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Aerobic Composting of Sugar Pressmud with Stabilized Spentwash and selected Microbial Consortium

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Abstract

India is the world's largest producer of sugar, with an annual production capacity of 29 million tonnes. Each crushing season, this intern produces over 10 million tonnes of pressmud, which is difficult to dispose of due to its inherent properties. The present study is part of larger investigation for treatment and disposal of pressmud and spentwash. Further, scope of this research article is confined to utilization of pressmud for aerobic composting of pressmud along with selected microbial consortium and stabilized spentwash. Composting was carried out in an open area with 50 kg of pressmud and 1% (w/w) dosage of microbial consortium. Stabilized spentwash was used at concentrations of 25, 50, 100, 150 and 200% (v/w) and applied at predetermined time intervals. The entire study lasted for 50 days and the results were compared to those recommended by the Fertilizer Control Order (FCO), Ministry of Agriculture, Government of India (1). In an organic compost, the FCO recommends a minimum concentration of 12%, 0.80%, 0.40%, and 0.40% in TOC, TKN, phosphorous and potassium, with a maximum C/N ratio of 20. During composting, the addition of 150% (CH5) stabilized spentwash resulted in a maximum nutrient concentration in the majority of the parameters analysed. CH5 showed that the concentration of TOC, TKN, C/N, phosphorous and potassium were 25.92±2.19%, 2.16±0.29%, 12.28±0.66, 6.55±0.11% and 15.90±1.37% respectively. Hence, it can be concluded that selected microbial consortium is capable of decomposing the organic matter found in pressmud. Additionally, the application of stabilized spentwash enhanced the nutritional content of end product.

Keywords: Pressmud, Spentwash, Aerobic composting, Organic compost

Introduction

Sugar is a widely consumed food source with a variety of applications. Global sugar production is about 181 million tonnes per year, with India leading the way with 29 million tonnes (2). Over 50 million farmers grow sugarcane over an area of roughly 5 million hectares for their livelihood. With its 65 sugar industries and a production capacity of 3.70 million tonnes, Karnataka is one of the major producers of sugar in India. The average sugar recovery rate from these industries is about 10.50%. The sugar industries major by-products include bagasse, molasses and pressmud. Bagasse is generated around 27-30% cane crushed and can be utilized as a raw material for the paper and pulp industries as well as a feedstock for animals. Molasses is generated around 3.8 - 4.0% of cane crushed and is used as a raw material in distilleries to produce industrial alcohol or ethanol. Similarly, pressmud is one of the significant by-product generated about 3.5 - 4.0% of cane crushed. Composition and properties of pressmud depends upon quality of sugarcane used and the manufacturing process. In India, about 1 million tonnes of pressmud is generated daily by sugar industries. Due to the intrinsic characteristics of this huge amount of generated by-product, industries face difficulty in its safe disposal. Pressmud is a soft, amorphous, dark brown substance composed primarily of fibres, colloids, cane wax, albuminoids, inorganic salts, soil particles, minimal sugar content and is illustrated in Table 1.

Compared to many other bulky materials, pressmud is a finely pulverised, thick and dense organic substance with a high nutritional content. It may be utilized as a raw material in brick kilns and wax extraction, but millions of tonnes of readily available plant

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Table 1. General composition of sugarcane pressmud (3)

Sl. No.	Composition	Percentage (%)
1.	Moisture content	70 - 75
2.	Fibre content	20 - 30
3.	Crude wax	7 - 15
4.	Sugar	0.9 - 1.5
5.	Crude Protein	5 - 10
6.	Nitrogen	2 - 2.50
7.	Lignin	9.0 - 9.3
8.	Cellulose	10.5 - 11.4
9.	Hemi-cellulose	9 - 10

nutrients are lost in the process. Application of raw pressmud to the soil over a period of time will deteriorate the properties like bulk density, soil structure, water holding capacity and chemical composition (4).

Pressmud is difficult to transport due to its sticky nature and pungent odour, as well as high moisture content. As a result, the majority of industries dump the generated pressmud in their premises. Since pressmud contains a trace amount of sugar (2), it creates fly nuisance and sanitation concerns, which results in health problems in their immediate surroundings. During the summer, pressmud dries up completely and is blown by the wind, causing bronchial allergies in workers and rural communities, due to presence of colloidal and suspended particles. Similarly, leachate is generated during the rainy season from the pressmud disposal yard, creating unsanitary conditions in the surrounding area. Furthermore, it percolates into the ground, polluting ground water.

