag and sent to the laboratory for analyses.

➢ *Laboratory Methods*

The pH and electrical conductivity were determined by electrometric method. Total nitrogen was determined by persulfate method, total organic carbon was determined by Walkey-Black method and phosphorus was determined by ascorbic method. Others includes calcium, magnesium, potassium and sodium which were determined by ammonium acetate method.

III. RESULTS

➢ *pH*

The pH values of the frass from BSFL treatment of 100% chicken waste; 100% fruit wastes; 100% pig waste; 100% spent grain; combinations of 50% chicken waste, 25% of pig waste and 25% of fruit wastes; combinations of 50% fruit wastes, 25% pig waste and 25% chicken waste; combinations of 50% pig waste, 25% fruit wastes and 25% chicken is shown in Figure 2. It is shown that pH of frass from different substrates of organic wastes managed by BSFL ranged from 7.2 to 9.0.

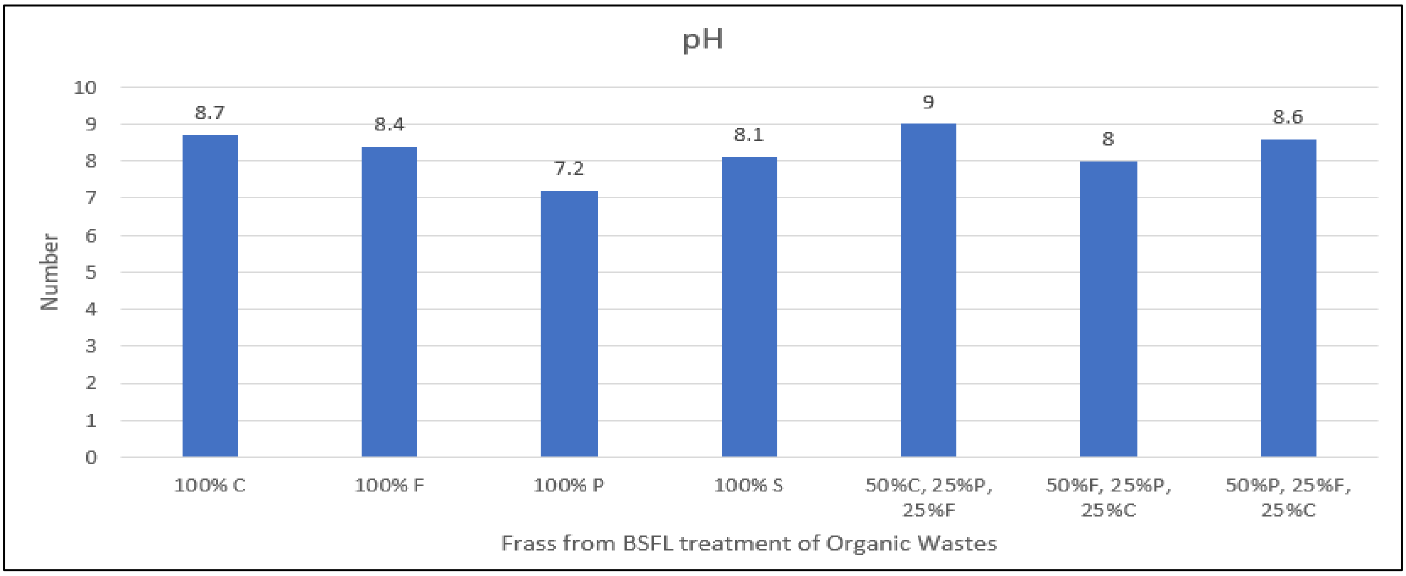

Fig 2 pH Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Electrical Conductivity*

The electrical conductivity (EC) values of the frass from BSFL treatment of 100% chicken waste; 100% fruit wastes; 100% pig waste; 100% spent grain; combinations of 50% chicken waste, 25% of pig waste and 25% of fruit wastes; combinations of 50% fruit wastes, 25% pig waste and 25% chicken waste; combinations of 50% pig waste, 25% fruit wastes and 25% chicken waste is shown in Figure 3. This figure showed electrical conductivity of frass from BSFL treatment of 100% spent grain was highest (4,900 µs/cm) while the lowest electrical conductivity (1,524 µs/cm) was realized from frass BSFL treatment of combinations of 50% pig waste, 25% fruit wastes and 25% chicken.

