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ORIGINAL RESEARCH

Cotton spinning waste as useful compost for organic Indian Spinach (*Basella alba*) production in Bangladesh

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Abstract

Purpose This study aims to ascertain the physiochemical characteristics of the compost made from recycled cotton spinning waste (CSW) for Indian Spinach cultivation in Bangladesh.

Method The physiochemical characteristics of the compost made of fresh cotton spinning waste (CSW), cotton spinning waste ash (CSWA), rice husk (RH), rice husk ash (RHA) with varying ratios following open air composting method was determined. The utility of the resulting compost was justified by applying it to Indian Spinach cultivation compared with chemical fertilizer and control (no-compost) treatments.

Results Among the several composting options, the compost prepared by mixing 87% CSW + 13% CSW ash (C3) and 87% CSW + 13% rice husk (C4) was found to be the quality compost with a higher C/N ratio, P, K, S and a lower Pb content. The vegetative growth, yield and nutritional qualities were significantly affected by the compost characteristics compared to chemical fertilizer because of increased nutrient uptake and biostimulation functions. Moreover, Indian Spinach cultivated with CSW compost provided 64 BDTk. profits compared to 28 BDTk. in case of control that indicates 128% increase in profit for the compost than that of control.

Conclusion The compost derived from the mixture of CSW+CSWA+RH+RHA substrates possesses an optimum moisture content (31.2%), pH (7.5), C/N ratio (16.8:1), macronutrients, and micronutrients that enable it to act as an alternative to chemical fertilizer. When it comes to yield and nutrition quality of the grown Indian Spinach, CSW based compost fared much better than chemical fertilizer in field test.

Keywords *Basella alba*, Compost, Cotton waste, Heavy metals, Plant nutrients, Yield

Introduction

Bangladesh is predominantly dependent on agriculture where the industrial sector has been flourishing over the last three decades and both sectors are equally important towards improving the base of its national economy (Khan 2013). The textile spinning is the main backward-linkage industry which produces the main raw material (yarn) to support the textile sector. Currently, there are 425 textile spinning mills in Bangladesh where about 2.5 billion kg of yarn and 0.361 million tons of cotton spinning waste are generated annually (GAIN 2018; Samsami et al. 2020, Islam et al. 2021a). Many types of waste that include broken fibers, fragments of cotton seeds, fine fly fibers and particulates are produced during the production of yarn in cotton spinning mills. It is reported that the lion shares of cotton spinning waste (CSW) is micro dust which comprises 50-80% fibers, leaf and husk fragments, 10-25 % sand, and 10-25 % water-soluble materials (Kumar 2008; Rahman et al. 2019; Yousef et al. 2020). Devi and Natarajan (2008) found that the wastes from the cotton ginning processing are rich in minerals, tricar-

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boxyalic acids, proteins. This finding inspired us to assume that a good quality compost from such waste could be developed by using an appropriate disposing treatment.

Agriculture is another driving force for boosting the economy of Bangladesh that currently faces the challenges of feeding a huge population with limited land resources like many other countries in the world due to shrinking land resources, rapid industrialization, increasing urbanization, repeated farming, an extreme use of chemical fertilizer and pesticide as well as reduced valuable soil microbes (Rahman et al. 2020; Phalan et al. 2014; Saha et al. 2017). Thus, a sustainable agricultural practice is desirable for food security and livelihood improvement of the country (Frison et al. 2011; Shahat et al. 2018; Pradhan et al. 2015). Nowadays a greater attention is paid towards addressing the environmental, anthropogenic, and technological advancement responsible for declining agricultural sustainability (Pretty and Bharucha 2014; Znad et al. 2018). Therefore, developing a connection between a balanced form of industrial solid waste management and a sustainable crop productivity through an integrated approach could offer an acceptable solution to achieve agricultural sustainability.

However, currently a huge amount of non-saleable CSW is just disposed of as landfills, which contributes to environmental degradation with the production of highly polluting leachate and methane (Puppim 2019; Khandaker et al. 2021). Apart from this, uncontrolled decomposition of such biodegradable waste may have a serious risk to accumulate not only heavy metals (like Ni, Zn, Pb, Hg, Cd, Cr) in the food chain but also hazardous organic contaminants in the environment (Sharma et al. 2018). Moreover, open burning of CSW being an alternative approach to volume reduction is frequently performed which consequently contributes to carbon dioxide emission responsible for global warming (Zacharia and Krishnan 2003; Awual and Hasan 2014). In addition, particulates and smokes are generated due to incineration may cause respiratory diseases (Memon et al. 2008). In Bangladesh, till now textile spinning industries are facing a challenge of finding a sustainable waste management system for this organic based CSW. Unfortunately, CSW is not economically valuable due to the lack of attractive meaningful uses and thus, it is just a burden to the industries. Therefore, the CSW management following aforementioned disposal methods (open dumping and open burning) not only lead to dangerous consequences on the environment but also on human health while its available beneficial organic nutrients remain untapped (Khandaker et al. 2020; Awual et al. 2020; Yadav and Garg 2011). Under this circumstance, finding an alternative sustainable and economical waste disposal system is highly sought after for CSW management.

Considering these aspects, converting CSW into a low-cost compost by an appropriate method and its subsequent application in the improvement of soil health and crop productivity is obviously a lucrative alternative approach to a sustainable solid waste management. It is well evident in the previous studies that the organic waste would be a suitable substitute for chemical fertilizer for use in agricultural field by recycling as compost (Islam et al. 2021b; Arshad et al. 2017; Hait and Tare 2012). Moreover, this compost can contribute to improved soil nutrient profile, structure and reduced soil erosion, climate change mitigation due to reduction of GHG (greenhouse gas) released from waste decomposition in open dumps and protection of land resources because of reducing the quantity of land filling waste (Rivera et al. 2020; Rani et al. 2020; Alam et al. 2019). However, not much is known to date about any systematic approach to CSW management through converting it into an economic resource in Bangladesh.

Aishwariya and Amsamani (2012) reported that vermicompost prepared after pretreatment of the cotton textile waste proved as a better alternative to chemical fertilizer with a sufficient supply of carbon and considerable amount of nitrogen, phosphorous, and potassium, (N, P and K). Furthermore, with the addition of cellulose degraders, nitrogen fixers and phosphate stabilizers, the compost can be transformed into a very worthy source of biofertiliser. In these contexts, it has been hypothesized whether the composting of CSW would be a valuable resource rather than an unproductive land filling or incineration by maximizing its benefits. Therefore, the present study was designed to sort out the physiochemical characteristics of CSW for suitability analysis for its conversion into a compost. Afterwards, the usefulness of CSW derived compost was established by its field evaluation in Indian Spinach cultivation. Indian Spinach (*Basella alba*) is one of the most popular leafy vegetables and widely cultivated in almost round the year (Basunia et al. 2020). Due to its short lifespan, rapid growing ability with minimum nutrient and repeated harvesting features have made it attractive for selecting efficacy study of CSW composts. This study is focused on the investigation of the possibility of CSW to be recycled as a compost for application in vegetable cultivation.

Materials and methods

Research design

This study is conducted in two stages. In stage-I, fresh samples of composting raw materials containing cotton spinning waste (CSW), cotton spinning waste ash (CSWA), rice husk (RH), rice husk ash (RHA) and CSW based compost after composting were analyzed for their pH, total carbon content, total kjeldahl nitrogen, C/N ratio, organic matter content as mass balance estimation, phosphorus, potassium and heavy metals content. In stage-II, CSW alone and mixed with other substrates (CSW ash, rice husk, rice husk ash) derived composts were applied for Indian Spinach (as test crop) cultivation to evaluate their feasibility in agriculture application compared to recommended doses of chemical fertilizer (RDCF) and control condition.

The fresh CSW was collected in clean plastic bags from Matin Spinning Mills Ltd, Gazipur, Bangladesh. The physical appearance of the fresh CSW is off-white color with small flocks. The obtained waste was opened manually and checked for any metals, particles or other undesired materials. Then, the CSW was properly sun dried prior to being transferred to a wide plastic bag to preserve for further use in chemical analysis and composting. The samples were manually chopped into 30 mm-long pieces using a grinder and dried in an oven at 65 °C until constant weight. Next, the oven dried samples were ground and subjected to physiochemical analysis. The rice husk (RH), a co-digesting substance was collected from the local rice processing mill nearby the experimental site and was also chopped using grinder to make samples for physiochemical analysis. The cotton spinning waste ash and rice husk ash were prepared in open air burning process of CSW and RH. Before starting the composting study, the predetermined physicochemical attributes of the fresh composting substances were analyzed as shown in Table 1.

ll the raw materials being proportionately mixed with the aid of a mechanical stainless still loader were homogenized in a plastic drum for 30 min just before the start of the composting process. The selection of proportion of materials was made on the basis of the preliminary laboratory assessment following the guidelines of Richards (2014). The different mixtures of co-digesting substances are illustrated in Table 2 with the respective composts labels along with initial optimum moisture content (%), carbon-to-nitrogen ratio (C/N ratio) and pH. At the early stage, the moisture level was maintained approximately 40-50% by either removing extra moisture from the waste by drying or addition of the water as per requirement. The moisture level of each composting pile was checked throughout the composting process at 5-day interval and water was sprayed (if necessary) to ensure optimum moisture condition at the early stage of mixture-homogenizing process of composting (initially water was added at 5, 10, 15 days of composting up to first turning the pile, and subsequently it was done after every turning). Total four turning frequencies were applied to the compost windrows pile: first, second, third and fourth turning were done at 15, 30, 45 and 60 days of composting, respectively.