Numerous researchers have conducted investigations on the characteristics of pressmud and the feasibility of its treatment. According to Gupta *et al.*, (2011), pressmud has a porous structure and can be used as an adsorbent for pollutants removal (5). Furthermore, by using suitable biodegradation techniques, pressmud has the ability to recycle plant nutrients. Keshavanath *et al.*, (2006) demonstrated the organic nature of pressmud by using it as a manure for carp harvesting (6). According to the study, pressmud application did not affect the organoleptic quality of carp. Lim *et al.*, (2016) investigated the technique of vermicomposting followed by composting to recycle nutrients from organic waste (7). The study showed, composting is one of the clean and sustainable processing strategies for recycling and reuse organic waste in agricultural areas as manure. Satisha & Devarajan, (2007) investigated windrow composting of sugar pressmud (8). This study suggests that C/N ratio, TOC, TKN, Potassium, Phosphorous, Cation Exchange Capacity, Bulk density and germination index are good indicators of compost maturity. Additionally, Raj & Antil, (2011) recommend that two or more factors should be taken into consideration while determining the maturity and stability of compost (9).

According to the literature reviewed thus far, pressmud treatment and its safe disposal are challenging, due to its intrinsic properties and quantity generated. The majority of sugar industries dispose of pressmud in an unscientific and crude ways, which leads to ground water contamination in nearby areas. As a result, it is critical to handle this issue immediately, in order to ensure the appropriate utilization and safe disposal of this complex organic by-product.

The present article is part of a larger investigation into the treatment and disposal of two complex organic by-products through aerobic composting process. Sugarcane pressmud and distillery spentwash are considered as base materials for the said research work. The scope of this article is confined to the utilization of pressmud as base material in aerobic composting with treated bio-methanated spentwash, termed as stabilized spentwash and selected microbial consortium.

Materials and Methods

Pressmud is a high-strength organic by-product from agro-based sugar industries. Incorporating the most efficient and effective methods of waste management minimises considerable pollution load on landmass and water bodies. Composting is one of the process that has gained popularity in recent years for the treatment and disposal of pressmud from sugar industries. Current study was carried out at Research Centre, Department of Civil Engineering, Angadi Institute of Technology & Management, Belagavi, Karnataka. Ugar Sugar Works Ltd., Ugarkhod, Belagavi, Karnataka, provided pressmud and bio-methanated spentwash. The microbial consortium was obtained from the University of Agricultural Science, Dharwad in Karnataka. This microbial consortium was in powdered form and additionally, it consists of nutrients required for the growth of the microorganisms.

As discussed in the preceding section, spentwash is utilized as a secondary base material for the current investigation. Raw spentwash from distilleries is quite complex in nature, making its disposal difficult without causing harm to the surrounding ecosystem. The majority of distilleries utilize anaerobic digestion as a partial treatment for spentwash and the effluent is referred to as bio-methanated spentwash. According to Pant & Adholeya, (2007) and Ghosh *et al.*, (2002), bio-methanated spentwash contains a significant quantity of contaminants and hence cannot be disposed of directly into the environment (10,11). Thus, the electrocoagulation process (12) was used to further treat the bio-methanated spentwash and the treated effluent is referred to as stabilized spentwash. This stabilized spentwash is used in this study, in various proportions for the aerobic composting of pressmud. Table 2 summarises the physico-chemical properties of stabilized spentwash.