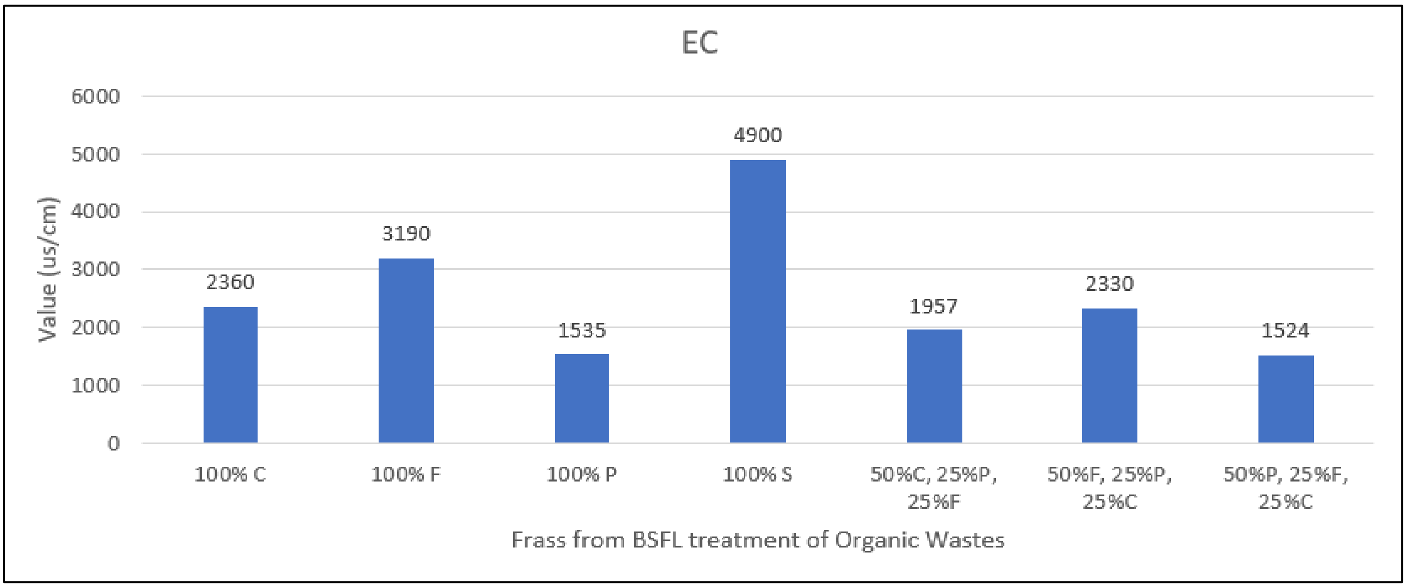

Fig 3 EC Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Total Nitrogen (TN)*

Extractable total nitrogen (TN) values of the frass from BSFL treatment of 100% chicken waste; 100% fruit wastes; 100% pig waste; 100% spent grain; combinations of 50% chicken waste, 25% of pig waste and 25% of fruit wastes; combinations of 50% fruit wastes, 25% pig waste and 25% chicken waste; combinations of 50% pig waste, 25% fruit wastes and 25% chicken waste is shown in Figure 4. Extractable highest total nitrogen (1.719 %) was found in the frass BSFL treatment of combinations of 50% chicken waste, 25% of pig waste and 25% of fruit wastes while the lowest value of total nitrogen was found in combinations of 50% fruit wastes, 25% pig waste and 25% chicken waste.