Compost piles were manually turned with a mechanical loader. The study was conducted for 60 days, from November 10 to December 10, 2019 for composting. So, total two turnings were done at 40 days of composting, three at 50 and four at 60 days of composting. Here, a 3-day interval of 40, 50 and 60 days of composting were classified representing the mesophilic, thermophilic and cooling phase according to the temperature profile of the composting pile. The ambient temperature and the temperature within each pile was measured on daily basis before turning using a digital thermometer probe (± 1°C) by inserting it up to 50 cm depth from the top side of the pile. It was done between 8:00 and 10:00 a.m. when the ambient temperature was stable. Each temperature reading denotes the mean values of three piles of each of the five different composts in a compost windrow. The initial C/N ratio was maintained between 25:1 and 35:1 while pH was close to 7, which are considered suitable for composting biodegradable waste (Day and Shaw 2001). The test for physiochemical characteristics of the fresh CSW and CSW based compost samples was done according to CRD (completely randomized design) and repeated for three times.

Table 1 Physiochemical characteristics of raw CSW, CSWA, RH and RHA

Physiochemical Properties	Test results			
	CSW	CSWA	RH	RHA
Physical condition	Cotton Fiber	Burning of CSW	Outer layer of grain	Burning of RH
Colour	Off white	Off white ash	Brown	Silver ash
Moisture content (%)	13.7	5.4	11.8	8.7
pH	7.6	6.5	5.4	6.2
OC %	21.6	7.2	42.0	3.4
N %	1.09	0.5	1.1	2.2
C: N	20:1	14:1	38:1	2:1
P %	1.32	0.7	1.1	0.4
K %	1.25	0.9	3.8	2.3
S %	1.04	0.1	0.8	0.3
Cu (mg Kg^{-1})	0.78	0.4	1.7	1.4
Zn (mg Kg^{-1})	10.51	4.6	8.1	2.5
Pb (mg Kg^{-1})	0.73	0.07	0.03	0.01
Cd (mg Kg^{-1})	1.02	0.03	0.03	0.02
Cr (mg Kg^{-1})	0.35	Nil	0.04	0.02
Ni (mg Kg^{-1})	Nil	Nil	Nil	Nil

Table 2 Ratios of the different co-digesting substances of compost and their initial moisture content (MC, %), pH, and C/N ratio

Treatments ^{z}	CSW ^{y}	CSWA	RH	RHA	MC (%) ^{x}	pH	C/N ratio
C_1	83%	7%	7%	3%	58	8.29	33
C_2	100%	-	-	-	53	7.14	28
C_3	87%	13%	-	-	54	7.51	30
C_4	87%	-	13%	-	57	7.92	32
C_5	90%	-	-	10%	56	7.85	32

^{y} Additive components as CSW = Cotton spinning waste, CSWA = cotton spinning waste ash, RH = rice husk, RHA = rice husk ash.

^{z} C1= CSW + CSWA + RH + RHA; C2= only CSW; C3= CSW + CSWA; C4= CSW + RH; C5= CSW + RHA.

^{x} MC (%) at initial stage was maintained same as 50% for all the composts sample, however 15 days after composting and first turning regime showed the variations among the composts.

Composting process

The composting was conducted inside the Dhaka University of Engineering and Technology (DUET), Gazipur Bangladesh using the traditional open air (aerobic) windrow composting method. This method is used due to its low cost, ease of handling, and high quality of the final product (Estevez-Schwarz et al. 2012). The size of each composting pile was 60 cm×60 cm× 60 cm. The longitudinal and transverse free space between the two piles were 45 cm and 60 cm, respectively, to prevent moisture absorption and better handling. A polythene sheet was used on the bottom of the piles that were compacted using some aggregates to prevent loss of leachates. Three piles were used for each compost sample designated three replications. The total amount of each experimental compost sample was 1500 kg comprising 5kg of each compost per treatment per replication. There were five composting treatments and each treatment has three replications. The treatment variables were indicated as C1, C2, C3, C4, and C5 and each contained a mixture of 5 kg sample of air-dried CSW, CSWA, RH and RHA at various amount. Each compost sample with their initial properties being used in each composting pile is illustrated in Table 1. After being homogeneously mixed in a drum, the raw material was placed in composting piles according to the respective treatments and replications. Then, a shade was constructed using GI sheets as roof material to cover the composting area to prevent rainwater while both sides were kept open for free access of air. The composting procedure is illustrated in Fig. 1.

Three replicate samples of each compost were taken from the five different locations of respective piles at the beginning and also at the end of composting to analyze the variance of different treatments. Each reading denotes the mean value of five randomly selected locations in each pile. Subsequently, for analysis purpose, one composite sample (1000 g) was prepared after compiling five subsamples of different locations (200 g of each subsample). This composite pile was divided into two equal groups and the moisture content (MC) and pH value were determined directly using one group. The rest of this composite pile was used for the estimation of total Kjeldahl nitrogen (N), organic carbon (OC), phosphorus (P), potassium (K) and heavy metals content after air drying, crushing by a grinder and screening using sieve (0.25 mm). The analyzed value was reported as the mean value of the three observations representing the three replications of each sample. The reduction of organic matter (OM), hereafter being denoted as mass loss during composting, was calculated after determining the mass volume of each pile at the initial and final stage of composting.

The extent of compost maturity and stability was assessed using the parameters like pH, organic matter content (%), carbon nitrogen (C/N) ratio and application in crop cultivation. The compost phytotoxicity was measured after evaluation of the effects of CSW derived compost on growth, yield and nutritional qualities of Indian Spinach cultivation.

Determination of moisture content

The moisture content at the initial stage is maintained between 40-50% according to the recommendation of Day and Shaw (2001). The moisture content of each pile was estimated in the laboratory by taking 10g of sample in porcelain dish from each of the composting types (C1-C5) followed by oven-drying at 105˚C for 48 h. The sample was weighed again and moisture content was calculated by dividing the readings of the reduction in weight from initial weight (Xu et al. 2020).

$$Mn = \frac{(Ww - Wd)}{Wd} \times 100 \quad (1)$$

In which:

Mn = moisture content (%) of material n
Ww = wet weight of the sample, and
Wd = weight of the sample after drying

Fig. 1 Different steps in cotton spinning waste (CSW) composting process

(A): Fresh CSW collection; (B): Open-air burning of CSW for cotton spinning waste ash (CSWA) production; (C): Fresh rice husk (RH) collection; (D): Open-air burning of RH for rice husk ash (RHA) production; (E): Composting piles preparation under a shade of aerobic windrow composting process; (F): Weighing the co-digesting substances used different compost combination; (G): Composting raw materials proportionately mixed and homogenized in a plastic drum; (H): Compost mixture placed in a prepared pile with strong polythene sheet at the bottom of the pile.

In order to determine when water should be added in the composting process, a field method of moisture testing was followed (Estevez-Schwarz et al. 2012). Briefly, a small sample of compost was squeezed by hand at 10-day interval during the 2 months of composting period. If it maintained its shape even after release from the squeezed condition, then it was assumed to contain around 50% moisture whereas if it disaggregated slowly on release, it was assumed to have around 40% moisture and water needed to be added for further enhancement of the composting. If the mixture released drops of water, it was considered to be highly moist and did not need any extra water.

Chemical properties analysis

Individual compost sample was collected for chemical properties analysis. pH was determined using a glass electrode pH meter (Ronaldo et al. 2008). The total carbon in the compost was determined by following the proposed method of Getahun et al. (2012). The Kjeldahl digestion method was followed to estimate the total nitrogen and phosphorous content (John 1970, Bremmer and Mulvaney 1982). Potassium (K) was quantified using flame photometer by Direct Feeding method (Goyal and Sindhu 2011).

Heavy metal analysis

The total contents of heavy metals of cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) were analyzed as potentially toxic elements available in the CSW derived compost samples. Before heavy metal analysis, the samples were digested following the method described previously (Hseu 2004). For digestion, 5.0g of sample was dried in an oven at 65°C for 24 h. The dried sample was ground and mixed with 2.5 mL and 7.5 mL concentrated nitric (HNO_3) and hydrochloric acid (HCl), respectively. Then the sample was kept into a 500 mL volumetric flask for overnight. The sample was then boiled for 2 h and added water to make 500 mL. After 5 min stirring, the component was cooled down and filtered using membrane filter paper. The filtrate was stored and the Cd, Cr, Cu, Ni, Pb and Zn were analyzed using an atomic adsorption spectrometer (AAS) (AA-7000, SHIMADZU, Japan).

