Utilization Potential of Brewery Waste Water Sludge as an Organic Fertilizer

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ABSTRACT

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Brewery waste water sludge (BWS) is produced as the result of aerobic biological treatment of brewery effluent. Analysis of this waste material revealed that it contained valuable nutrients for plant growth with high water retention. Germination and plant growth trials were carried out with chili and pumpkin. The potential of applying sun dried brewery waste water sludge and admixing with two different types of compost were evaluated and outlined in this paper.

Key words: Brewery waste water sludge, compost, germination water retention.

INTRODUCTION

The brewing industry is one of the largest industrial users of water. Even though substantial technological improvements have been made in the past, it has been documented that approximately 3 to 10 litres of waste effluent is generated per litre of beer produced in breweries[3]. Brewery effluent is a waste material discharged to the drains. The high organic content of brewery effluent classifies it as a very high strength waste in terms of chemical oxygen demand, from 1000 mg/L to 4000 mg/L and biochemical oxygen demand of up to 1500 mg/L. The treatment of brewery waste water effluent is a costly affair for the brewer in order to meet the government regulations and to practice environmentally friendly manufacturing[8]. Biological treatment is widely applied and two treatment options are available. Generally, aerobic treatment has been applied for the treatment of brewery waste water and recently anaerobic systems have become an attractive option[5,6]. The aerobic treatment of brewery effluent requires a comparatively large energy input compared to anaerobic treatment. During the aerobic process, complex organic substances are completely oxidised to carbon dioxide, water, sulphate, phosphate and nitrate by a community of microorganisms dominated by heterotrophic bacteria (bacteria requiring organic compounds for their carbon energy source) and fungi. Furthermore, since it is an oxidative biological reaction, large amounts of biomass are produced which settle as sludge which requires further disposal. The common disposal route for brewery waste water sludge has been landfill. The treatment of organic solid waste is currently a growing area of investigation as new options, that substitute the conventional treatment system, are explored. Due to increasing environmental concerns and regulations, there have been attempts to utilize this brewery by product in an environmentally friendly manner[1,2,5–7,9,10]. In developing countries, non-utilization of by products is a drag on economic growth and businesses and the business community is increasingly recognizing the potential. This paper investigates the application of brewery waste water sludge (BWS) as an organic fertilizer in agriculture.

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MATERIALS AND METHODS

The BWS was sun dried to obtain dry substrate and seed germination and plant growth trials were conducted to evaluate the application of brewery waste water sludge as an organic fertilizer, both on its own and in combination with either compost-A (derived from municipal solid waste) or compost-B (derived from farm wastes).

Germination trials with pumpkin seeds

Dried BWS was mixed with different proportions of either compost-A or compost-B as described in Table I.

Three volumes of the above treatments or BWS or compost-A or compost-B were added to seven volumes of river sand and mixed thoroughly. These mixtures (400 g) were transferred into plastic cups (500 mL) with holes in the bottom surface and five seeds of pumpkin (East West Seeds International, Nonthaburi, Thailand) were sown into each cup. Six replicates were conducted for each type of treatment, waste water sludge, compost 'A' and compost 'B'. Each cup was watered with 40 mL of tap water per day and kept in an open area with sufficient sunlight for 24 days.

TABLE I. Proportion of compost and BWS in mixtures.

Treatment number	Compost (% by volume)	Brewery waste water sludge (% by volume)
1	90	10
2	80	20
3	70	30
4	50	50
5	20	80
6	10	90

Germination trials with chili seeds

Three volumes of the above treatments (mixture of BWS and compost B as shown in Table I) 2, 3, 4 or BWS or compost-B were added to seven volumes of river sand and mixed thoroughly. These mixtures (400 g) were transferred into plastic cups (500 mL) with holes in the bottom surface and five seeds of chili (Best Seeds Co. (Pvt) Ltd, Rajagiriya, Sri Lanka) were sown into each cup. Six replicates were conducted for each type of treatment, waste water sludge and compost 'B'. Each cup was watered with 40 mL of tap water per day and kept in an open area with sufficient sunlight for 69 days.