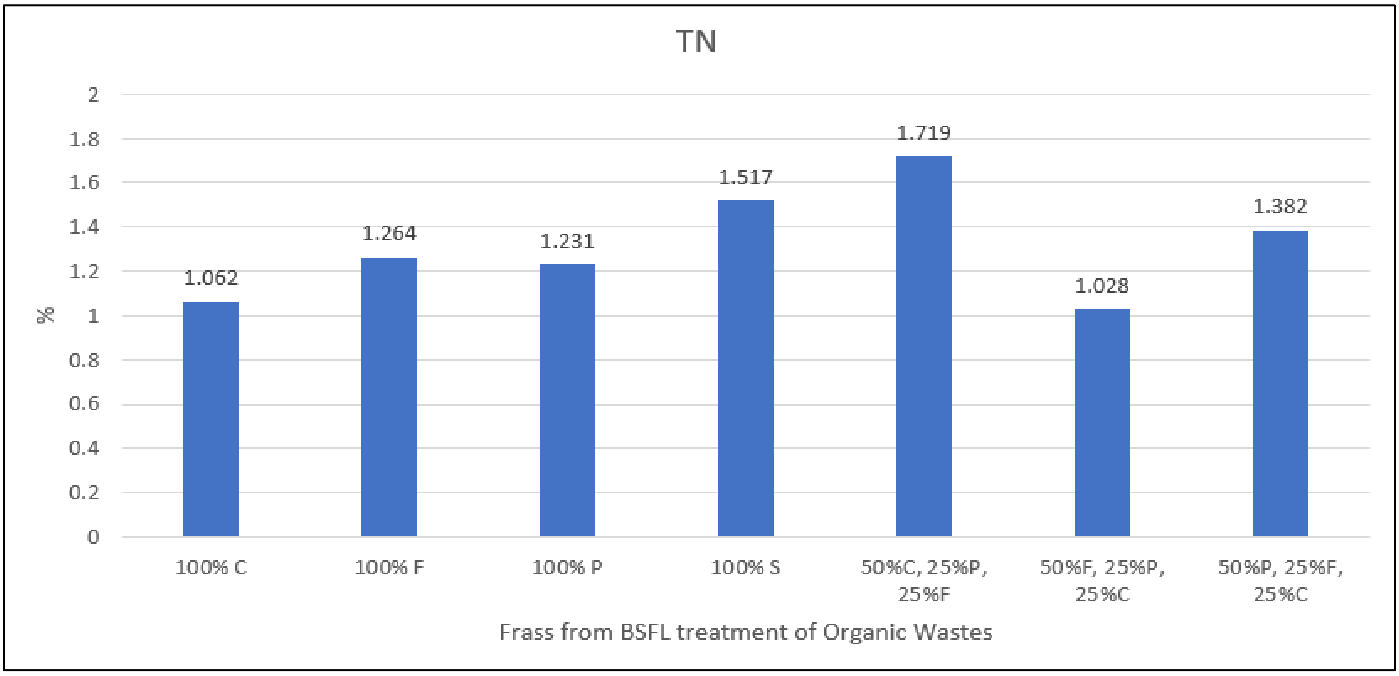

Fig 4 TN Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Total Carbon (TC)*

Extractable total carbon (TC) values of the frass BSFL treatment of 100% chicken waste; 100% fruit wastes; 100% pig waste; 100% spent grain; combinations of 50% chicken waste, 25% of pig waste and 25% of fruit wastes; combinations of 50% fruit wastes, 25% pig waste and 25% chicken waste; combinations of 50% pig waste, 25% fruit wastes and 25% chicken is shown in Figure 5. This figure indicated that highest extractable total carbon (19.89%) was realized from the frass of BSFL treatment of combinations of 50% chicken waste, 25% of pig waste and 25% of fruit wastes while the lowest (11.9%) was from the frass of BSFL treatment of combinations of 50% fruit wastes, 25% pig waste and 25% chicken waste.

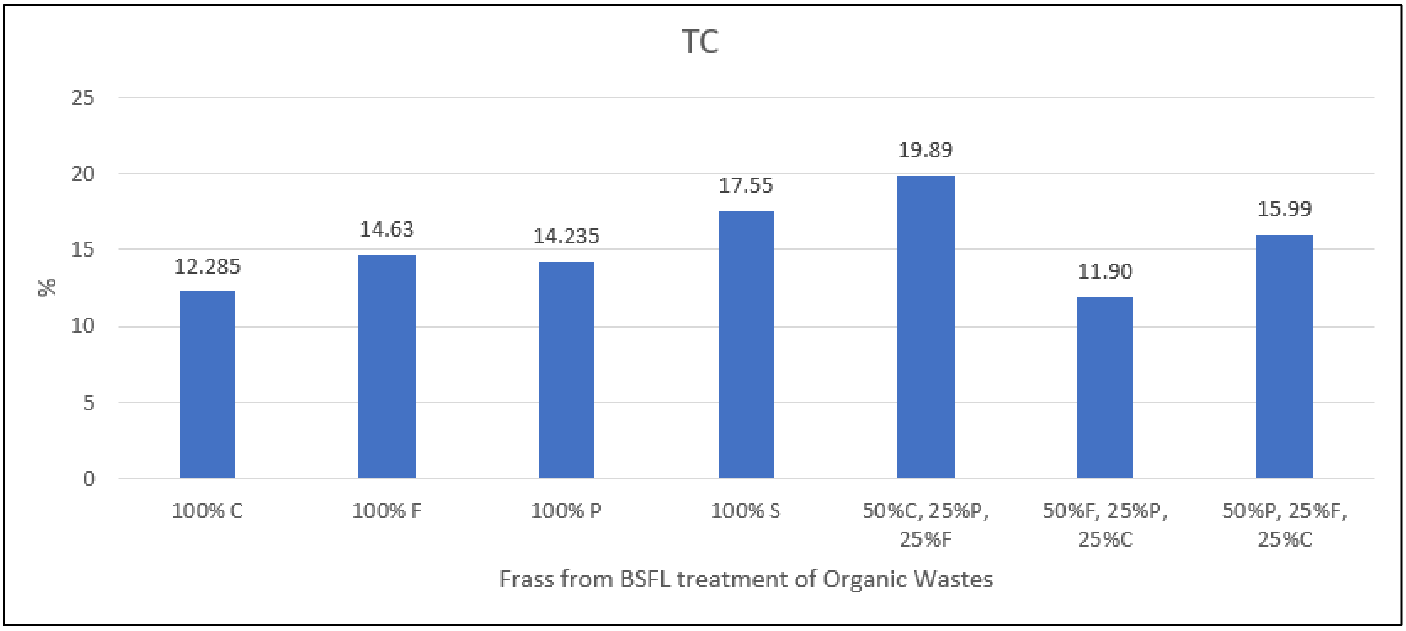

Fig 5 TC Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Phosphorus (P)*

Extractable phosphorus values of the frass from BSFL treatment of 100% chicken waste, 100% fruit wastes, 100% pig waste, 100% spent grain, combinations of 50% chicken waste with 25% of pig waste and 25% of fruit wastes, combinations of 50% fruit wastes with 25% pig waste and 25% chicken waste, combinations of 50% pig waste with 25% fruit wastes and 25% chicken is shown in Figure 6. This figure showed highest extractable P (1.58mg/kg) was attained in frass from BSFL treatment of 100% spent grain. The lowest P (0.96mg/kg) was realized in frass from BSFL treatment of 100% pig waste.