Field evaluation of CSW based compost for Indian Spinach cultivation

Indian Spinach (*Basella alba*) was cultivated in the research field of Bangladesh Agriculture Research Institute (BARI 2018), Gazipur, Bangladesh during winter season from October 2019 to February 2020. The treatments consisted of T_1 as control (without compost/fertilizer), T_2 for recommended doses of chemical fertilizer (RDCF) and treatments T3, T4, T5, T6 and T7 were denoted as five different composts of C1, C2, C3, C4 and C5. The experiment was laid by following randomized complete block design (RCBD) maintaining three replications. A 30m×10m plot was divided into 21 small sub-plots (1.5 m × 2 m) for 7 treatments with 3 replications of each treatment having a plot-to-plot distance of 30 cm. The required RDCF ($N_{70}P_{20}K_{20}S_8Zn_2B_1$) was calculated (129.32g) for designated following the RDCF and applying rules (1.0 ton per hector) of BARI (2018). On the other hand, the required amount of each type of CSW composts was calculated (900g) for each selected plot according to the cow dung compost applying rules (3 tons per hector) of BARI (2018). Proper supervision was maintained to ensure growth of the plants in different plots by required watering and cultural management as per requirement.

Growth and yield of Indian Spinach

As per Indian spinach growth observation strategies, the height and number of leaves were counted at 21, 28, 35, 42 and 50 days after plantation. 1.0 m^2 area was marked by a steel frame in the middle of each experiment unit and all the required study samples were collected from inside the marked area after 50 days of cultivation. The harvested Indian spinach was measured immediately by a balance to calculate the yield of spinach. Then the harvested spinaches were collected in poly bag for nutrient analysis.

Determination of nutritions in spinach

Ascorbic acid, beta-carotene and calcium were determined to investigate the food value of Indian Spinach grown by the different treatments. Fresh leaves from the different Indian Spinach samples were collected and the above mentioned nutrients were determined following standard methods.

Ascorbic acid

Ascorbic acid was determined by the methods described by Keller and Schwager (1977). Briefly, 10 mL of the Indian Spinach extract was taken in a conical flask and the extract was passed through cations exchange column. Then, 5 mL of potassium iodide (KI) and 2 mL of glacial acetic acid were added to the extract. Finally, it was titrated with 0.001N KIO_3 solution. Afterwards, total ascorbic acid was calculated using the following formula:

Total ascorbic acid content (mg/100 g) $= \frac{TFV}{Wv} \times 100$ (2)

Where, T= Titrated volume of KIO_3 (mL), F=0.088 mg of ascorbic acid per ml of 0.001N $KIO_{3,}$
v= Volume of the extract (mL) taken for titration, W=-weight of sample taken (g), V= Total volume of sample extracted (mL).

β-Carotene

β-carotene pigments (known as naturally occurring pro-vitamin-A carotenoids) were extracted by 80% acetone and estimated according to the methods of Maclachlan and Zalik (1963) and hereafter being mentioned as Vitamin-A content (mg/100g). Initially, 2 g of Indian Spinach pulp was taken in a flask and 20 mL of acetone-hexane solution was mixed homogeneously. The sample was centrifuged. Next, the optical density was measured using UV2100 spectrophotometer at 663 nm, 645 nm, 505 nm and 453 nm. The amount of β-carotene in Indian Spinach was determined using the following formula (mg/100g on weight basis):

β- Carotene = 0.216 (OD663) + 0.452(OD453)-1.22(OD645) - 0.304(OD505) (3)

Where, OD663= Optical density at 663nm wave length, OD453= Optical density at 453nm wave length, OD645= Optical density at 645nm wave length, and OD505= Optical density at 505nm wave length.

Calcium (Ca)

For calcium determination, 5 g of Indian Spinach sample was taken and dried into an air circulated oven at 65°C for 24 h. The dried sample was crushed using a grinder to make powder. Then 2.5 mL of concentrated HNO_3 and 7.5mL of HCl was added to 5 g of powdered sample and then it was transferred to a 500 mL volumetric flask. The sample was kept into the flask overnight and after that it was heated to boiling for 2 h. Next, it was made 500 ml after dilution with distilled water. The contents of the flask were stirred for 5 m and allowed to cool down. Finally, the specimen was filtered by a filter paper. The filtrate was stored in a sample bottle for further laboratory analysis. The AAS was calibrated with a standard solution of calcium. Then, a calibration curve was prepared by the series of standard solution 0.2, 0.5, 1, 2, 5, and 10%. AAS readings of each standard solution and Indian Spinach extracts were recorded at the desired wavelength.

Profit of Indian Spinach cultivation using composts

The gross return, total variable cost and gross margin were used as the means of profit analysis when Indian Spinach cultivated using CSW derived composts compared to chemical fertilizer and control (without fertilization). These findings illustrate how CSW compost can lead to economic benefits in comparison with chemical fertilizer or without any fertilizer. The following parameters were generated to calculate the gross margin (profit) from the following equations:

$$Gross\ return\ (TK) = Yield\ (g) \times Market\ price\ of\ the\ products\ (Tk/g) \quad (4)$$

$$Total\ production\ cost\ (TK) = (Variable + Non-variable\ cost) \quad (5)$$

Where, variable cost included as: (DAM 2020)
Seed price= 25TK Kg^{-1}
Crop harvesting cost= 1.33 TK m^{-2}
Chemical fertilizer cost= 1200 TK kg^{-1}
Composts price= 9.85Tk Kg^{-1}
Non-variable cost included as:
Land preparation and labor cost= 1.22Tk m^{-2}

Where,
Land preparation cost per m^2= 1.22 TK
Seed price of 4 g m^{-2}= 0.10 TK
Recommended doses of chemical fertilizers price of 30.18 g m^{-2}= 36.21 TK
Composts price of 300 g m^{-2}= 2.96 TK
Harvesting cost per m^2= 1.33 TK

Where,
Land preparation cost per m^2= 1.22 TK
Seed price of 4 g m^{-2}= 0.10 TK

Recommended doses of chemical fertilizers price of 43.10 g m^{-2}= 51.73 TK
Harvesting cost per m^2= 1.33 TK

Where,
Land preparation cost per m^2= 1.22 TK
Seed price of 4 g m^{-2}= 0.10 TK

$$Profit\ (TK) = (Gross\ return - Total\ production\ cost) \quad (6)$$

[NB: TK- stands for Taka, the Bangladeshi currency, which is 85 TK equivalents to 1.0 US dollar]

Statistical analyses

The field study of composts application in Indian Spinach cultivation followed randomized complete block design (RCBD) with three replications. Data were expressed as the means ± standard deviations of the triplicate measurements. Differences between mean values were examined by one-way analysis of variance (ANOVA), and statistical significance was assumed at a level of $P<0.05$. Further mean separation of the treatments was done using HSD test. All the recorded data were analyzed using R-software program (version 4.0.2). Graphical presentation of different physical, chemical and biological study parameters was also statistically interfaced using Origin software with error bars.

Results and discussion

Physiochemical characteristics of raw materials used in composting

Characteristics of CSW used as the main feedstock are important parameters in designing and operating aerobic composting (Table 1). The initial pH of CSW was 7.6 that belong to the optimum pH required for aerobic digestion (6.5-8) (Haider et al. 2015). The initial moisture content%, organic carbon% and C/N ratio of CSW was found as 13.7, 21.6 and 20:1, respectively. CSW contains almost similar amount (1%) of macronutrients like N, P, K, S while as micronutrient Zn was in higher amount (10.6 mg/kg). The present findings of CSW characteristics were consisted with Munendra et al. (2014) and Shilev et al. (2003) reported chemical properties of cotton dust based composts. Generally, the C/N ratio is desired to be about 30:1 as an indication for successful composting (Shilev et. al. 2003). In our study, the C/N ratio of CSW was 19:1 which is within the standard limit that revealed feasibility of using the CSW as composting feedstock. On the other hand, the range of pH between 5.5 and 8.5 is considered the optimal for decomposing microorganisms in composting process (Shilev et al. 2003). When the bacteria and fungi digest organic matter, they release organic acids. As the pH decreases during composting, the growth of fungi increases which facilitates the decomposition of lignin and cellulose. If the system becomes anaerobic, the acid accumulation can lower the pH to 4.5, thus limiting the microbial activity (Shilev et al. 2003). As in this study, we followed the open air composting method, therefore, the pH of the final compost did not reach the unacceptable ranges.

Besides CSW, other substrates like CSWA, RH and RHA used in this study were also individually analyzed for their initial physicochemical characteristics (Table 1**)**. The moisture content (MC) (%) of CSWA, RH and RHA revealed that the highest MC was in RH (11.8%) followed by RHA (8.7%) and the lowest in CSWA (5.4%). The highest moisture reduction tendency was observed in CSWA and RHA might be due to the burning of CSW and RH for their ash sample preparation. pH value of CSW, RH and RHA was found as 6.5, 5.4 and 6.2, respectively and those are within the standard limit of composting (Estevez-Schwarz et al. 2012). The maximum C: N ratio was noticed in RH (38:1) that dramatically reduced to 2:1 in RHA while CSWA had 14:1 that was also reduced to their fresh CSW (20:1). These findings were in good agreement with Estevez-Schwarz et al. (2012) where they postulated that the highest C/N ratio would lead to less oxidation and improved compost quality because of high carbon content compared to low nitrogen.

Characteristics of CSW and in combination with other co-digesting substances derived composts Composting temperature

The temperature was recorded as 35 °C in all the compost piles that was higher compared to the available air temperature of 30 °C at the initial stage of composting process (Fig. 2). For sanitization of the feedstock and composting process efficiency, three distinct temperature phases were passed through by all the piles at the time of composting (Eusufzai et al. 2013; CCME 2005). The temperature remained between 15 and 45 °C at the mesophilic phase, 45-70 °C at thermophilic phase and at the cooling phase, the temperature dropped below 60 °C.

