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Research Article

Composting to Improve Slaughterhouse Wastes Based Fertilization Strategies of Urban Vegetable Farmers of Ouagadougou, Burkina Faso

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ABSTRACT

Slaughterhouse wastes (SW) are used without composting to produce vegetables in Ouagadougou. Here we wanted to know what are the reasons of this particular practice and its effects on soil and plant production and finally what additional value could be added with a composting of these wastes. We conducted a survey with urban vegetable farmers in Ouagadougou to characterize their practices regarding the use of slaugtherhouse wastes (SW) and their socio-economic status. With the agreement of few farmers, soil samples were analyzed and lettuce yields determined. The SW were composted considering three treatments (SW alone; SW + urea and SW + dolomite). The composts were then used to produce lettuce in a pot experiment. We found that about 50% of the total cropped surface receive SW and that the farmers' education level and their farm size are important factors determining the use of those wastes. The soil receiving SW exhibited available P of 3 to 4 times lower than those receiving the manure. The composting of the SW allowed increasing their available P contents up to three times and improving lettuce root biomass production. Raising awareness among farmers about the composting of SW and training them on good composting practices would allow a better recovery of those waste in agriculture.

Key words: Slaughterhouse wastes, Vegetables, Soil, Composts, Burkina Faso

INTRODUCTION

In developing countries, the meat industries (Slaughterhouses) are facing wastes disposal problem because of the lack of processing methods (Roy *et al.* 2013). Paradoxically in those countries, soil fertility management is limited by the high cost of mineral fertilizers (Ciceri and Allanore 2019) and the scarcity of the classic organic resources as manure and crop residues (Lompo *et al.* 2009) while the slaughterhouse wastes (SW) composed mainly of animal blood and rumen contents are important source of organic matter (Wang *et al.* 2018) that could be used to improve soil productivity.

In most of studies related to the use of SW in agriculture, a direct application of those wastes to the soil was rarely treated but rather their application after a composting (Sanabria-León 2007; Ragályi and kádár 2012). A threefold increase of maize yield due to the residual effect of the application of composts made from SW was observed by Ragályi and kádár (2012) in Hungary. Improvements of soil Ca, Mg, K and available P as well as maize and soybean yields due to the application of SW composts were observed by Nunes *et al.* (2014) in Brazil.

In Burkina Faso, the slaugtherhouse of the main city Ouagadougou produces about 3000 t of wastes per year (Kiba-Soma, personal communication). Those wastes are directly applied to the soil without processing by vegetables farmers from a site located at the vicinity (Kiba *et al.* 2012). Kiba *et al.* (2012) showed a diversity of farmers' fertilization strategies between and within the vegetables sites of Ouagadougou which is mainly explained by the sites identities namely their proximity to the sources of solid and liquid wastes. Although the previous authors showed that the SW are used in the farmers' fertilization strategies, the reasons of this practice were not highlighted and its effects on plant and soil properties were not specifically analyzed.

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This study aims at analyzing the determinants of the direct application of SW as soil amendements and its effects on soil and plants. It also aims at determining possible additional values that a composting of those wastes would bring to improve the fertilization strategies of the farmers. We hypothesized that i) there are some socio-economic reasons explaining the direct use of the SW to produce vegetables instead of the use of manure, ii) the application of the SW leads to a soil productivity and nutrient contents similar to that with the use of manure iii) a composting improves the chemical properties of the wastes and their agronomic efficiency.

MATERIALS AND METHODS

Characterization of fertilization strategies

A survey was conducted at a vegetable site named Wayalguin, located at the fringes of Ouagadougou, Burkina Faso (12◦21′58′′N/1◦31′05′′ W). It is one of the main vegetable sites where SW are used as amendment (Kiba *et al.* 2012). The site as well as the cropping practices are described in Kiba *et al.* (2012). A total of 33 farmers were questioned about their fertilization strategies as well as on selected socio-economic status that could influence these strategies such as farmer age, farm age, farm size, education, affiliation to farmer's organization, land ownership.