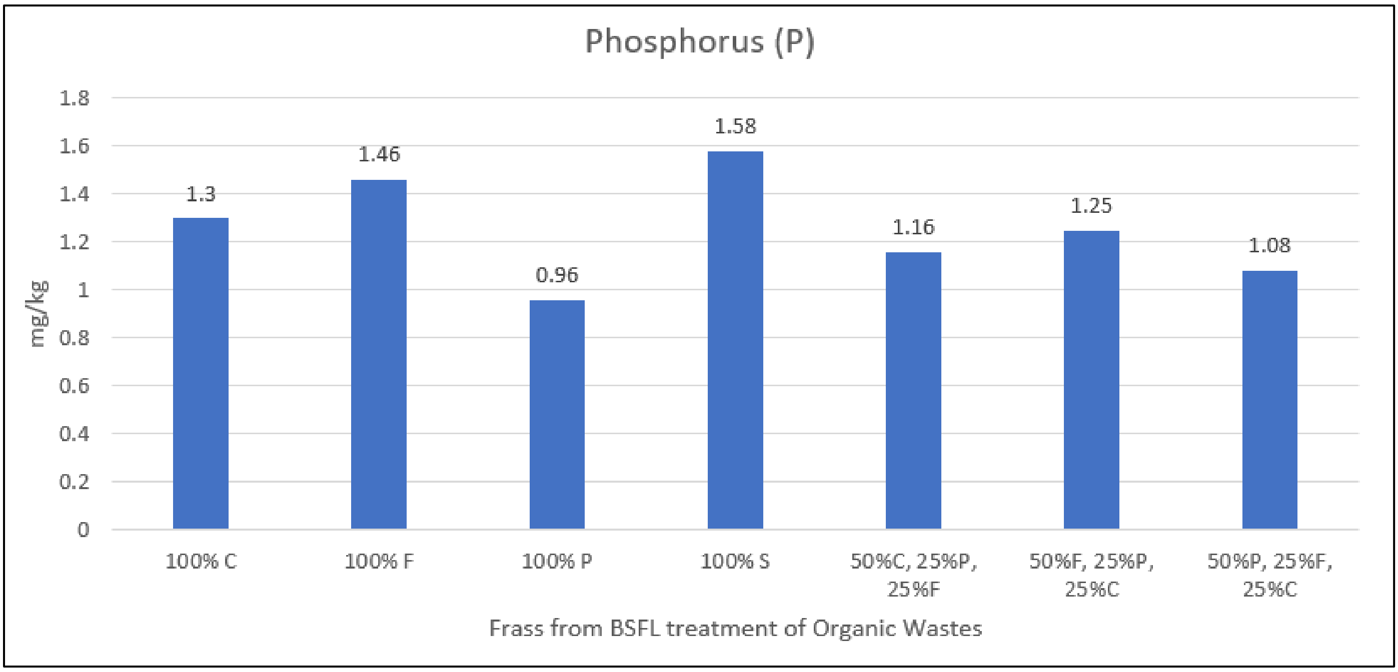

Fig 6 P Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Potassium (K)*

Extractable potassium (K) values of the frass from BSFL treatment of 100% chicken waste, 100% fruit wastes, 100% pig waste, 100% spent grain, combinations of 50% chicken waste with 25% of pig waste and 25% of fruit wastes, combinations of 50% fruit wastes with 25% pig waste and 25% chicken waste, combinations of 50% pig waste with 25% fruit wastes and 25% chicken is shown in Figure 7. It is indicated in this figure that highest potassium (1061.5mg/kg) was realized in frass from BSFL treatment of combinations of 50% pig waste with 25% fruit wastes and 25% chicken while the lowest potassium (893.52mg/kg) was attained in frass from BSFL treatment of spent grain.