In this study the temperature recorded above 40 °C in all the compost piles after first turning regime within 15 days of composting. The maximum temperature was recorded in C1 (combination of CSW: CSWA: RH: RHA) as 49 °C after 15 days of composting while minimum was in C2 (only CSW) as 40 °C. In C3 (combination of CSW: CSWA), C4 (combination of CSW: RH) and C5 (combination of CSW: RHA) the temperature was recorded as 42 °C, 46 °C and 48 °C, respectively, after first turning done at 15 days of composting. A declining trend in temperature was observed in all the composting piles with the progression of composting process, however, temperature tends to slightly increase after each turning of the piles.

At the second turning regime as observed 30 days after composting, mean temperature increase of 8 °C from average 56 °C in C1, C4 and C5 composting pile whereas 1 °C and 3 °C temperature increase was observed in the C2 and C3 piles, respectively. More than 50 °C mean temperature was recorded in the C1, C4 and C5 composting piles for maximum duration of composting from 40-50 days, compared to C2 and C3 where temperature remained below 45 °C till 50 days of composting process.

Afterwards, the mean temperature was found as stable at 40 °C in all the compost piles at the final stage of composting after 60 days. The differences in high temperature persistence durations in the piles ought to be due to the various types of bulking agents used in the composting (Himanen and Hänninen 2011). In this study, C2 and C3 were the product of only CSW and CSW: CSWA while C1, C4 and C5 contained rice husk which degraded in relatively shorter time of having more organic carbon compared to cotton waste having rich lignin taking a long period requirement for decomposition (Eusufzai et al. 2013). Huang et al. (2004) also reported the duration differences in the thermophilic temperature using sawdust as a bulking agent in swine manure composting process.

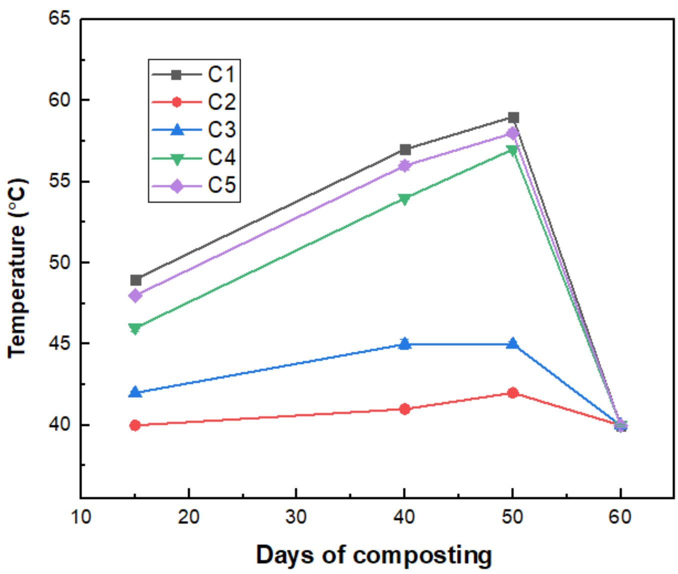

Fig. 2 Compost piles temperature at different day's interval
C1= CSW + CSWA + RH + RHA; C2= only CSW; C3= CSW + CSWA; C4= CSW + RH; C5= CSW + RHA, CSW = Cotton spinning waste, CSWA = cotton spinning waste ash, RH = rice husk, RHA = rice husk ash

Moisture content (MC)

The maturity index and stability nature of the ultimate product of composting mostly depend on the presence of moisture in the compost and was found as predominant than temperature of the composting piles (Liang et al. 2003). Therefore, it is desirable to sort out the sufficient moisture content in the composting materials that can remarkably enhance the decomposition during processing. At first regime of turning, the moisture content (MC) was increased a bit from 50% to 53-58% in all the treatments during the initial 15 days after the addition of water (Fig. 3A, Table 2). These ranges were within the optimum level of MC (50-60%) as reported by Tiquia et al. (1996). Afterwards, there was a gradual declining trend of MC observed until 60 days at the end of composting that might be due to aeration and high temperature causing water vaporization. Nonetheless, the highest amount of water loss was noticed in C2 among the five compost treatments suggested an increased turning frequencies done at 40 (two turning), 50 (three turning) and 60 (four turning) days of composting might have accelerated water loss. This observation is consistent with the findings of Zhou (2017). Furthermore, compost having a high moisture content (more than 60%), would be hard to spread and may be considered not fully composed yet. But with a less than 40% of moisture content, it would be easy to handle this in field application, which means that the organic matter has been decomposed well and mature enough to enable proper mixing with soil (Shilev et al. 2003). The present findings found these preferable limits of the compost qualities that make it best suit for farmland application.

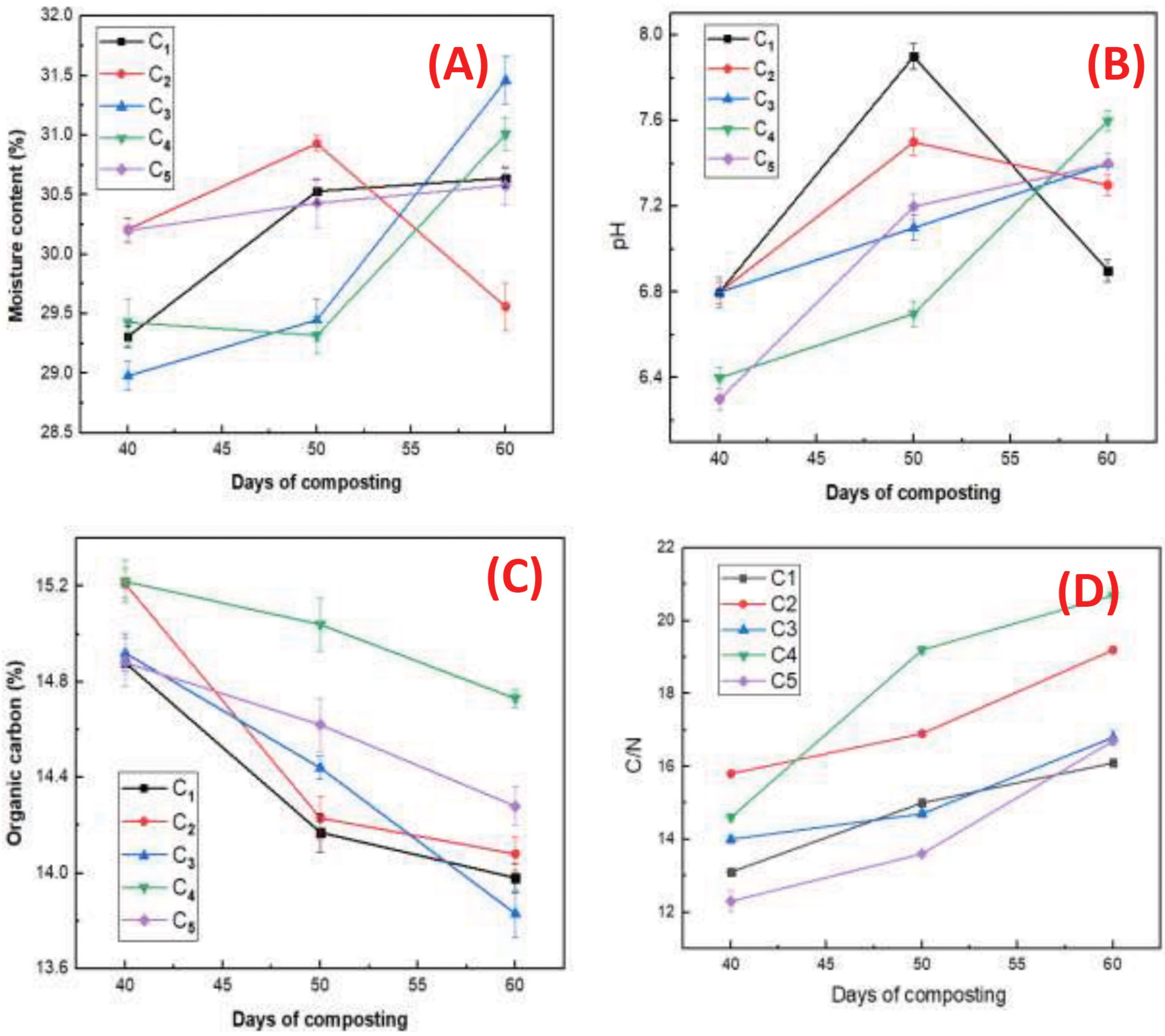

Fig. 3 Physiochemical characteristics of CSW derived composts at different days of composting; (A) Moisture content (%), (B) pH, (C) Organic carbon, and (D) C/N ratio

C1= CSW + CSWA + RH + RHA; C2= only CSW; C3= CSW + CSWA; C4= CSW + RH; C5= CSW + RHA, CSW = Cotton spinning waste, CSWA = cotton spinning waste ash, RH = rice husk, RHA = rice husk ash

pH

The initial pH ranged between 7.14 and 8.29 in all the compost piles and gradually decreased at the final stage of the composting period of 60 days. At initial stage at 15 days of composting after first turning and watering regime, the pH slightly increased to acidic (Table 2) and declined to 6.4-6.8 at 40 days of composting (Fig. 3B). Shen et al. (2011) postulated that the initial pH increase and decrease might be happened due to ammonia generation through the organic matter mineralization and organic acid production under anaerobic conditions being promoted by the addition of water. Then the pH value increased again till 50 days in all five treatments and reached to 6.7 and 7.7 with some fluctuations until the end of the composting process at 60 days. Vakili et al. (2012) postulated that the good range of pH for composting is 6.5 to 8.0 that substantiates our results. Notably, the lowest value of pH was observed in C1 compared to others at 60 days of composting that denoted the possible reason of excessive ammonia release having a well ventilated space in the piles where CAWA, RH, RHA were used as the co-digestion substrates with CSW. At the final stage of composting at 60 days, C4, however, recorded a remarkably higher pH (7.5) than C2, C3 and C5 where pH ranges from 6.9-7.1, which is most likely occurred because of having low pH value of CSW and CSWA being used as composting substances in C2, C3 and C5 compost while for C1 type compost rice husk was used that has a higher pH value.