Soil sampling and lettuce yield assessment on farm

Soil samples were taken at a depth of 15 cm for the characterization of their total organic C, total N, P, K available P and pH in 6 farmers' fields identified as using SW alone or combined with manure and/or mineral fertilizers, and in 3 fields where fertilization was based on manure combined to mineral fertilizers. It was possible with the agreement of the farmers to evaluate the lettuce biomass production. The lettuce fresh biomass was harvested from two micro-plots of 0.25 m^2 installed in each field and an average yield was calculated using the production of the two micro-plots. For each field, subsamples from each harvest were taken and dried at 60° for the determination of the dry matter which was then used for the determination of nutrient contents.

Collection of SW and composting

The fresh SW were collected at the "Abattoir Frigorifique de Ouagadougou" one of the main slaughterhouses of Burkina Faso. Then the wastes were transported to the research station of "Institut de l'Environnement et de Recherches Agricoles (INERA)" located at Kamboinsé where composts pits were installed. The wastes had a moisture rate of 80% and contained 520, 21.4, 1.91, 0.42 gkg^{-1} of total C, N, P, K, water available P, a C/N ratio of 24 and a pH of 5.85 (Soma 2008). Three compost pits having each a volume of 2 m^3 were used to produce three types of composts from October to December 2007 according to 3 treatments as follow: 1) CSW1: Slaughterhouse wastes (SW) only, 2) CSW2: SW + Dolomite (20 kg t^{-1} of fresh wastes) and 3) CSW3: SW + Urea (12 kg t^{-1} of fresh wastes). Each pit received 600 kg fresh wastes shared in 6 layers. The amounts of additives (dolomite or urea) were divided in five equal portions and homogeneously applied on the whole surface of each of the first 5 layers. Because of the high moisture of the wastes, the compost piles were turned over every day during the first week and then according to Savadogo *et al.* (personal communication) they were turned over every 3 days during the following two weeks and then every 7 days till the end of the composting. In total, an amount of 165 liter of water was applied in each pit to maintain the moisture rate at 50% during the composting. The composts of each pit were sampled at 7, 14, 21, 35, 42, 49, 60 and 90 days after composting at 5 sampling points then a composite sample was made from these samples which was dried and ground for chemical analyses.

Chemical analyses

Soil total organic C and N were measured on ball-milled samples by CN analyzer (Flash EA, 1112 series, Italy). The total P, K, Ca, Mg were extracted with HNO3 (14M) and measured with inductively coupled plasma mass spectrometer (ICP-MS; Agilent 7500 ce, USA) after ignition at 550° C. Soil Bray P was determined according to Bray and Kurtz (1945). Soil pH was measured with a pH-meter (WTW InoLab, Weilheim, Germany) in a ratio soil: water of 1:2.5 according to Afnor (1981). The total C of the composts was determined by weight loss after a calcination at 550 °C during 2 hours using an electrical furnace CARBOLITE. The total elements N and P contents of the composts were determined by an automatic colorimeter SKALAR (Skalar SANplus Segmented flow analyzer, Model 4000–02, Breda, Holland) after a wet digestion using the Kjedhal method adapted by Novozansky *et al.* (1983). The pH was determined with a pH-meter (WTW InoLab, Weilheim, Germany) in a ratio compost: water of 1:5 according to Afnor (1981). The compost water soluble P was extracted in a ratio compost: water of 1:100 and measured with the automatic colorimeter as described above for the total P.

Pot experiment

A pot experiment was conducted under greenhouse conditions at the research station of INERA Kamboinsé to evaluate the agronomic value of the composts. Pots of 2 liter of volume were filed with 2 kg of dry soil previously mixed with the composts at a rate of 6.7 g dry matter kg^{-1} soil. The soil was taken at the research station at 0-20 cm of depth. It contained 3.8 g kg^{-1} of total organic C and had a pH of 6.3. In addition to the 3 composts treatments a control treatment with only soil was included. Each treatment had 4 replicates. An amount of 2 g of mineral fertilizer NPK (14-23-14) was added to all the 3 treatments at 2 weeks after transplanting the lettuce (*Lactuca sativa*), cultivar Batavia, previously grown in a nursery. The plants were watered twice a day to maintain a moisture of about 70% of the soil water holding capacity. At 45 days after transplanting the lettuce plants were harvested for the measurement of dry leaves, roots and total biomass production.