Additionally, microorganisms are critical in the composting process. Several preliminary laboratory experiments have been conducted to evaluate the decomposition of pressmud using various individual fungal microorganisms. However, the findings of these preliminary studies showed that no individual microbe could decompose the pressmud satisfactorily. Hence, this study employs a fungal microbial consortium based on the preliminary studies, literature review and interaction with industry experts. The selected microbial consortium consists

Table 2. Physico-chemical characteristics of stabilized spentwash used in this investigation

Sl. No.	Characteristics	Stabilized Spentwash
1.	pH	8.39
2.	Conductivity (mS/cm)	37.7
3.	Chloride (mg/l)	12200
4.	BOD3 @ 27°C (mg/l)	1820
5.	COD (mg/l)	11200
6.	Total Dissolved Solids (mg/l)	20100
7.	Total Suspended Solids (mg/l)	22800
8.	Phosphorus (mg/l)	680
9.	TKN (mg/l)	1244
10.	Potassium (mg/l)	2627

of Phanerochaete, Trichoderma Viride, Aspergillus Niger and Pleurotus. The characteristics of microbial consortium and its degradation capacities are elaborated in A. Byakodi & Suresh Babu, (2021) (13). To summarize, the selected microbial consortium is capable of degrading lignocellulosic materials and convert into stable organic compounds.

Experimental setup

Composting of pressmud was carried in an open area, as shown in Fig. 1. Additionally, the area was prepared for composting by properly levelling the land and creating channels as needed to prevent mixing of composting heaps with each other. Also, to prevent composting piles from mixing with the soil beneath, a water-resistant plastic liner was used. Further, to minimise disturbances from domestic animals and rodents, a green netting was put around the composting area.

In total, 18 composting heaps were set up, each with 50 kg of open dried pressmud. Stabilized spentwash was applied at concentrations of 25, 50, 100, 150, and 200 (v/w) percentage of pressmud and each of these were prepared in triplicate for observation. Additionally, control for pressmud composting was also carried out in triplicates using water in the same quantity and frequency as that of other composting heaps.

To begin with 50 kg of weighted pressmud was placed on top of 4' x 4' water-resistant plastic liners. Microbial consortium of 1% (w/w) was added to the pressmud heaps along with water. To maintain an optimal moisture content, the maximum amount of liquid (stabilized spentwash and water) that can be applied in a single application was restricted to 30 litres (Table 3). During the acclimatization of the microbial consortium of 10 days, all the composting heaps were mixed with water at 5-day intervals to ensure proper aeration.

Entire study was carried out for a duration of 50 days including, 10 days for acclimatization of microbial consortium. The application of stabilized spentwash was restricted to 20 days (10^{th} day - 30^{th} day), with a frequency of 5 days. Table 3 summarises the procedure for applying stabilized spentwash to each application. Following the addition of stabilized spentwash, composting piles were only aerated every 5 days. Representative samples were collected from the composting piles every 10 days for physico-chemical analysis. The temperature of the composting heaps were monitored on daily basis to determine the amount of heat generated as a result of the composting process. The entire methodology of this study is shown in Fig. 2.

Results

Fertilizer Control Order (FCO) (1), Government of India, have prescribed the standards for nutrient requirements for various types of composts and fertilizers. These criteria define a range of physico-chemical characteristics that must be adhered to in order to achieve an optimal nutrient content in a compost. The FCO recommends that organic compost have a pH range of 6.5 to 7.5 and an electrical conductivity of less than 4 dS/m. Total organic carbon (TOC) should be greater than 12%, total kjeldahl nitrogen (TKN) should be greater than 0.80%, phosphorous and potassium should be greater than 0.40% and the C/N ratio should be less than 20. While none of these factors alone can be used to determine the compost quality, a combination of three or more parameters can yield an accurate result.

All composting heaps were prepared in accordance with the experimental setup described earlier. Representative samples were collected and analysed for physico-chemical characteristics at 0, 10, 20, 30, 40 and 50th day. Additionally, these results were statistically analysed using One-way ANOVA with post hoc Tukey Test at $p \leq 0.01$. Furthermore, the standard deviation and error are presented graphically. Throughout the composting process, the pH remained in the neutral range, varying between 7.11 and 7.84. Similarly, temperature is one of the essential factors for efficient organic matter decomposition. Temperature was measured on daily basis and evolution of heat was evident from all the composting heaps. Throughout the composting process, thermophilic phase was seen in all composting heaps with temperatures greater than 45°C until the 15^{th} day, following which the temperature gradually decreased till 30^{th} day to reach atmospheric temperature. Thereafter, temperature of the composting piles remained consistent with atmospheric temperature, until the end of composting.