The fluctuating nature of the pH during the composting experiment suggests that high CSW and CSWA contents inhibited the mass transfer of air through the waste, and the poor oxygen supply leading to slow the aerobic biodegradation rate and hydrolytic acidification. Therefore, CSW and CSWA derived composts have the lower pH at the final stage of composting at 60 days. Roca- Pérez et al. (2009) explained the reason behind the decline in pH as the nitrification process resulting in a large volume of CO_2 emission and volatilization of ammoniacal nitrogen and hydrogen ions (H^+) release.

In addition, the different initial pH values and C/N ratios in the different treatments may have affected the pH increases that occurred during 15 days of composting process because a low initial pH would have inhibited microbial activity (Beck-Friis et al. 2001) and a high C/N ratio would indicate that less nitrogen may be available for generation of ammonia that could contribute to increase in pH during the first turning at 15 days of composting process (Venglovsky et al. 2005).

Moreover, the availability of plant nutrients and uptake efficiency is strongly related to the pH of the growing medium of the plant. Therefore, the pH value of compost should range between 5 and 8, with a preferred value between 6 to 7.5 which is very common for most of the plants (Shilev et al. 2003). In this context, our study findings corroborate this range of pH that suggests the stability of CSW based final compost for successful application in crop cultivation without phytotoxicity.

Organic carbon

It has been revealed that the amount of organic carbon (OC) in the respective compost piles gradually reduced with extending the compost durations. At 40 days after composting, a lower amount of organic carbon (14.9%) was recorded in C1, C3, C5 while a higher amount (15.3%) in C2, C4 (Fig. 3C), those reduced from the initial OC recorded at 15 days of composting as 20.0 and 22.4%, respectively (Table 2).

At the end of the composting at 60 days, C4 recorded the highest mean OC of 14.9% followed by C5 (14.4%) and C2 (14.2%), while C3 had the lowest OC of 13.8% followed by C1 (13.9%). Our result is consistent with the observation of Moldes et al. (2007). Microorganisms are playing an indispensable part in decomposing organic substances and thereby consume carbon for their energy might also took part in reducing OC during composting (Bernal et al. 2009). Moreover, Sangodoyin and Amori (2013) postulated that OC reduction also occurred because of total mass reduction by microbial activities through CO_2 and moisture evaporation. The full growth and firmness of compost are mostly characterized by the substantial reduction of OC (Zheng et al. 2007; García et al. 1991).

C/N ratio

In this study, all the co-substrates of composting were mixed in different ratios so as to have an average initial C/N ratio of about 31 (Table 2) that belongs to the range of an ideal value of 25 to 35 for most of the composting (Bernal et al. 2009). The C/N ratio in all the five composts significantly decreased to 16.1 for C1, 19.2 for C2, 16.8 for C3, 20.7 for C4 and 16.7 for C5 compared to their initial C/N ratio over the whole duration of composting (Fig. 3D). The degeneration of the organic matter, mineralization and nitrogen reduction are supposed to be the responsible for causing such reduction. However, there was a significant variation observed regarding C/N ratio that slightly increased with the increase in composting periods from 40 days to 60 days in all the prepared composts. At 60 days of composting, the estimated C/N ratio revealed less than 20 in all the prepared composts that defined as the stable and properly developed compost is in agreement with the results of Huang et al. (2004).

The rice husk belonging to a rich carbon source used in our study might be responsible for causing a higher

C/N ratio at the initial stage at 15 days of composting. Moreover, the nitrogen loss occurred by ammonia release at the initial stage of composting could contributed to higher C/N ratio. Makan and Mountadar (2012) stated that the C/N ratio at initial stage was higher because of the lower organic matter degeneration while nitrogen decreased through volatilising in the form of ammonia. This phenomenon might be reason for causing a rapid degradation of C/N ratio at 40 days after composting from the initial level. Afterwards, at 50 and 60 days of composting the C/N ratio gradually increased owing to the augmented supply of oxygen provided by three and four times turning of composting piles and increased temperature that could boost up microbial activity.

Shilev et al. (2003) reported that a stable compost is produced after the composting process having the value of C/N ratio between 10:1 and 20:1. Because compost with a final C/N ratio of more than 20:1 cannot easily release nitrogen even though it inhibits nitrogen mineralization and thus supplies nitrogen to soil if C/N ratio is above 30:1. These features of C/N constituents of compost effect on its maturity status and use efficiency for crop production, particularly in case of supplementation of nitrogen fertilizer for improved plant health. Furthermore, the compost maturity and stability are identified based on the C/N ratio of the composting finished products. In this respect, the California Compost Quality Council (CCQC) proposes a guideline for making a compost mature or very mature, provided it has a C/N ratio of ≤25. Additionally, each compost sample needs to go through two tests from two groups of each (group A and group B) where group A indicates the status of organic matter decomposition while group B denotes the chemical characteristics of the final finished product of composting. After completion of these processes, CCQC certifies the compost suitability for plant's growth but not based on C/N ratio. As CSW derived composts have the C/N ratio in the range of 16~20 in this study, therefore, this particular feature strongly supports our hypothesis that these can be safely used for vegetable cultivation.

Mass reduction designated as organic matter (%)

In open composting process, the total amount of feedstock used for compost preparation gradually degenerated through different forms of losses (volatilization in gas like N_2O, CO_2, H_2O and NH_3) (Shen et al. 2011; Parkinson et al. 2004). Consequently, organic matter content (%) was estimated according to the dry mass losses of each of five composts in the present study (Fig. 4). This process indicates the differences in the mass content at the early stage and the end of the composting process as designated by organic matter (%). It has been reported that 36.5 to 45.1% mass reduction was observed in all the five composts from the initial weight of 1500 kg to the final weight of 822.6 to 952.4 kg after 60 days of composting. This loss is attributed to more turnings (four) done at 60 days of composting than that with less (three) at 50 days of composting or two turning at 40 days of composting. At the end of the composting process at 60 days, a remarkable loss of organic matter in all the treatments (36.5-45.1%) was observed that justified a good composting. However, in C3 compost the highest amount of organic matter reduction was found where CSWA was used as a composting substance while the least OM loss was in C4 where rice husk used as the composting substance that reduces the OM loss because of lower porosity than that of ash sample (Tibu et al. 2019).

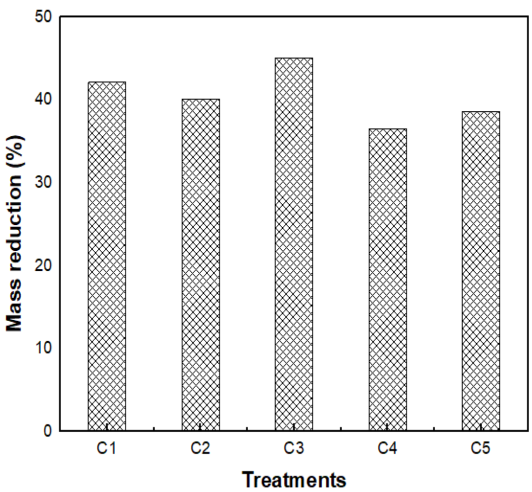

Fig. 4 Mass (organic matter content %) reduction of compost at different day's interval
C1= CSW + CSWA + RH + RHA; C2= only CSW; C3= CSW + CSWA; C4= CSW + RH; C5= CSW + RHA, CSW = Cotton spinning waste, CSWA = cotton spinning waste ash, RH = rice husk, RHA = rice husk ash.

Changes in nutrient contents

The changes in macronutrient contents during the composting process are important deciding factor for the ultimate use of the prepared compost as shown in Table 3.

Nitrogen

The nitrogen (N) content in all of the studied composts decreased gradually from the initial level during the entire composting process and changes varied significantly at 40, 50 and 60 days of composting (Table 3). At the end of the composting at 60 days, the highest amount of N (0.88%) was observed in C1 compost which was statistically similar to C5 (0.85%) followed by C3 compost (0.83%). The lowest amount (0.71%) was in C4 which was statistically identical with C2 compost (0.74%). The variation in the reduction of nitrogen content at 40, 50 and 60 days of composting were observed in compost treatments might be due to temperature differences during the turning process that enhances volatility of N in the form of ammonia through the reaction: (Brito et al. 2014; Primo et al. 2010).