Statistical analysis

Principal Component Analysis was performed on the centered-standardized survey data using the option "unconstrained-supplementary variables" with CANOCO 5.1 to summarize the variation of the fertilization strategies and interpret it with the help of the farmers' socio-economic status. The data of the fertilization strategies and some parameters of the farmers socio economic status as education, affiliation to farmer's organization, and land ownership were encoded as dummy variables using 1 for the presence and 0 for the absence. A one-way ANOVA was performed on lettuce biomass production in the pot experiment with GenStat 9.2 using the Least Significant Difference comparison.

RESULTS

Fertilization strategies

Three main fertilization strategies were identified in the vegetable site of Wayalguin (Table 1). A strategy based on the combination of manure and mineral fertilizers adding water soluble N, P K (MAN+MIN) and two slaughterhouse based strategies combining the slaughterhouse wastes with mineral fertilizers or with manure and mineral fertilizers (SW+MIN and SW+MAN+MIN respectively). The strategy SW+MIN was practiced on a largest surface (about 50% of the total surface of the studied farms) followed by the SW+MAN+MIN and MAN+MIN. However, the strategy SW+MAN+MIN was practiced by the largest number of farmers. The carrot (*Daucus carota*) was the most cropped vegetable followed by lettuce, cabbage and eggplant.

Fertilization strategies and farmers' socio-economic status

The PCA analysis showed that about 87% of the variability in fertilization strategy was explained by the first two canonical axes (Fig. 1). The strategy SW+MIN was correlated with the first axis and determined by the education of the farmers while the strategy MAN+MIN was correlated with the second axis and more determined by the farmer age and land ownership and farm age. The strategy SW+MAN+MIN was correlated by the first two axes similarly and determined by the farm size. The oldest farms were held by less educated farmers and those less educated farmers were more organized.

Soil properties and lettuce yields

The soil chemical properties are shown in Table 2. For soil total C, N, P, K, Ca, Mg and pH, no particular trend was observed according to the fertilization strategies. For soil available P, lowest values were measured with the strategy SW+MIN. With the strategy MAN+MIN highest soil total N, P, K and available P were measured in soil with the highest total C. With the strategy SW+MIN, highest total N and P were measured in soil with the highest total C. With the strategy SW+MAN+MIN, the highest soil total N, P and Ca were measured in soils with the highest total C. No particular trend was observed for lettuce biomass production according to the fertilization strategies (Table 3). The lowest biomasses had the lowest P contents but not the lowest N, K, Ca and Mg contents.

Changes in slaughterhouse wastes chemical composition during composting

The changes in C/N ratio and total C of the wastes during the composting are shown in Fig. 2. The C/N ratio decreased for all the 3 treatments from 24 to 21, 18 and 14 for CSW1, CSW3 and CSW2 respectively. An increase of the C/N ratio was observed from the 60 to 90 days after composting. The total C showed a decrease from 525 g kg^{-1} to 425, 400 and 325 for CSW1, CSW3 and CSW2 respectively. The water soluble P of the composts (Fig. 3) increased for the treatments CSW1 (0.4 to 0.9 $g.kg^{-1}$) and CSW3 (0.4 to 1.3 $g.kg^{-1}$) while it decreased for the treatment CSW2 (0.4 to 0.3 $g.kg^{-1}$). An increase of pH was observed for all treatments till 20 days after composting. Then the pH decreased to about 5 for the treatments CSW1 and CSW3 and to 6.3 for the treatment CSW2 after 3 months.