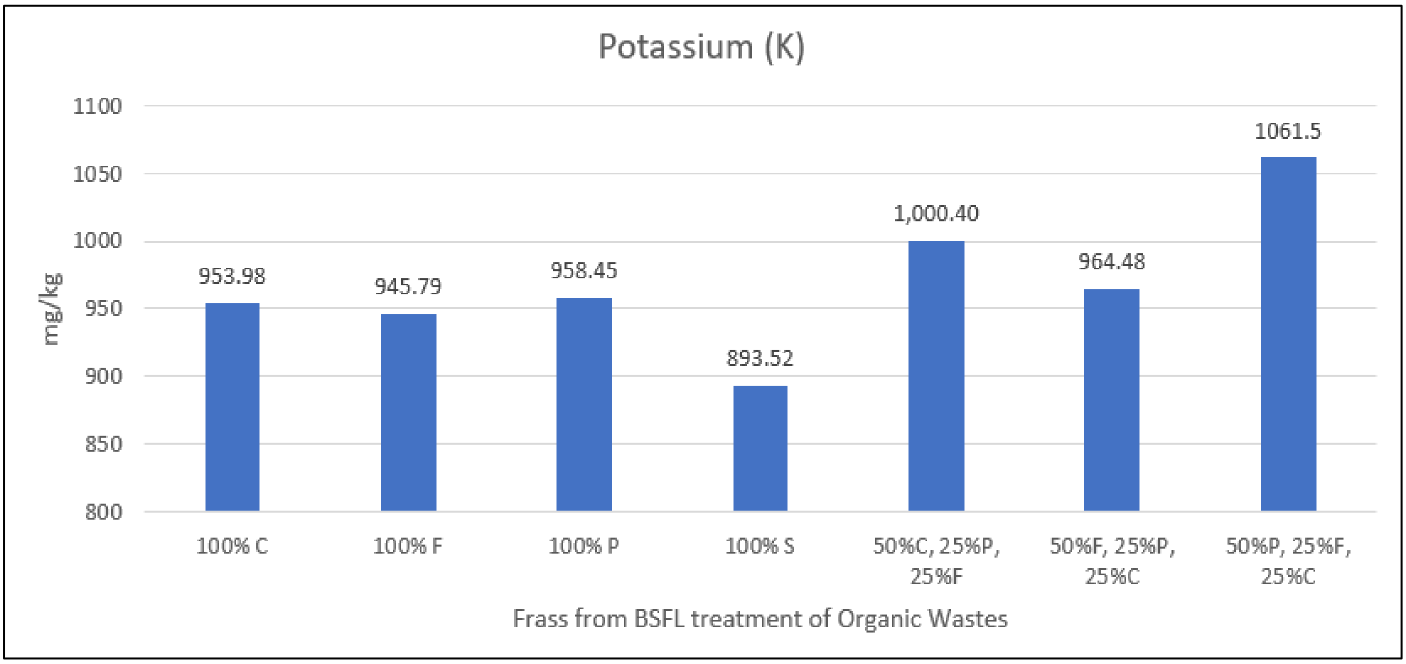

Fig 7 K Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Sodium (Na)*

Extractable sodium (Na) values of the frass from BSFL treatment of 100% chicken waste, 100% fruit wastes, 100% pig waste, 100% spent grain, combinations of 50% chicken waste with 25% of pig waste and 25% of fruit wastes, combinations of 50% fruit wastes with 25% pig waste and 25% chicken waste, combinations of 50% pig waste with 25% fruit wastes and 25% chicken is shown in Figure 8. This figure showed highest extractable Na (1101.7mg/kg) was realised in frass from BSFL treatment of 100% pig manure. The lowest Na (958.08) of frass from BSFL treatment was attained in combinations of 50% chicken waste with 25% of pig waste and 25% of fruit wastes.

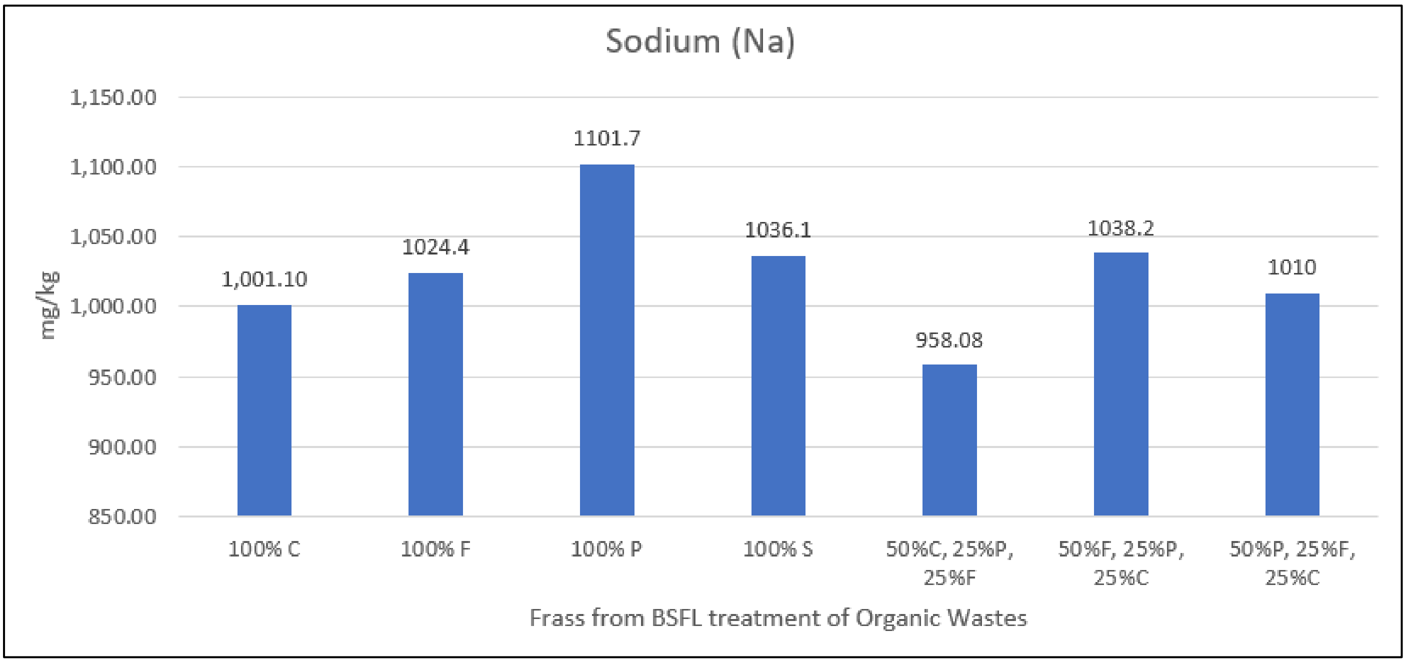

Fig 8 Na Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Magnesium (Mg)*

Extractable magnesium (Mg) values of the frass from BSFL treatment of 100% chicken waste; 100% fruit wastes; 100% pig waste; 100% spent grain; combinations of 50% chicken waste, 25% of pig waste and 25% of fruit wastes; combinations of 50% fruit wastes, 25% pig waste and 25% chicken waste, combinations of 50% pig waste., 25% fruit wastes and 25% chicken is shown in Figure 9. From this figure, highest extractable magnesium (891.58mg/kg) was realized in frass from BSFL treatment of combinations of 50% pig waste., 25% fruit wastes and 25% chicken while the lowest extractable Mg (537.49mg/kg) was attained in frass from BSFL treatment of pig waste.