Total Organic Carbon (TOC)

Total Organic Carbon is a measure of the quantity of organic matter in composting piles and its variations during the composting process is indicated in Fig. 3. Composting heap analysis at a given interval indicates that the raw pressmud initial TOC was 53.16%. The addition of microbial consortium to composting heaps and its active degradation decreased the TOC to 22.88±2.20% on the 10^{th} day, indicating a 56.9% reduction. Additionally, on the 30^{th} day of composting, all composting heaps showed a reduced rate of degradation and a minimum TOC of 16.10±0.04% in CH4, implying a maximum reduction of 69.7%. Following that, the TOC of the composting heaps progressively climbed until the 50^{th} day, reaching a high



Figure 1. Experimental setup for aerobic composting of pressmud.

Table 3. Details of stabilized spentwash addition to composting heaps

Sl. No.	Composting Heaps	CPM mixture [PM + Microbial Consortium]	Stabilized Spentwash (%)	Single Application limited to 30 litres	
				Stabilized Spentwash*	Water*
1.	CH 1	50kg+500gm	0	-	30
2.	CH 2	50kg+500gm	25	2.5	27.5
3.	CH 3	50kg+500gm	50	5	25
4.	CH 4	50kg+500gm	100	10	20
5.	CH 5	50kg+500gm	150	15	15
6.	CH 6	50kg+500gm	200	20	10

* Unit for addition of stabilized spentwash and water are in litres.

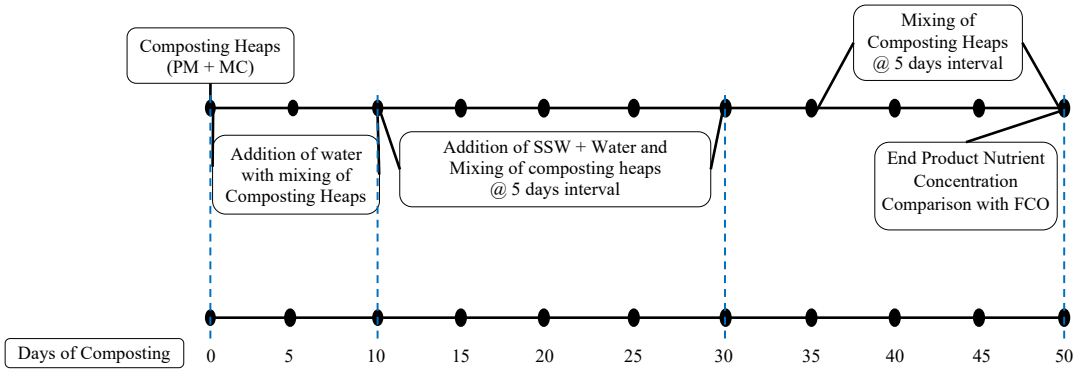


Figure 2. Flowchart showing the methodology of the study.

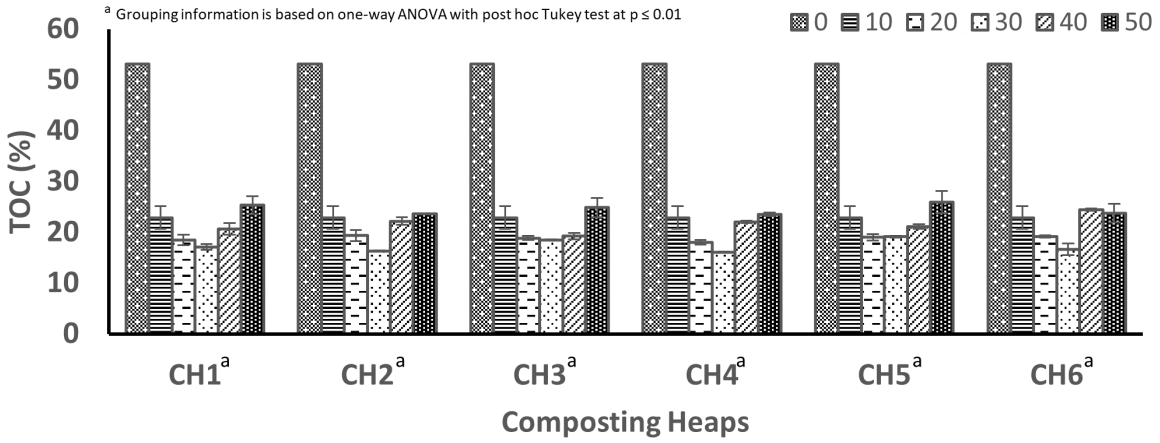


Figure 3. Variation of TOC during aerobic composting process.

of 25.92±2.19% in CH5.