Table 1: Cropped surface with main vegetables according to the fertilization strategies in the vegetables site of Wayalguin in Ouagadougou, Burkina Faso. The numbers in between brackets are the number of farms. MAN: manure; MIN: mineral fertilizers; SW: Slaughterhouse wastes.

	Fertilization strategies			
Crops	MAN+MIN	SW+MIN	SW+MAN+MIN	Total surface/crop
	Cropped surface m^2 (number of farms)			
Lettuce (*Lactuca sativa)*	50 (1)	1456 (6)	1156 (4)	2662
Cabbage (*Brassica oleracea)*	0	30 (1)	859 (3)	889
Eggplant (*Solanum melongena*)	0	0	600 (1)	600
Carrot (*Daucus carota*)	1800 (1)	7720 (10)	6045 (6)	15565
Total surface/ Fertilization strategy	1850	9206	8660	

Table 2: Soil properties under various fertilization strategies in the vegetables site of Wayalguin in Ouagadougou, Burkina Faso. MAN: manure; MIN: mineral fertilizers; SW: Slaughterhouse wastes.

	Total C	Total N	Total P	Total K	Total Ca	Total Mg	Bray P	pH
Fertilization strategies	g kg^{-1}						mg kg^{-1}	
MAN+MIN	11.6	0.68	0.34	0.38	0.54	0.07	52.9	7.03
MAN+MIN	16.8	1.49	0.50	0.44	1.04	0.10	32.0	7.49
MAN+MIN	6.89	0.63	0.42	0.31	1.45	0.11	70.6	8.25
SW+MIN	13.1	1.17	0.21	0.60	0.54	0.05	14.4	6.26
SW+MIN	21.4	1.66	0.35	0.42	1.23	0.12	12.9	7.61
SW+MIN	12.7	0.76	0.17	0.61	0.67	0.09	22.5	8.09
SW+MAN+MIN	17.6	1.67	0.56	0.43	1.60	0.11	49.5	7.23
SW+MAN+MIN	7.73	0.69	0.27	0.83	0.83	0.12	62.9	8.01
SW+MAN+MIN	9.25	0.91	0.24	0.33	0.99	0.12	41.7	7.78

Table 3: Lettuce biomass production and nutrient contents in the vegetables site of Wayalguin in Ouagadougou, Burkina Faso. MAN: manure; MIN: mineral fertilizers; SW: Slaughterhouse wastes.

Fertilization strategies	Biomass (dry matter)	N	P	K	Ca	Mg
	$t\ ha^{-1}$	$g\ kg^{-1}$dry matter				
MAN+MIN	1.14	39.6	4.92	18	17	5.4
SW+MIN	1.14	44.6	5.87	19	24	4.9
SW+MIN	0.87	43.3	4.23	20	21	5.7
SW+MIN	0.88	40.9	2.68	15	12	2.7
SW+MAN+MIN	0.77	36.5	4.65	22	19	4.2
SW+MAN+MIN	1.33	41.1	5.10	29	19	4.8

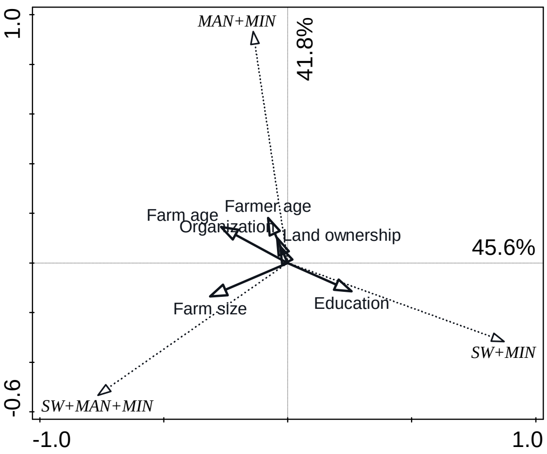

Fig. 1: Variability of fertilization strategies (vectors in dotted lines) as explained by the socio-economic status (vectors in continuous lines) of farmers from the vegetables site of Wayalguin in Ouagadougou, Burkina Faso. Numbers are the percentage of the variability explained by the first two axes of the principal component analysis. Size and orientation of the vectors represent correlation among them and with the axes. MAN: manure; MIN: mineral fertilizers; SW: Slaughterhouse wastes.