Plant growth field trials

A programme of comparative plant growth field trials using BWS, compost-A, compost-B and selected mixtures of BWS and both types of composts to evaluate the quality and growth promoting ability of the BWS was carried out. Beds (0.9 m × 3.2 m) were prepared at the brewery premises and the appropriate composts and BWS/compost mixtures were applied to the soil (500 g/square meter) and mixed thoroughly. Twelve chili seeds (Best Seeds Co. (Pvt) Ltd, Rajagiriya, Sri Lanka) were sown per bed, according to the recommended planting distance (60 cm 45 cm) of the department of Agriculture, Sri Lanka. On the forty seventh day and seventieth day 15 g and 50 g of appropriate composts and BWS/compost mixtures were applied per plant respectively. The beds were watered daily with same amount of tap water for 100 days.

Measurement of water retention capacity

Water retention, which is an important property for agricultural and horticultural applications of BWS was compared with compost 'A', compost 'B' and sand. Aliquots of 140 g of BWS or compost 'A', compost 'B' or sand were transferred into plastic cups (500 mL) with holes in the bottom surface. Tap water (500 mL) was added to each of the cups containing the relevant samples and the water was allowed to drain. The cups were kept at ambient temperature and weights were recorded on a daily basis until a constant weight was obtained. Five replicates were conducted for each type of sample.

Measurement of pH

One volume of sample (10 mL) was mixed with five volumes of distilled water (50 mL) and left for two hours at ambient temperature. The pH of this solution was measured with a digital pH meter (Jenway 3510, Essex, England).

Analysis of compost and brewery waste water sludge

Chemical and physical parameters were analysed using methods as described by Sri Lankan Standards Institution (Sri Lanka standard 1246:2003 UDC.628.477.4).

Dry weight measurement

Plants were removed carefully from the soil and the roots were washed thoroughly with tap water and dried at 105°C (WTC Binder-7200 Oven, Tuttlingen, Germany) until a constant weight was obtained. Chilies were also removed from the plants and the dry weights were determined as above.

Analysis of minerals and heavy metals

The mineral and heavy metal contents were determined as described by the Sri Lankan standards Institution (Sri Lanka standard 1246:2003 UDC.628.477.4).

RESULTS AND DISCUSSION

Sun dried BWS, composts A and B were analysed for both chemical and physical parameters. The availability of nutrients was determined. The results are summarised in Table II.

The pH of BWS was more towards neutral whereas both types of composts studied appeared to be alkali. Previous work by Luque *et al.*[7] demonstrated that the pH of BWS from three South American breweries varied from 6.5 to 11.5. This could be mainly due to differences of the raw water used and certain process variations in the waste water treatment plants. The organic carbon and total nitrogen content of BWS was higher than that of both composts derived from municipal wastes and farm yard wastes (Table II). It has been established that many ectomycorrhizal fungi can take up organic nutrients directly from soil and play vital symbiotic roles in plant nutrition and ecosystem functioning. Recent investigations reveal that these fungi lose their ability to grow and break down forms of organic nitrogen when exposed to elevated levels of inorganic nitrogen[4]. In addition composts prepared with BWS had the highest population of fungi and actinomycetes[2]. Thus BWS could be a better alternative for inorganic fertilizers in agricultural applications. The total phosphorous content of the BWS was almost the same as in farm yard compost. Furthermore, potassium and the micronutrients manganese, copper and zinc were low in BWS compared to the two types of composts studied. One of the main hurdles in the agricultural application of waste water sludge has been the presence of heavy metals

TABLE II. Analysis of dry BWS and composts A and B.

Parameter	BWS	Compost A	Compost B
Moisture (%)	10.70	13.20	15.83
pH	6.97	8.64	8.40
Volatile matter (%)	9.0	12.5	9.0
Organic carbon (%)	27.1	9.8	18.3
Total nitrogen (%)	4.5	1.1	1.6
Available nitrogen (%)	0.4	0.4	0.2
Total P (as P_2O_5) (%)	3.3	0.6	3.2
Citric acid soluble P (%)	1.4	0.4	1.6
Potassium as K_2O (%)	0.2	0.7	2.7
Manganese (mg/kg)	46	231	495
Magnesium (mg/kg)	1106	102	2813
Zinc (mg/kg)	75	272	100
Copper (mg/kg)	42	354	203

TABLE III. Analysis of heavy metals in dry BWS.