The initial reduction in TOC for all composting heaps till 30th day was comparable to that reported by Zhang & Sun, (2017) and Satisha & Devarajan, (2007) (8,14). Microorganisms are essential in the composting process since they break down organic matter. As a component of total organic carbon, pressmud is composed of lignin, cellulose and hemicellulose. The initial rapid decrease in TOC is attributed to microbial activity, which is confirmed by the rise in temperature throughout the first 15 days. Further, progressive increase in TOC till the end of study period is attributed to the addition of stabilized spentwash and its mineralization.

According to Raj & Antil, (2011), a minimum of 42% reduction in TOC is required to stabilize organic matter during the composting process (9). During our investigation, all composting heaps exhibited a minimum TOC decrease of 51.24% in CH5 and a maximum reduction of 55.73% in CH4. This confirms the active breakdown of organic carbon in composting heaps and can be considered as stabilized.

Total Kjeldahl Nitrogen (TKN)

Nitrogen is an essential aspect in evaluating the composting process and its variation during the study is shown in Fig. 4. The initial TKN value for the raw pressmud was 4.73%, indicating a high concentration. Following addition of the microbial consortium, the activity of microorganisms increases and intern the TKN value rapidly decreased to 0.92±0.16%. This is also due to the active breakdown of organic materials in composting piles. The TKN concentration rose as the composting process progressed, ranging from 1.26±0.02% in CH2 to 1.78±0.06% in CH5 on the 20th day. Following that, all composting piles exhibited minor fluctuation until the end of the composting period, with a maximum TKN of 2.16±0.29% in CH5.

Zhang & Sun, (2017), reported a similar trend of rapid reduction followed by steady rise in TKN (14). The rapid decrease in TKN from 4.73% to 0.92±0.16% indicates that ammonia was released during the early stage of composting. It is evident from the field conditions, since there was a foul odour during the first several days of composting. Raj & Antil, (2011) and Satisha & Devarajan, (2007) suggested, ammonia consumption will be greater during the thermophilic phase of composting, as seen by the rapid reduction in TKN during the first 10 to 15 days (8,9). Following that, the steady increase in TKN in all composting heaps until the 20th day can be attributed to the addition of stabilized spentwash to the composting heaps starting on the 10th day and continuing until the 30th day with a 5-day interval. According to Zhang & Sun, (2017), conversion from thermophilic to mesophilic phase decreases ammonia evolution and promotes nitrate mineralization in composting heaps, therefore stabilizing the TKN in the composting heaps (14).

C/N Ratio

The C/N ratio is a critical parameter for evaluating the decomposition of organic matter and the composting process. As the name implies, the C/N ratio is a unitless ratio determined by the ratio of total organic carbon to total nitrogen. Fig. 5 shows the variation of C/N ratio during the study period. At first, the C/N ratio of raw pressmud was 11.24, which was lower than the typically suggested value of 30 (8). As the composting progressed, the C/N ratio increased to 27.83±6.01 on the 10th day of composting due to the relative degradation of TOC and TKN respectively. The C/N ratio decreased significantly from the 10th to the 20th day, ranging from 10.77±0.75 in CH5 to 15.28±0.58 in CH2. Following that, all composting piles had a consistent fluctuation until the end of the composting period, with a minimum C/N ratio of 12.28±0.66 in CH5.