Table 3 Macronutrients content in CSW derived composts at different days of composting

Treatment combinations (Different CSW composts and days of composting)		N[z]	P	K	S
C1 = (cotton spinning waste + cotton spinning waste ash + rice husk + rice husk ash)	40	1.14±0.01b	1.25±0.02c	0.78±0.01b	0.35±0.00c
	50	0.95±0.01b	1.10±0.01e	0.77±0.01b	0.37±0.00c
	60	0.88±0.01a	1.37±0.01b	0.81±0.00c	0.36±0.01b
C2= (only cotton spinning waste)	40	0.96±0.00d	1.13±0.01d	0.66±0.01c	0.43±0.00b
	50	0.84±0.00c	1.27±0.01c	0.83±0.02a	0.45±0.01b
	60	0.74±0.01c	1.27±0.01c	0.96±0.01a	0.46±0.01a
C3= (cotton spinning waste + cotton spinning waste ash)	40	1.07±0.01c	1.39±0.01b	0.76±0.01b	0.72±0.00a
	50	0.98±0.01b	1.33±0.01b	0.73±0.01b	0.46±0.00b
	60	0.83±0.01b	1.45±0.01a	0.77±0.01c	0.47±0.01a
C4= (cotton spinning waste + rice husk)	40	1.05±0.01c	1.05±0.01e	0.86±0.01a	0.12±0.01d
	50	0.78±0.01d	1.19±0.01d	0.78±0.01ab	0.36±0.01c
	60	0.71±0.01c	1.25±0.02c	0.87±0.01b	0.37±0.01b
C5= (cotton spinning waste + rice husk ash)	40	1.22±0.02a	1.44±0.02a	0.65±0.03c	0.34±0.01c
	50	1.08±0.01a	1.52±0.02a	0.74±0.02b	0.53±0.01a
	60	0.85±0.01ab	1.37±0.02b	0.87±0.02b	0.45±0.01a

[z] Macronutrient content in different types of CSW derived composts (C1= cotton spinning waste + cotton spinning waste ash + rice husk + rice husk ash, C2= only cotton spinning waste , C3= cotton spinning waste + cotton spinning waste ash, C4= cotton spinning waste + rice husk, C5= cotton spinning waste + rice husk ash) at different days of composting.

[y] Data represents means ± SD (n=3). Means with the different letters in a column are significantly different at 5% level of significance ($P \leq 0.05$) by HSD test using R-software.

Phosphorus, potassium and sulphur

The changes in the phosphorus (P) and potassium (K) contents display an upward tendency over composting periods from 40 to 60 days (Table 3). The highest P content was observed in C3 (1.45%) while the lowest was in C4 (1.25%) which was similar to C2 (1.27%) at the final stage of composting at 60 days. On the other hand, the highest K content was found in C2 (0.96%) and the lowest was in C3 (0.77%) at 60 days of composting. However, the gradual increasing trend in P and K content according to the days of composting (DOC) in all the composts sample revealed higher microbial activities may exist in maximum turning that is done in 60 DOC compared to 40 DOC (Zhou 2017). Regarding the sulphur (S) content, the fluctuation trend was observed among the composts as per the composting durations and treatment variations. The highest amount of S was determined in C3 (0.47%) which was statistically similar to C2 (0.46%) and C5 (0.45%) while the lowest was in C1 (0.36%) similarly followed in C4 (0.37%). This might be attributed to the impact of different substances on composting (Zhou 2017).

Heavy metals

The presence of heavy metals is the most important factor that limits the successful utilization of compost because of bioaccumulation potentiality of these metals in the respective compost. In this study, there are six heavy metals (copper, zinc, nickel, chromium, lead and cadmium) found in the CSW derived composts (Table 4).

Cu, Ni, Cr and Pb content of the piles decreased throughout the composting period, which was in agreement with Hanc et al. (2012) and Larney et al. (2008). The observed quantitative changes in Cu, Ni, Cr and Pb in the compost chemical fractions might be affected by biochemical–microbial transformations taking place in the course of composting of the organic matter (Jakubus and Czekała 2010). On the contrary, Zn content of the piles increased throughout the composting period. Similar result was observed in Pascual et al. (1997) which showed that Zn content of compost increased. Previous studies have demonstrated that the composting and maturation processes increase insolubility of metals which become less available to plants (García et al. 1990). Cd content of the piles showed different trends. Cu content in C1, C2 and C3 showed a decline throughout the composting period while C4 and C5 remained constant throughout composting periods. This might be due to the co-digestive substances differences used in the composting and their efficiency on continuous mineralization during compost and even loss by respiration (Amir et al. 2005). Zn was reported in higher amount compared to other heavy metals in the previous reports that substantiates the present findings (Zheljazkov and Warman 2004; Wong et al. 2001).

Cu (2.24–1.46 mg/kg), Zn (9.28–7.45 mg/kg), Ni (2.32–1.22 mg/kg), Cr (2.22–0.87 mg/kg), Cd (0.38–0.17 mg/kg) and Pb (1.57–0.78 mg/kg) concentrations found in the composts are within the Canadian Compost Quality standards (CCME 2005), and European Union and USA Biosolids ranges (Brinton 2004) (Table 4). This indicates that all the developed composts can safely be used in agriculture for crop cultivation. The heavy metals content in our findings were comparatively lower than those of the findings of Cherif et al. (2009) and Tibu et al. (2019). This might be happened due to the feedstock source differences that minimized the possible heavy metal accumulation. Oforie (2013) claimed that feedstock derived from different sources have marked influenced on heavy metal reduction in the prepared compost that supports our present speculation. In addition, the heavy metal accumulation and movement reduction also occurs through earthworms' activation in bioaccumulation of these metals into their tissue and subsequent decomposition of these earthworm tissues overloaded with metal burdens (Ma et al. 2003; Liu et al. 2012).

Field evaluation of CSW recycled composts for Indian Spinach cultivation

Vegetative growth

Data on vegetative growth such as leaf number plant, plant height of Indian Spinach treated with different composts are shown in Table 5. The results showed that plant height at different days after planting till the final harvest varied significantly due to difference in compost treatments. It has been observed that T3 provided the highest plant height (28.33 cm) that was statistically similar to T7 (28.07 cm) followed by T4 (27.47 cm), T5 (26.20 cm), T6 (26.20 cm) and the lowest was observed in T1 treatment (15.20 cm). The similar trend of result was also noticed in leaf number per plant where the maximum leaf per plant was obtained for T4 (17.86); T7 treated plants produced the second highest leaf number per plant (17.80), followed by T6 (15.86), T2 (15.60) whereas the lowest was recorded for T1 treatment (10.06).

The growth of Indian Spinach at the early stage was found weaker with CSW derivate composts compared to chemical fertilization treatment. This could be attributed to the fast release of the available nutrients from the chemical fertilizers for plants at the early stage of growth while a slow release of these nutrients occurs from the CSW composts (Duong et al. 2013). However, at the later stages plant growth in all the studied compost treatments grew better and resulted in a higher final total yield than those in chemical fertilization treatments. This trend is more clearly understood from the current findings as presented in Fig. 5 and Table 5.

Plant growth using compost in field refers to its quality and potential for agricultural application (Som et al. 2009). Since this characteristic of compost indicated as compost maturity is strongly connected to the loss of phytotoxicity (Raj and Antil 2011), it can be closely evaluated in the current study by examining the vegetative growth and yield of Indian Spinach as influenced by the compost. The best performance was noticed with the solely prepared compost of CSW which is indica-

Table 4 Heavy metals content of CSW derived composts at different days of composting

Treatment combinations (Different CSW composts and days of composting)		Cu [z]	Zn	Ni	Cr	Cd	Pb
C1 = (cotton spinning waste + cotton spinning waste ash + rice husk + rice husk ash)	40	2.24±0.02a [y]	8.65±0.01a	2.03±0.01ab	2.22±0.01a	0.24±0.01c	1.56±0.01a
	50	2.13±0.01a	8.35±0.01d	2.17±0.02b	2.20±0.01a	0.27±0.01ab	1.33±0.01a
	60	1.57±0.01d	8.88±0.01d	1.47±0.01a	0.96±0.01a	0.17±0.01d	0.88±0.01b
C2= (only cotton spinning waste)	40	1.87±0.02b	7.45±0.00d	1.98±0.01bc	1.26±0.01c	0.38±0.01a	1.57±0.02a
	50	1.96±0.01b	8.75±0.01b	2.32±0.01a	1.94±0.02b	0.28±0.01a	1.36±0.01a
	60	1.46±0.01e	8.97±0.00c	1.32±0.01b	0.92±0.01b	0.18±0.01cd	0.91±0.01a
C3= (cotton spinning waste + cotton spinning waste ash)	40	2.23±0.23a	8.37±0.01b	1.96±0.01c	1.76±0.11b	0.32±0.02b	1.35±0.01c
	50	1.92±0.01b	8.55±0.01c	2.13±0.11b	1.68±0.01c	0.22±0.02c	1.23±0.02b
	60	1.73±0.01c	8.23±0.01e	1.43±0.01a	0.97±0.01a	0.26±0.01a	0.78±0.01c
C4= (cotton spinning waste + rice husk)	40	2.14±0.01ab	8.24±0.02c	1.76±0.02d	1.06±0.00d	0.25±0.00c	1.26±0.01d
	50	2.09±0.01a	8.22±0.02e	2.03±0.05c	1.53±0.01c	0.18±0.01c	1.03±0.05c
	60	1.87±0.01a	9.13±0.01b	1.22±0.02c	0.92±0.01b	0.25±0.01ab	0.87±0.01b
C5= (cotton spinning waste + rice husk ash)	40	2.15±0.01ab	8.26±0.04c	2.05±0.02a	2.11±0.01a	0.22±0.02c	1.43±0.01b
	50	2.12±0.02a	8.86±0.01a	1.93±0.02d	1.03±0.03d	0.22±0.02bc	0.97±0.01c
	60	1.77±0.01b	9.28±0.01a	2.01±0.01d	0.87±0.01c	0.22±0.01bc	0.88±0.01b

[z] Heavy metal content in different types of CSW derived composts (C1= cotton spinning waste + cotton spinning waste ash + rice husk + rice husk ash, C2= only cotton spinning waste, C3= cotton spinning waste + cotton spinning waste ash, C4= cotton spinning waste + rice husk, C5= cotton spinning waste + rice husk ash) at different days of composting.