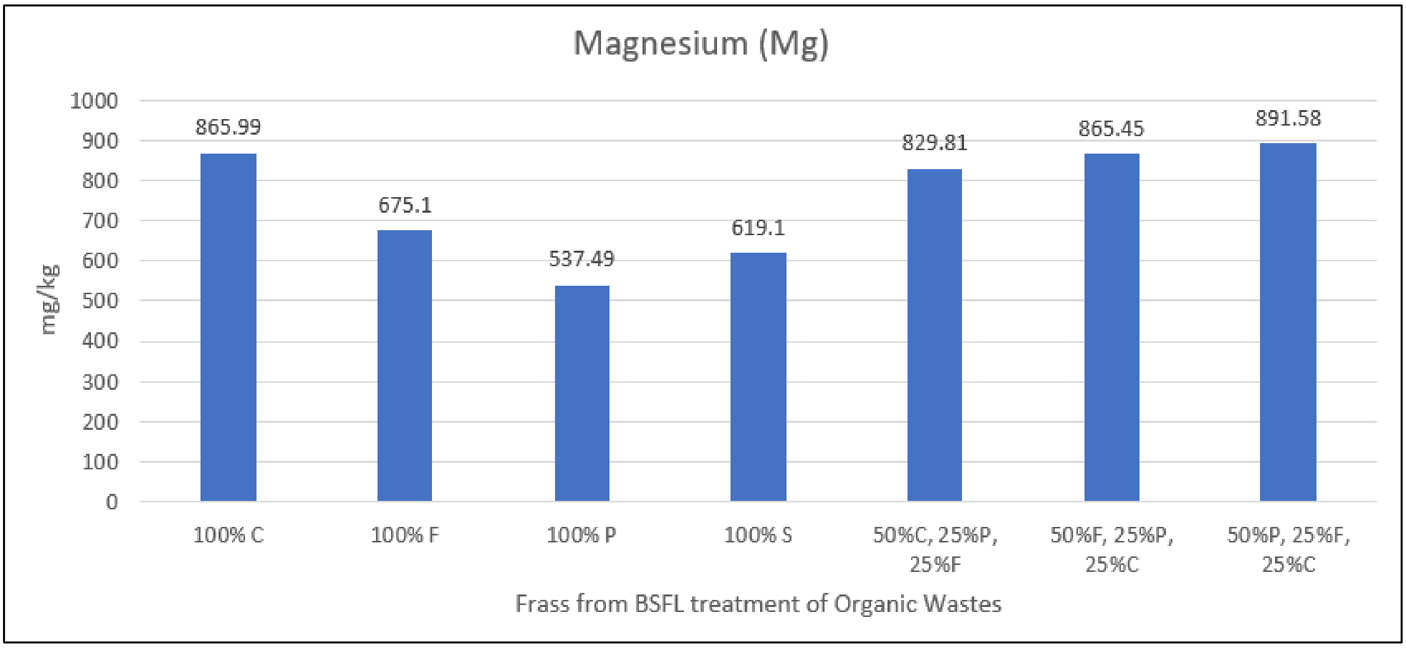

Fig 9 Mg Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Calcium (Ca)*

Extractable calcium (Ca) values of the frass from BSFL treatment of 100% chicken waste; 100% fruit wastes; 100% pig waste; 100% spent grain; combinations of 50% chicken waste, 25% of pig waste and 25% of fruit wastes; combinations of 50% fruit wastes, 25% pig waste and 25% chicken waste, combinations of 50% pig waste., 25% fruit wastes and 25% chicken is shown in Figure 10. It is shown that highest extractable calcium (2,097.3mg/kg) was attained in frass from BSFL treatment of 100% chicken manure while the lowest extractable Ca (1,060.3mg/kg) was realized in frass from BSFL treatment of spent grain.