Metal	Concentration (mg/kg)
Mercury	Not detected (detection limit 0.02 mg/kg)
Cadmium	Not detected (detection limit 0.02 mg/kg)
Lead	2.9
Nickel	17

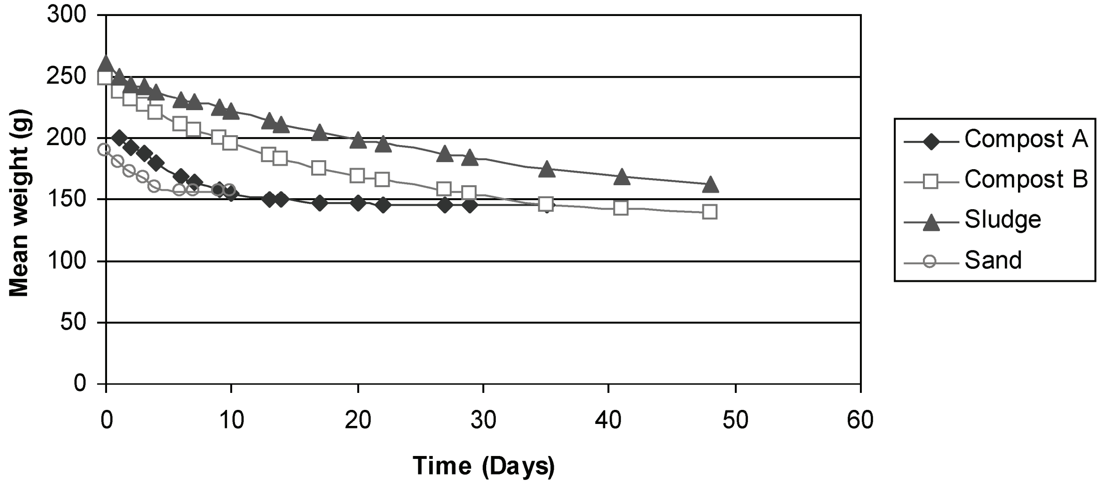

Fig. 1. Water retention over time.

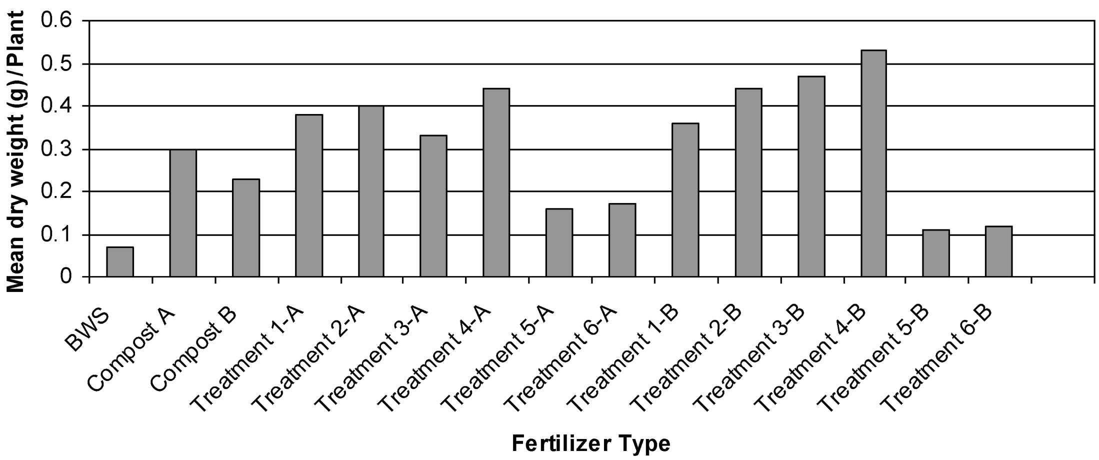

Fig. 2. Summary of results of pumpkin seed germination trials. (See Table I for treatment details.)

and the consequent toxic effects on crops and soil, and the leaching of heavy metals into nearby water sources. The analysis of selected heavy metals in BWS is tabulated in Table III. The results revealed that mercury and cadmium were well below the detection level and that lead and nickel were lower than expected in the Sri Lankan standards for organic fertilizer which are 250 mg/Kg and 100 mg/Kg respectively.