[y] Data represents means ± SD (n=3). Means with the different letters in a column are significantly different at 5% level of significance ($P \leq 0.05$) by HSD test using R-software.

tive of mature and phytotoxin-free composts (Jeong et al. 2017). In some cases, further diluted compost mixed with rice straw could have stimulated growth and yield of Indian Spinach. This could be most likely due to organic molecules being dissolved in compost water-extractable fractions that promote seedling development at early stage of plant growth (Jeong et al. 2017).

In this context, Suge et al. (2011) reported similar findings and showed that addition of suitable organic matter to the soil improves the soil physicochemical properties which in turn lead to a better root development, increased nutrient uptake and water retention capacity causing a higher yield of vegetables.

The present findings substantiated the previous observation of (Ibrahim and Fadni 2013) where organic fertilizer had a significant effect on different stages of tomato plant growth with increased plant height and the number of nodes. Azarmi et al. (2009) mentioned that applying vermicompost increased the leaf area of cucumber up to 18% which is in agreement with our findings. Hernández et al. (2016) reported a higher yield of Lettuce (*Lactuca sativa* L.) with compost (sewage sludge with saw dust in 1:1 ratio) treatment compared to chemical fertilizer.

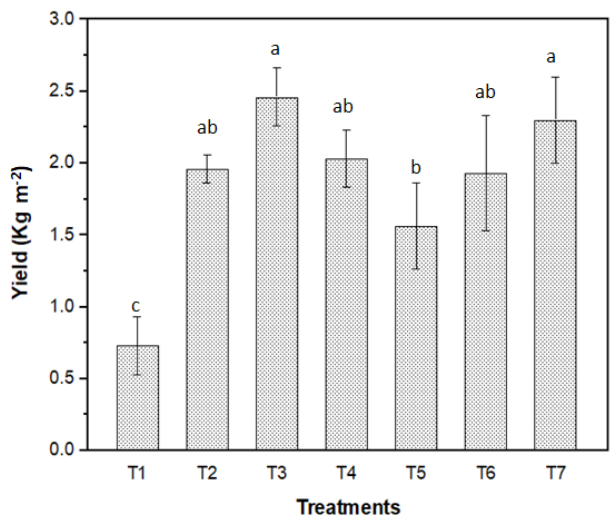

Fig. 5 Yield (kg m^{-2}) of Indian Spinach grown with different CSW derived composts

T1= control (without compost/fertilizer), T2= recommended doses of chemical fertilizer (RDCF), T3= C1= cotton spinning waste + cotton spinning waste ash + rice husk + rice husk ash, T4=C2= only cotton spinning waste, T5= C3= cotton spinning waste + cotton spinning waste ash, T6=C4= cotton spinning waste + rice husk, T7=C5= cotton spinning waste + rice husk ash.

Yield of Indian Spinach influenced by CSW derived composts

Yield of Indian Spinach was significantly influenced by different CSW generated composts compared to the chemical fertilizer and control treatment. The yield of T3 and T7 treated samples provided the statistically similar results followed by T4 and T2 treatment (Fig. 5). The highest yield (2.4 kg m^{-2}) was recorded in T3 treatment: CSW+CSWA+RH+RHA which was statistically identical with T7: CSW+RH (2.3 kg m^{-2}) followed by T4 treatment (2.2 kg/m^{-2}): CSW alone and T2 treatment (1.9 kg m^{-2}): chemical fertilizer alone. The similar findings were also reported by Chaudhary et al. (2003) where tomato yield was better using a mixture of vermicompost and chemical fertilizer compared to only chemical fertilizer. In addition, Rajkhowa et al. (2003) observed the highest number of nodules per plant of green gram (*Vigna radiate*) using 75% chemical fertilizer + vermicompost.

In this study, the control treatment (T1) produced the lowest yield (0.7 kg m^{-2}) followed by T5: CSW+CSWA (1.5 kg m^{-2}). It has been revealed that CSW with other co-digestion substances generated compost (T3) as well as the combination of CSW and RH (T7) derived compost produced a better yield compared to only CSW derived compost and chemical fertilizer. These findings suggest that CSW+CSWA+RH+RHA based compost retains more nutrients than only CSW generated compost that is consistent with the observations of Gandhi et al. (1997). Furthermore, the yield of Indian Spinach significantly increased due to the improved uptake of N, P and K nutrients from the CSW derived composts and chlorophyll content also increases in the leaves (Tejada et al. 2008).

Table 5 Effect of cotton spinning waste (CSW) recycled composts on plant height and leaf number of cultivated Indian Spinach

Treatments [z]	Plant height (cm) at different days after planting (DAP)					Leaf number at different days after planting (DAP)				
	21	28	35	42	50	21	28	35	42	50
T1	4.06±0.0c [y]	[ns] 7.97±1.0	12.21±0.0c	14.74±0.0b	15.20±0.5c	2.53±0.2c	4.93±0.1ab	6.06±0.1bc	7.66±0.1b	10.06±0.5c
T2	4.76±0.4c	8.33±0.4	13.09±1.6b	17.41±1.8a	25.00±0.3b	2.53±0.1c	4.33±0.2c	6.86±0.2ab	8.06±0.1ab	15.60±2.1ab
T3	6.18±0.3a	8.89±0.9	14.75±0.7a	18.64±0.1a	28.33±1.8a	2.66±0.2abc	5.06±0.2ab	7.06±0.3a	8.33±0.1a	14.86±2.0b
T4	5.60±0.0ab	8.65±0.4	14.50±1.1a	18.62±0.1a	27.46±1.4ab	3.00±0.0a	5.13±0.1a	7.33±0.1a	8.46±0.1a	17.86±0.7a
T5	5.05±0.0b	8.60±0.4	14.71±0.7a	18.52±0.3a	26.20±1.7ab	2.93±0.4a	4.80±0.4ab	7.00±0.0a	8.26±0.1a	14.73±0.9b
T6	4.96±0.8b	8.74±0.4	14.52±1.1a	18.29±0.3a	26.20±0.5ab	2.93±0.1a	4.93±0.5ab	7.06±0.1a	8.26±0.1a	15.86±1.7ab
T7	5.58±0.2ab	8.68±0.3	14.52±1.1a	18.51±0.2a	28.06±0.9a	2.86±0.2ab	5.00±0.2ab	7.13±0.2a	8.33±0.1a	17.80±0.4a

[y] Data represents means ± SD (n=3). Means with the different letters in a column are significantly different at 5% level of significance ($P \leq 0.05$) by HSD test using R-software. ns= not significant

[z] T1= control (without compost/fertilizer), T2= recommended doses of chemical fertilizer (RDCF), T3= C1= cotton spinning waste + cotton spinning waste ash + rice husk + rice husk ash, T4=C2= only cotton spinning waste, T5= C3= cotton spinning waste + cotton spinning waste ash, T6=C4= cotton spinning waste + rice husk, T7=C5= cotton spinning waste + rice husk ash.

Effects of CSW derivate compost on nutrition quality of Indian Spinach

The values of the different nutritional qualities including β-carotene, ascorbic acid, and calcium content demonstrated no significant variations among the different composts treated Indian Spinach. T_5 compost gave the maximum value of β-carotene (vitamin-A) (0.62 mg/100 g) and the T_2 compost presented the lowest (0.48 mg/100 g) (Fig. 6A). On the other hand, ascorbic acid (vitamin-C) content was the highest in T_2 treated plant (71.20 mg/100 g), whereas it was the lowest in T_1 treatment (46.20 mg/100 g) (Fig. 6B).

Results showed a significant difference among the T1 (control), T2 (RDCF) and CSW derived composts treated Indian Spinach sample regarding the calcium content (Fig. 6C). The highest Ca contents (132 mg/100g) were obtained from Indian Spinach cultivated without compost or chemical fertilizers as T1 (control) treatment. The lowest Ca content was obtained from Indian Spinach grown with CSW+RH compost (108 mg/100g) followed by CSW+CSWA (109 mg/100g) compost which was very similar to the findings of RDCF (chemical fertilizer) treatment (111 mg/100g).