C/N ratio interlinks the decomposition of organic carbon sources with the use of nitrogen in the composting process. Although the raw pressmud used in this investigation had a low carbon to nitrogen ratio, the percentages of organic carbon and total nitrogen were greater, as discussed in previous sections. The addition of a microbial consortium triggered the breakdown of organic carbon and total nitrogen at distinct rates, re-

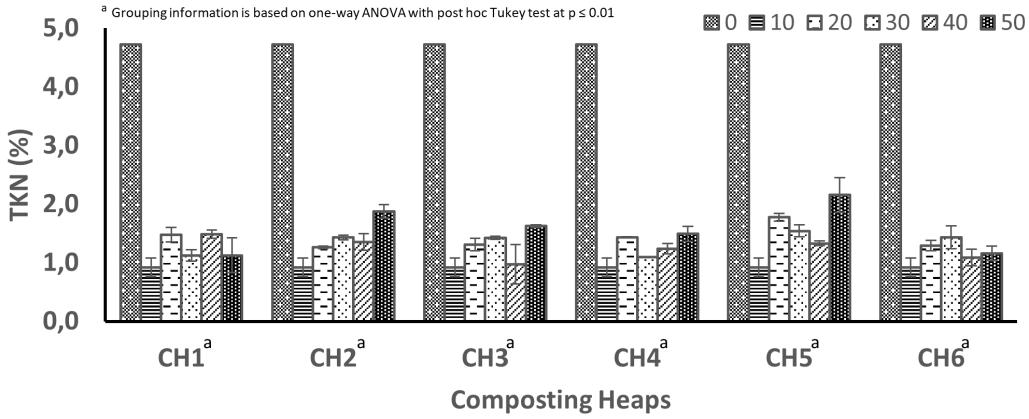


Figure 4. Variation of TKN during aerobic composting process.

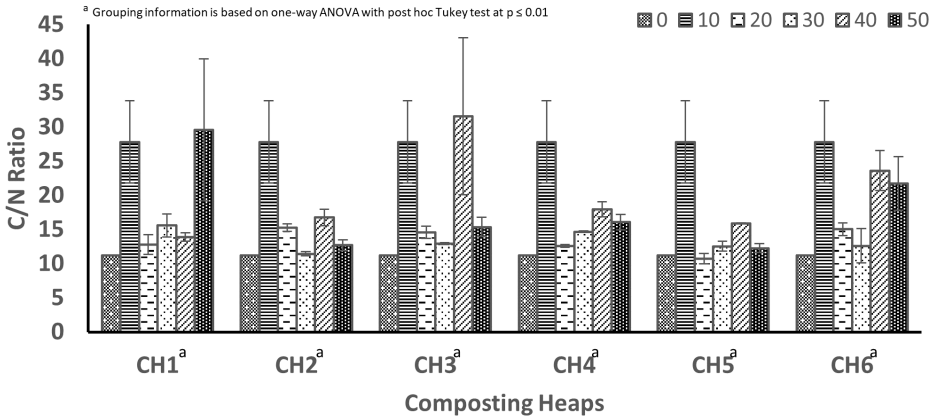


Figure 5. Variation of C/N ratio during aerobic composting process.

sulting in an increased C/N ratio on the 10th day of composting. The reduction in TOC was 56.90%, whereas the reduction in TKN was 80.54%, suggesting maximal use of nitrogen molecules in composting heaps. Thereafter, the C/N ratio in all composting has decreased until the 20th day, primarily due to a reduction in TOC and partially due to the inclusion of stabilized spentwash. Both TOC and TKN decreased from the 20th to the 30th day of composting, suggesting progressive breakdown of carbon molecules and conversion of ammonia to nitrate. The C/N ratio showed varying trends from the 30th to 50th day of the composting period due to the addition of stabilized spentwash, indicating the inclusion of additional carbonaceous matter and nitrogen.

Potassium

Potassium is a significant macronutrient in organic compost and its variations during the study are shown in Fig. 6. The initial potassium concentration of the raw pressmud was 0.83%, which is consistent with observation made by Zhang & Sun, (2017) and Bhat S.A. *et al*, (2017) (14,15). Addition of microbial consortium and stabilized spentwash have increased the Potassium concentration to 5.69±0.74% on the 10th day of composting. This initial rise in potassium content is due to the microbial mineralization of organic materials. Potassium decreased in all composting heaps from 10th to 20th day with a maximal reduction of 1.89±0.07% in CH2. Additionally, from the 20th to 30th day of composting, all composting piles demonstrated a rising tendency, with a minimum rise of 4.19±0.27% in CH1 and a maximum increase of 14.87±0.60% in CH3. These increases in potassium concentration are likely due to the inclusion of stabilized spentwash and the composting stages. Following that, potassium levels fluctuated consistently and increased in proportion to the addition of stabilized spentwash at the end of the composting period. The highest concentration of potassium was found in CH5 at 15.90±1.37%.