Water retention is a valuable property and important in soil for releasing the humidity to the plants as needed. Thus water retention of BWS was compared with both types of composts and sand. During a period of fifty days, BWS demonstrated the highest water retention capacity followed by Compost B and compost A (Fig. 1). This property of BWS has been linked to the high content of organic matter, the high cationic exchange capacity and other nutrients as documented by Luque *et al*[7].

Germination studies of pumpkin and chili seeds were performed to compare and evaluate BWS and mixtures of BWS and both types of composts at different proportions. The mean dry weights of pumpkin and chili plants are shown in Figs. 2 and 3 respectively. This investigation demonstrated that the pumpkin seeds sown in combinations of BWS and composts showed elevated growth compared to the ones on BWS or composts alone (Fig. 2). Furthermore dry weight increased with increasing proportions of BWS up to 50% by volume (Fig. 2 and Table I). Further increases in the content of BWS in the fertilizer mixture resulted in the reduction of dry weights of pumpkin plants. Addition of 50% BWS by volume to compost A and compost B resulted in 47% and 130% elevations in dry weights respectively compared to the plants germinated on the corresponding composts alone. Pumpkin plants germinated on compost B and mixtures of BWS and compost B appeared to be healthier than those germinated on compost A and mixtures of BWS and compost A. Based on the outcome of the pumpkin study, chili germination trials were performed using compost B and selected mixtures of compost B and BWS (20%, 30% and 50% by volume). The overall observations were similar to what was observed in the pumpkin study. Optimal dry biomass accumulation was obtained for the treatment containing 30% BWS by volume (Fig. 3 and Table I). Addition of 30% BWS resulted in a 155% elevation in dry biomass in chili plants compared to the ones germinated on compost B alone.

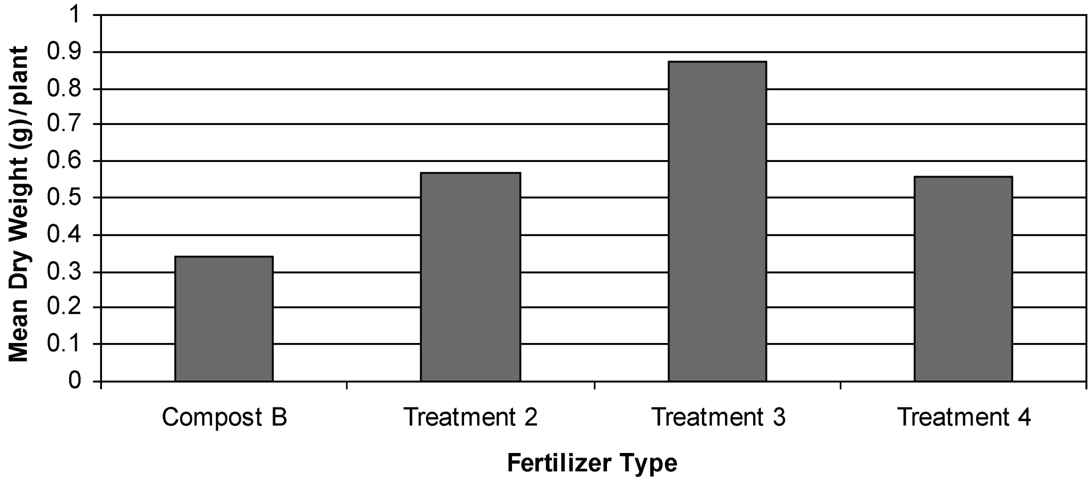

Fig. 3. Summary of results of chili seed germination trials using compost B and mixtures of compost B and 20%, 30% and 50% by volume BWS as treatment 2, 3 and 4 respectively.

The dry biomass of pumpkin plants germinated on compost B and a mixture of 50% BWS and 50% compost were analysed for selected nutrients. It can be seen that the percentage of nitrogen incorporated in the plant tissue was almost double in plants germinated on the mixture (Table IV), whereas organic carbon content was almost the same for both fertilizers. Even though the BWS contain low potassium, it is evident that comparatively more potassium uptake has occurred in the plants germinated on the mixture (Table II and IV). Availability of nitrogen from BWS may have enhanced the microbial activity of the compost, aiding more of its uptake.