The highest amount of Ca content was observed in T1 (control) treated sample might be due to the fact that the soil used for Indian Spinach cultivation itself is rich in calcium that is absorbed by the plant to achieve to the highest level in T1 (control). On the other hand, Ca content was comparatively lower in the CSW composts that is due to the fact that when composts were added into the same soil, existing part of free available calcium may have been adsorbed onto colloidal sites of humic substances present in organic matter of those composts. As a result, entry of calcium into the plants under the condition of treated composts may have been restricted. This finding is in agreement with the results of Premamali et al. (2019).

In this research, the quality of the Indian Spinach as a leafy vegetable is specified favorably by the concentration of β-carotene and vitamin C (ascorbic acid) whereas negatively by the concentration of calcium

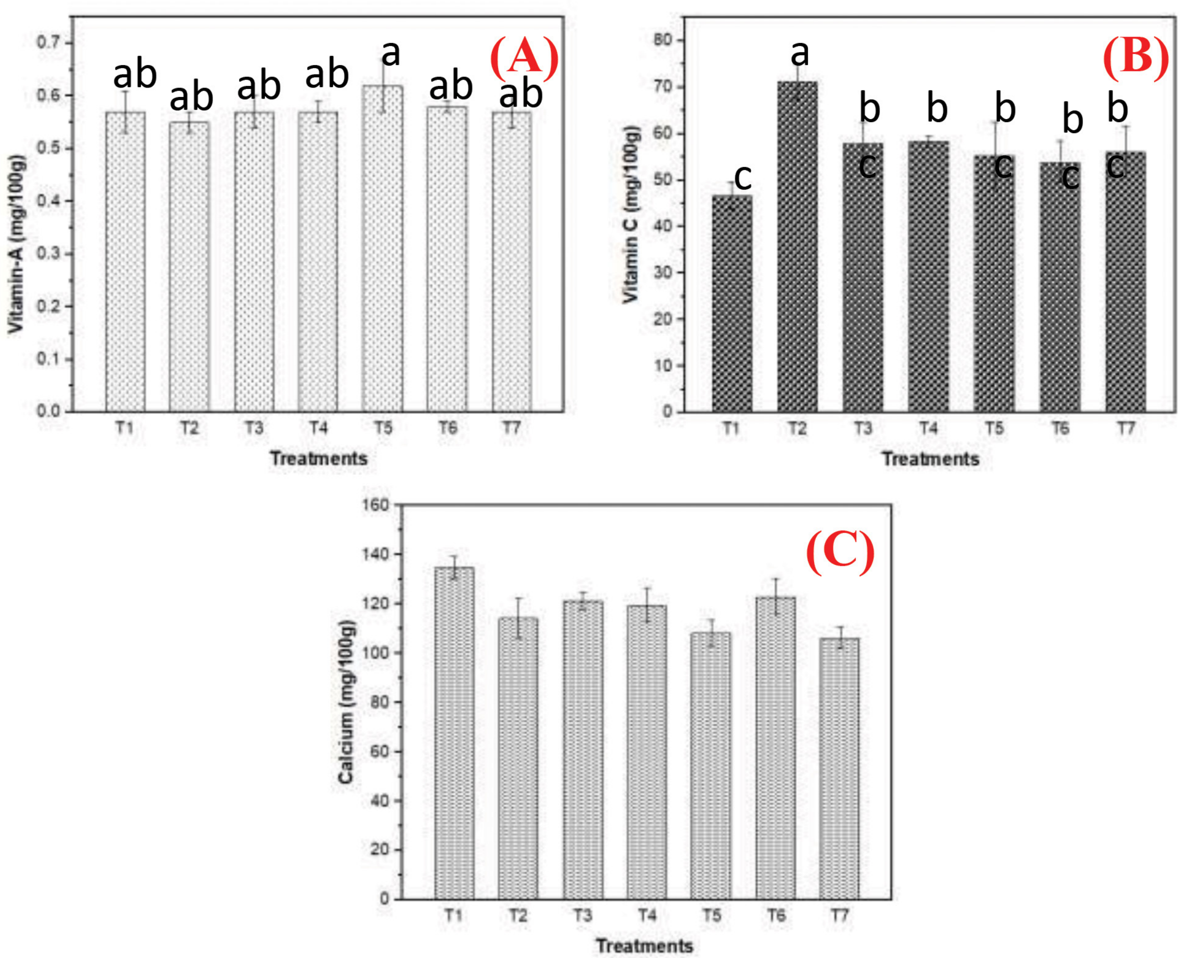

Fig. 6 Nutritional qualities of Indian Spinach grown with different CSW derived composts
(A) Vitamin-A, (B) Vitamin-C, (C) Calcium (*Not-Significant).
T1= control (without compost/fertilizer), T2= recommended doses of chemical fertilizer (RDCF), T3= C1= cotton spinning waste + cotton spinning waste ash + rice husk + rice husk ash, T4=C2= only cotton spinning waste, T5= C3= cotton spinning waste + cotton spinning waste ash, T6=C4= cotton spinning waste + rice husk, T7=C5= cotton spinning waste + rice husk ash.

(Figs 3-A, B, C). It can be observed that the concentration of β-carotene and vitamin C were found significantly higher while calcium was lower in compost treated Indian Spinach compared to chemical-fertilized treated one. If the concentration of vitamin C, which is expected to be rich in vegetables, is taken as the numerator, and the concentration of calcium, which is not required to be contained in vegetable, is considered as the denominator, an indicator of the quality can be obtained as shown in Fig. 6B and 6C. This type of indication is more logical because the consumers judge not only the nutrition values but also the harmful compounds like pesticide residue in vegetables. Excessive calcium content is known to be harmful on human health because of its conversion into calcium oxalate being responsible partly for kidney stone (Nakata 2012). The food value data obtained in the current study clearly show that the quality advantages of organically produced vegetable over the chemical fertilizer produced vegetable. Similar results have been reported in other studies (Xu 2001; Larson et al. 2000).

Ibrahim and Fadni (2013) demonstrated that in comparison with the control group, cattle manure and compost increased the vitamin C of the tomato to 36% and 56%, respectively. It has been reported that the Vitamin C content in capsicum was the highest (9.2 mg/100g) in treatment with only compost and the lowest in treatment compost + inorganic fertilizer (2.4 mg/100g) (Premamali et al. 2019). The findings of the current study regarding nutrition content are in harmony with previous study of (Del Amor 2017), where they postulated that compost and chicken manure treatments gave the highest value of vitamin C in bell peppers.

Analysis of cost and returns using CSW derivative composts

In Table 6, the treatment T3: compost-1 produced using CSW + CSWA + RH + RHA provides a yield of 2.4 kg m^{-2} displayed maximum gross return (Tk 106), gross margin (Tk 64), which was closely followed by T7: compost-5 derived from CSW+RHA (gross return Tk 101 and gross margin TK 59) and T4: compost-2 used only CSW (gross return Tk 97 and gross margin Tk 55), respectively. These findings assumed that compost prepared with the integrated use of CSW+CSWA+RH+RHA may offer maximum economic benefit than sole use of CSW derived compost and chemical fertilizer or integrated use of CSW+RHA; CSW+CSWA and CSW+RH. To validate this hypothesis, further research is suggested using a long-term experiment with large field data. However, as far as improved soil health and crop production improvement strategies are concerned, we should minimize the use of chemical fertilizer. Therefore, in this study the T2, i.e., only chemical fertilization application is not considered beneficial based on gross return (Tk 84) and gross margin (Tk 30) that ranks third in the lowest yield production. Meanwhile, the least gross return (Tk 31) and gross margin (Tk 28) are noticed in control treat-

Table 6 Economic benefits of Indian Spinach cultivation using CSW recycled composts

Treatments	Fertilizer Type	Production cost (Tk m^{-2})	Yield (Kg m^{-2})	Gross return (Tk) [z]	Gross margin (Tk)
T1	Control	2.6	0.7	31	28
T2	Chemical Fertilizer	54.3	1.9	84	30
T3	Compost (C1)	41.8	2.4	106	64
T4	Compost (C2)	41.8	2.2	97	55
T5	Compost (C3)	41.8	1.5	66	24
T6	Compost (C4)	41.8	1.9	84	42
T7	Compost (C5)	41.8	2.3	101	59

[z] 1Kg Indian Spinach price is 44Tk (DAM 2020) [NB: TK- stands for Taka, the Bangladeshi currency, which is 85 TK equivalents to 1.0 US dollar]

ment (T1) followed by T5, i.e., compost-3 derived from CSW+CSWA where gross return and gross margin are observed as Tk 66 and 24 with no chemicals being used here.

Conclusion

The compost derived from the mixture of CSW+CSWA+RH+RHA substrates has an optimum moisture content (31.2%), pH (7.5), C/N ratio (16.8:1), macronutrients, and micronutrients that enable it to serve as fertilizer substitute. Field application of CSW based compost emerged as favorable for better yield and improved nutrition quality in Indian Spinach production compared to chemical fertilizer. In addition, the Indian Spinach cultivated using this compost is significantly cheaper than that grown with the chemical fertilizer one. These results show that the techniques used in the study could be successfully applied to composting of the cotton spinning wastes as a sustainable and economically viable approach to organic vegetable production in Bangladesh.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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