The analysis showed 2627 mg / l of potassium in the stabilized spentwash. The addition of this stabilized spentwash on the 10th day, in conjunction with the previously introduced microbial consortium, have resulted in an increase in potassium percentage. The reduction in potassium percentage from the 10th to the 20th day is attributable to vigorous breakdown of organic matter during the thermophilic phase of composting, which lasted 15 days in composting heaps. During this phase, potassium is used as a micronutrient to breakdown organic matter by microorganisms. The rise in potassium percentage between the 20th and 30th days and further variations are be attributed to potassium fixing during the mesophilic phase of composting.

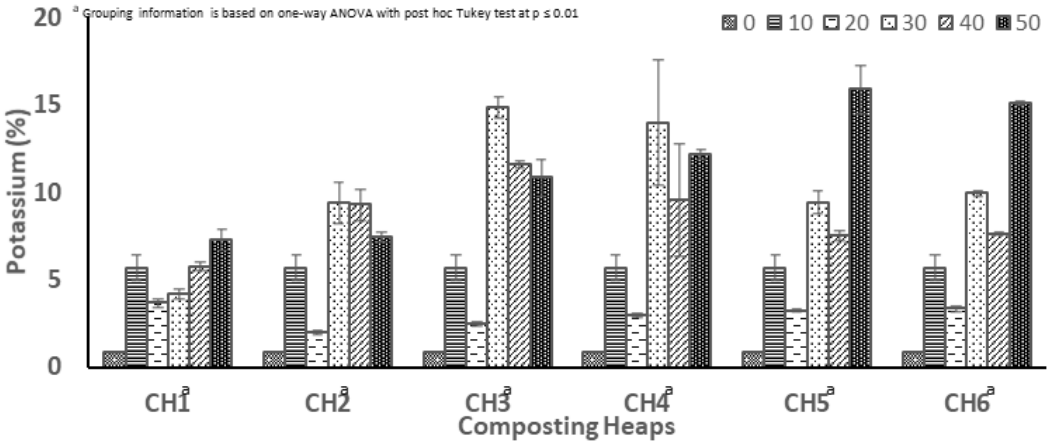


Figure 6. Variation of Potassium during aerobic composting process.

Phosphorus

Phosphorus is an essential macronutrient in the composted product and its variations during the composting process is shown in Fig. 7. The initial phosphorus content of raw pressmud was 1.30%, which is consistent with the findings of Satisha & Devarajan, (2007) (8). Addition of the microbial consortium and stabilized spentwash have increased the phosphorus percentages to 4.11±0.31% on the 10th day of composting. Phosphorus percentage increased again from the 10th to 20th day of composting, reaching a maximum of 6.30±0.42% in CH3. This rise is a result of microorganisms decomposing organic materials in conjunction with the addition of stabilized spentwash. During this time period, a thermophilic phase of composting existed, which enhanced phosphorus fixation. Additionally, from the 20th to 30th day of composting, all composting piles exhibited a reduction in phosphorus percentage, with a maximum reduction of 3.26±0.33% in CH6. This drop in phosphorous is a result of enzymatic reactions occurring during the mesophilic phase of composting process. Thereafter, the percentage of phosphorus in all composting heaps rose until the 50th day with maximum rise of 8.56±0.70% in CH1. This variations in phosphorus percentage is similar to the studies conducted by Bhat *et al.*, (2017) and Kumar *et al.*, (2010) (15,16).

Discussion

Aerobic composting of pressmud was conducted for 50 days, using varied amounts of stabilized spentwash and selected microbial consortium. The findings of this study were compared with the FCO (1), for determining the quality and suitability of produced compost material. Based on the findings of this study, it is clear that all composting heaps, including the control, exceeded the standards prescribed by FCO. The control for the study had a TOC concentration of 25.33±1.76%, TKN concentration of 1.13±0.29%, C/N ratio of 29.60±10.38, potassium concentration of 7.29±0.63%, and phosphorus concentration of 8.56±0.70%. This implies selected microbial consortium is capable of decomposing the complex organic matter present in pressmud. Furthermore, the results also suggest that the inclusion of stabilized spentwash in varied amounts shows consistent nutritional concentrations. A maximum dosage of 150% (CH5) stabilized spentwash is recommended, since any dosage over this reduces the nutritional value of the finished product.