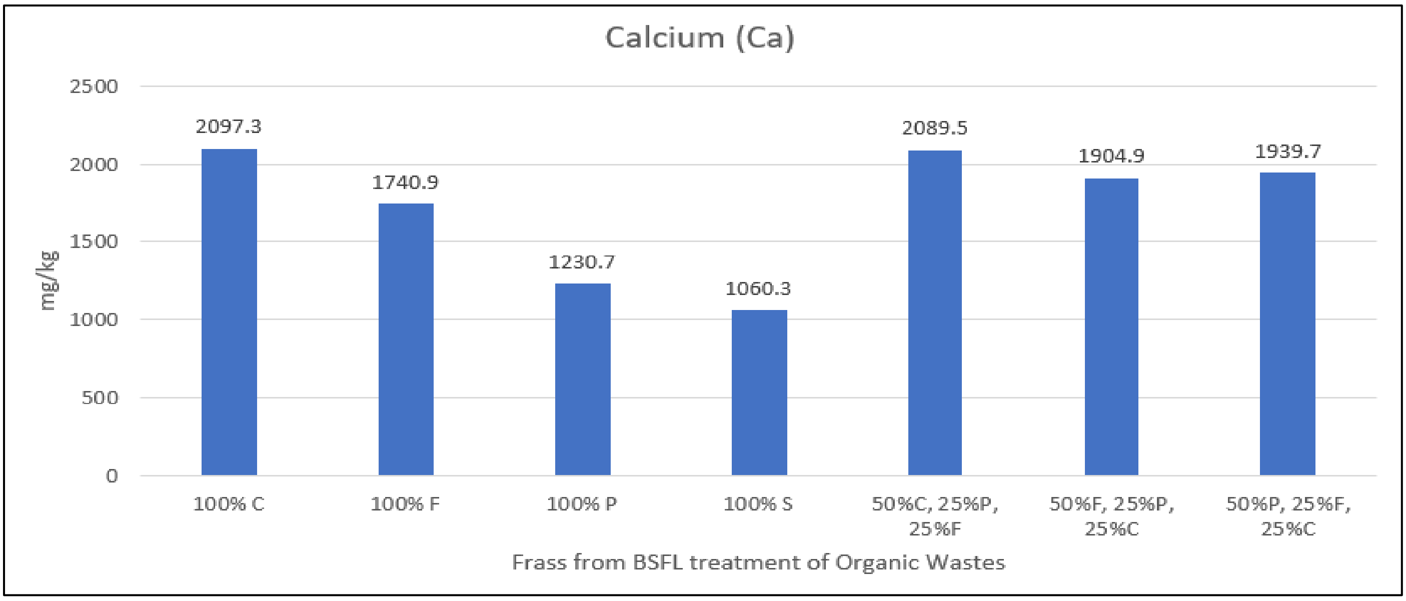

Fig 10 Ca Values of Frass from Different Organic Wastes Managed by BSFL

➢ *Macro Nutrient of Plant-dominated and Animal-dominated Frass*

The descriptive statistics for the content of macronutrient of frass is shown in Table 1. It can be deduced that mean TN for plant-dominated frass revealed a lower value (1.2697 mg/kg) than for animal-dominated frass (1.3485 mg/kg), mean TC for plant-dominated frass (14.6933 mg/kg) were lower value than that of animal-dominated frass (15.6000 mg/kg), mean K for plant-dominated frass (934.5967mg/kg) revealed a lower value than that of animal-dominated frass (993.5825mg/kg), likewise mean Mg for plant-dominated frass (719.8833 mg/kg) revealed a lower value than that of animal-dominated frass (781.2175 mg/kg), and mean Ca for plant-dominated frass (1568.70 mg/kg) revealed a lower value than that of animal-dominated frass (1839.30 mg/kg). However, mean P for plant-dominated frass (1.4300 mg/kg) showed a higher value than that of animal-dominated frass (1.1250mg/kg). Mean Na for plant-dominated frass (1032.90 mg/kg) showed a higher value than that of animal-dominated frass (1017.72 mg/kg). Analysis of variance (Table 2) that compares the variability in scores between the differences in plant-dominated frass and animal-dominated frass and the variability within each of these group indicated p = .714 for TN, p =.716 for TC, p = .690 for Na, p = .618 for Mg, , p =.147 for K, and p = .444 for Ca which were higher than 0.05 and therefore, there are no statistically significant difference in the means between plant-dominated frass and animal-dominated frass for these parameters. However, p = .048 for P, was below 0.05 and therefore, there is statistically significant difference in the means between plant-dominated frass and animal-dominated frass for P.

Table 1 Descriptives Statistics for the Content of Macronutrient of Frass

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
TN	Plant-dominated frass	3	1.2697	.24455	.14119	.6622	1.8772	1.03	1.52
	Animal-dominated frass	4	1.3485	.27945	.13973	.9038	1.7932	1.06	1.72
	Total	7	1.3147	.24649	.09316	1.0867	1.5427	1.03	1.72
TC	Plant-dominated frass	3	14.6933	2.82553	1.63132	7.6743	21.7123	11.90	17.55
	Animal-dominated frass	4	15.6000	3.23567	1.61783	10.4513	20.7487	12.29	19.89
	Total	7	15.2114	2.85147	1.07775	12.5743	17.8486	11.90	19.89
P	Plant-dominated frass	3	1.4300	.16703	.09644	1.0151	1.8449	1.25	1.58
	Animal-dominated frass	4	1.1250	.14271	.07136	.8979	1.3521	.96	1.30
	Total	7	1.2557	.21462	.08112	1.0572	1.4542	.96	1.58
K	Plant-dominated frass	3	934.5967	36.78041	21.23518	843.2291	1025.9643	893.52	964.48
	Animal-dominated frass	4	993.5825	49.87289	24.93645	914.2236	1072.9414	953.98	1061.50

	Total	7	968.3029	51.85248	19.59839	920.3473	1016.2584	893.52	1061.50
Na	Plant-dominated frass	3	1032.9000	7.43572	4.29302	1014.4286	1051.3714	1024.40	1038.20
	Animal-dominated frass	4	1017.7200	60.40252	30.20126	921.6061	1113.8339	958.08	1101.70
	Total	7	1024.2257	43.68638	16.51190	983.8225	1064.6289	958.08	1101.70
Mg	Plant-dominated frass	3	719.8833	129.13652	74.55700	399.0904	1040.6762	619.10	865.45
	Animal-dominated frass	4	781.2175	164.44916	82.22458	519.5422	1042.8928	537.49	891.58
	Total	7	754.9314	141.96948	53.65942	623.6316	886.2313	537.49	891.58
Ca	Plant-dominated frass	3	1568.7000	447.85815	258.57102	456.1587	2681.2413	1060.30	1904.90
	Animal-dominated frass	4	1839.3000	412.16427	206.08214	1183.4547	2495.1453	1230.70	2097.30
	Total	7	1723.3286	415.59585	157.08047	1338.9665	2107.6906	1060.30	2097.30