Field trials were performed with chili to study the feasibility of direct application of BWS as fertilizer. The field growth trials with chili plants revealed that the plants cultivated on beds applied with BWS gave the highest mean dry weight per plant (Table V). Furthermore the addition of BWS (50% by volume) to both types of composts improved plant growth in terms dry weight (Table V). The above mean dry weight observations were similar to what was noted during germination trials with chili seeds (Fig. 2). The results for the mean height of the plants also demonstrated similar trends as for dry weight. Inclusion of BWS elevated the mean dry weight of chili plants by 74% and 16% for compost A and compost B respectively during the field trial.

The highest number of chilies produced per plant was also observed for plants cultivated with BWS alone (Table VI). Addition of BWS to compost A had a positive effect on both number of chilies per plant as well as mean dry weight per chili (Table VI). Addition of BWS to compost B did not demonstrate any significant improvements in these parameters. Previous work by Luque *at al.*[7] also demonstrated a significant correlation between the applied dose of BWS and yields in corn, sorghum and peanuts grown on test areas. Furthermore investigations by Craft and Nelson[2] revealed that compost made with BWS was suppressive against seedling and root diseases caused by the fungus *Pythium graminicola.* The analysis of selected content of nutrients in chili plants cultivated with BWS alone was almost the same as with the two types of composts studied or the mixtures containing BWS (Table VII). The overall findings demonstrated that BWS on its own can also be utilized as a fertilizer in addition to an admix for composts.

TABLE IV. Comparison of nutritional content of pumpkin plants.

Parameter	Compost B	Treatment 4-B (50% of compost B and 50% of BWS)
Organic carbon (%)	43.7	43.9
Total nitrogen (%)	1.8	3.3
Potassium as K_2O (%)	7.5	10.4
Magnesium as MgO (%)	1.6	0.5
Calcium as CaO (%)	1.1	0.2

CONCLUSIONS

The results presented in this work have shown that BWS can be a valuable source of nutrients for plants. Sun dried BWS can be applied directly to promote plant growth

TABLE V. Growth of chili plants during field trials.

Fertilizer type	Mean height of plant (cm)	Mean dry weight of plant (g)
BWS	29.33^{A}	7.89^{a}
Compost A	17.25^{B}	2.27^{c}
Compost B	25.40^{A}	4.93^{abc}
50% BWS and 50% compost A	26.60^{A}	4.08^{bc}
50% BWS and 50% compost B	32.10^{A}	5.72^{ab}

Means were compared using Duncan's multiple range test. Means with same letter are not significantly different.

TABLE VI. Yield of chilies during field trials.

Fertilizer type	Mean number of chilies per plant	Mean dry weight of chilies (g)
BWS	19.4^{A}	1.94^{ab}
Compost A	4.4^{B}	0.58^{c}
Compost B	13.3^{A}	2.40^{a}
50% BWS and 50% compost A	15.8^{A}	2.70^{a}
50% BWS and 50% compost B	10.6^{AB}	1.32^{bc}

Means were compared using Duncan's multiple range test. Means with same letter are not significantly different.

TABLE VII. Comparison of nutritional content of chili plants cultivated in field trials.

Parameter	BWS	Compost A	Compost B	50% BWS and 50% compost A	50%BWS and 50% compost B
Organic carbon (%)	44.2	45.8	45.0	49.1	44.2
Total nitrogen (%)	2.8	2.9	2.9	1.8	3.2
Total phosphorous as P_2O_5 (%)	0.3	0.4	0.5	0.4	0.4
Potassium as K_2O (%)	3.6	4.3	4.0	3.5	3.5
Magnesium as MgO (%)	0.2	0.2	0.2	0.1	0.1
Calcium as CaO (%)	2.3	1.8	1.8	2.0	1.9

or in combination with mature compost. Furthermore, the selected heavy metal content was far below the recommended levels in Sri Lanka. This work also revealed that co-composting with BWS is not required, saving time and energy. Sun drying the BWS for agricultural application is more economical than flocculating and centrifuging as outlined by Stocks and co workers.[9] Agriculture dependent developing countries such as Sri Lanka rely mainly on imported inorganic chemical fertilizers and thus byproducts such as BWS could play a role in the development of the economy in an environmentally friendly manner.

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