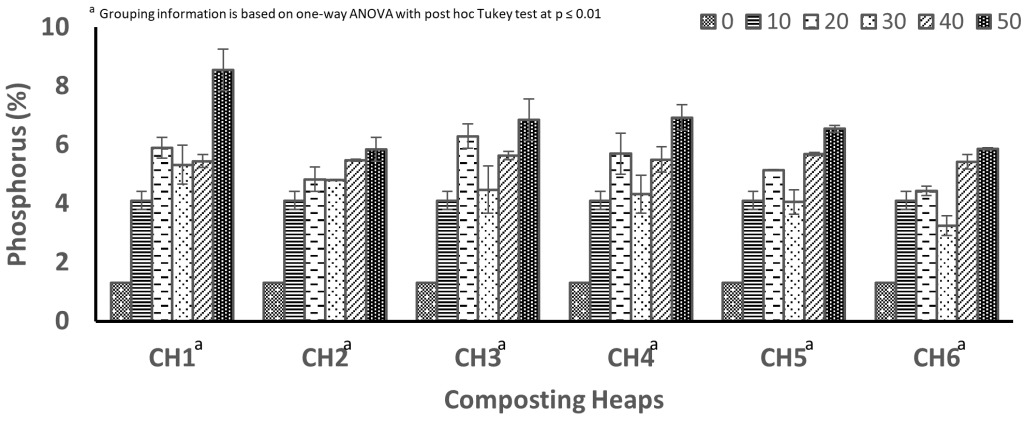


Figure 7. Variation of Phosphorous during aerobic composting process.

In the majority of the parameters examined, CH5 exhibited a maximum nutritional concentration. These maximum values include 25.92±2.19%, 2.16±0.29%, 15.90±1.37% TOC, TKN and potassium concentration respectively. Additionally, a minimum C/N ratio of 12.28±0.66 was detected in CH5, as well as a phosphorous concentration of 6.55±0.11%. This indicates inclusion of stabilized spentwash increased the nutritional content of the produced compost as compared to the control.

Conclusion

Sugar is a widely consumed food source and plays a significant role in economic development of the country. Pressmud is one of the by-products generated during the production of sugar. In India around 1 million tonnes of pressmud is generated on daily basis and safe disposal of this enormous quantity is a difficult task. Present study is a part of larger investigation for treatment and disposal of two of the complex by-products. Pressmud from sugar industry and spentwash from distillery are considered as base materials for the above said research work. The scope of this study is confined to the aerobic composting of pressmud in conjunction with stabilized spentwash and a selected microbial consortium. Aerobic composting was carried out in an open field with 50 kg of open dried pressmud and stabilized spentwash in various proportions. This has resulted in better nutrient concentration than the FCO-mandated standards (1). In organic compost, the FCO recommends a TOC of more than 12%, TKN of more than 0.80%, Phosphorus and Potassium of more than 0.40% and a C/N ratio of less than 20. Our investigations have shown a maximum concentration of TOC, TKN, Phosphorous and Potassium of 25.92±2.19%, 2.16±0.29%, 6.55±0.11% and 15.90±1.37% respectively in CH5. Additionally, a minimum C/N ratio of 12.28±0.66 was observed in CH5 with 150% addition of stabilized spentwash. This implies that aerobic composting in conjunction with the selected microbial consortium is capable of decomposing complex organic matter. Furthermore, the addition of stabilized spentwash at 150% (CH5) helped increase nutritional content in comparison with control. This also provides an opportunity to utilize stabilized spentwash as a disposal alternative and recycle its plant nutrients. It can be concluded that adding 150% (CH5) stabilized spentwash to pressmud optimises the aerobic composting process and results in a better final product with high nutritional content. Further, it is suggested to conduct studies on utilization of prepared compost material with commercially available organic compost to study the effect on yield of the crop.

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