Table 2 ANOVA for the Content of Macronutrient of Frass

		Sum of Squares	df	Mean Square	F	Sig.
TN	Between Groups	.011	1	.011	.151	.714
	Within Groups	.354	5	.071		
	Total	.365	6			
TC	Between Groups	1.409	1	1.409	.149	.716
	Within Groups	47.376	5	9.475		
	Total	48.785	6			
P	Between Groups	.159	1	.159	6.821	.048
	Within Groups	.117	5	.023		
	Total	.276	6			
K	Between Groups	5964.563	1	5964.563	2.933	.147
	Within Groups	10167.513	5	2033.503		
	Total	16132.076	6			
Na	Between Groups	395.027	1	395.027	.179	.690
	Within Groups	11055.973	5	2211.195		
	Total	11451.000	6			
Mg	Between Groups	6448.937	1	6448.937	.282	.618
	Within Groups	114483.065	5	22896.613		
	Total	120932.002	6			
Ca	Between Groups	125527.474	1	125527.474	.689	.444
	Within Groups	910792.000	5	182158.400		
	Total	1036319.474	6			

IV. DISCUSSION

This study's pH value (7.2) of frass recovered from 100% pig manure digestate by BSFL was at variance with the work of [11] as the pH (8.62) of the same substrate was digested by BSFL. When 100% fruit waste was digested by BSFL, the pH (8.4) of frass in this study is consistent with the pH (8.4) of frass from fruit/vegetable and brewery wastes was [12] while [13] reported pH (8.2) of frass from digestate of carrot and beetroot waste by BSFL. On the other hand, there was wider variation of pH (8.4) from this study as compared with the work of [14] pH (5.4 to 6.2). In addition, this study found pH (8.7) of frass from digestate of 100% chicken manure which is in agreement with pH (8.5) of frass from the same substrates [15] and [16] reported pH (8.6). The electrical conductivity results of this study ranged from 1,524 µs/cm to 4,900 µs/cm are at variance from the work of [17] which ranged from 3,600 µs/cm to 4000 µs/cm. The mean extractable total nitrogen from this study was 1.315% which is in agreement with the work of [11] who revealed TN of 1.47% from frass derived from the management of pig manure by BSFL. On the other hand, this study is at variance with several studies such as [18] reported TN of 3.61% from the frass recovered from the management of spent grain using BSFL. [12] on the other hand, reported 2.01 % of TN from the frass recovered from the management of brewery waste by BSFL. [15] reported 2.66% of TN from frass of chicken manure managed by BSFL. Furthermore, [19] reported 4.2% of TN from frass derived from spent coffee grounds and donut doug managed by BSFL. This study range of TC was 11.90% to 19.89%. The estimated carbon to nitrogen ration in this study was 11.6. This value was at variance with the works of [18] who recorded a value of 10.7. The P from this study ranged from 0.96mg/kg to 1.58mg/kg Mean value from this study (1.26mg/kg) was not in agreement with the works of [19], [12], [20] and [21] whose values were 5.0g/kg, 19.1-25.4g/kg, 7.1g/kg and 0.4-10.9g/kg respectively. The range of K from 893.52mg/kg to 1061.5mg/kg was not in agreement with the works of [22], [23], [24], [25], [26] whose results were 2.1-47.6 g/kg, 10.3 g/kg, 44 g/kg, 0.54-0.99 g/kg, and 1.33 g/kg respectively. The extractable mean value of Na from this study was 1.024.23mg/kg. Our study was not in agreement with the work of [27] whose mean value was 5.7g/kg. The mean extractable Mg was 754.93 mg/kg. Our study was not in agreement with the work of [27] whose mean value was 4.7g/kg. This study showed that Ca ranged from 1060.3mg/kg to 2,097.3 and the mean was 1,723.33mg/kg. Our study was not in agreement with the work of [27] whose mean value was 8.8g/kg.

V. CONCLUSION AND RECOMMENDATION

This study found mean TN for plant-dominated frass was lower (1.2697 mg/kg) than for animal-dominated frass (1.3485 mg/kg), mean TC for plant-dominated frass (14.6933 mg/kg) was lower value than that of animal-dominated frass (15.6000 mg/kg), mean K for plant-dominated frass (934.5967mg/kg) was lower than that of animal-dominated frass (993.5825mg/kg), likewise mean Mg for plant-dominated frass (719.8833 mg/kg) was lower than that of animal-dominated frass (781.2175 mg/kg), and mean Ca for plant-dominated frass (1568.70 mg/kg) was lower than that of animal-dominated frass (1839.30 mg/kg). However, mean P for plant-dominated frass (1.4300 mg/kg) was higher than that of animal-dominated frass (1.1250mg/kg). Mean Na for plant-dominated frass (1032.90 mg/kg) was equally higher than that of animal-dominated frass (1017.72 mg/kg). Analysis of variance indicated $p = .714$ for TN, $p =.716$ for TC, $p = .690$ for Na, $p = .618$ for Mg, $p =.147$ for K, and p = .444 for Ca which were higher than 0.05. and, therefore, there were no statistically significant differences in the means between plant-dominated frass and animal dominated frass for these parameters. However, $p = .048$ for P was below 0.05. and therefore, there is statistically significant difference in the means between plant-dominated frass and animal-dominated frass. It is therefore recommended that depending on plant macronutrients requirements, frass with more macronutrient should be chosen from animal-dominated substrates such as pig and chicken manure.

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