Table 4: Lettuce dry biomass production at 45 days after transplanting as affected by the application of composts from slaughterhouse wastes. The numbers in between brackets are standard deviations. CSW1: Slaughterhouse waste (SW) only; CSW2: SW + Dolomite (20 kg t^{-1} of waste); CSW3: SW + Urea (12 kg t^{-1} of waste).

	Leaves	Roots	Total biomass
Treatments	$g\ plant^{-1}$		
Control	4.83 (0.17)	0.70 (0.24)	5.53 (0.32)
CSW1	7.38 (2.29)	1.22 (0.30)	8.59 (2.16)
CSW2	4.97 (2.12)	1.82 (0.29)	6.79 (2.41)
CSW3	4.63 (0.65)	1.46 (0.39)	6.09 (1.05)
Lsd (0.05)	*2.66*	*0.58*	*2.75*
P value	*0.028*	*0.003*	*0.023*

Slaughterhouse wastes composts and lettuce production

The application of the composts increased lettuce leaves, root and total biomass production compared to the control (Table 4). The composts were ranged as follow: CSW1>CSW3>CSW2 according to their ability to increase the lettuce leaves and total biomass production while for the increase in root biomass the treatments were ranged as follow: CSW2>CSW3>CSW1.

DISCUSSION

Slaughterhouse wastes (SW) as amendment

Wayalguin is known as a vegetable site where slaughterhouse wastes are the most used amendment due to the proximity of this site to the main slaughterhouse of the city (Kiba *et al.* 2012). The cost of transportation probably limits the use of this organic resource in the remote sites. Indeed, according to Kaboré *et al.* (2011) distance and accessibility are important factors determining the use of organic resources. Our results showed that more than 50% of the studied farms use the SW totally in replacement to the manure indicating that farmers give an importance to this organic resource probably because they realized its agronomic values. The high cost of the manure compared to the SW as indicated by the farmers during the survey and its low availability (Lompo *et al.* 2009) may explain why some farmers replaced it totally with the SW. We did not observe any restrictions regarding the use of SW on the most cropped vegetables of the site. This finding suggest that the SW is a trusted source of amendment to the farmers just like the manure.

Our results highlighted that the majority of educated farmers are open to changes in their practices as they replaced the classic source of organic amendment which is the manure by a new and cheapest source which is the SW. The fact that education of farmers facilitates the adoption of technologies is documented (Ghimire *et al.* 2015). The majority of farmers who chose to invest in manure meaning to invest more finances are those who owned the land which confirms that land ownership facilitates investment in soil fertility management. The fact that the farmers with the largest farms combine manure and SW points out the low availability of organic resources which does not allow the farmers to opt using a single source when the demand is high but rather a combination of many. We found that less educated farmers resort to organization probably because this is the practical way for them to share experiences and learn from each other in order to fill the lack of knowledge.

Effects of SW application on soil and plant

The soils of the urban vegetable sites are known to have better chemical properties due to the higher rates of fertilization than most of soils in rural areas particularly those used for food crops as they do not receive or receive very little fertilizers. Indeed, the total element contents of our soils are remarkably high, particularly for total nitrogen due the high rate of urea application in those vegetable sites (Kiba *et al.* 2012). One would expect to have soil pH lower than the measured values particularly for the soils amended with SW known to be acidic (Soma 2008). However, the use of waste water for irrigation may have contributed to increase the soil pH because those waste water contains sodium and bicarbonate at high concentrations (Kiba *et al.* 2012). The soils amended with SW exclusively exhibited low available P (Bray P) contents. This might be due to the low available phosphorite from animal material contained in those

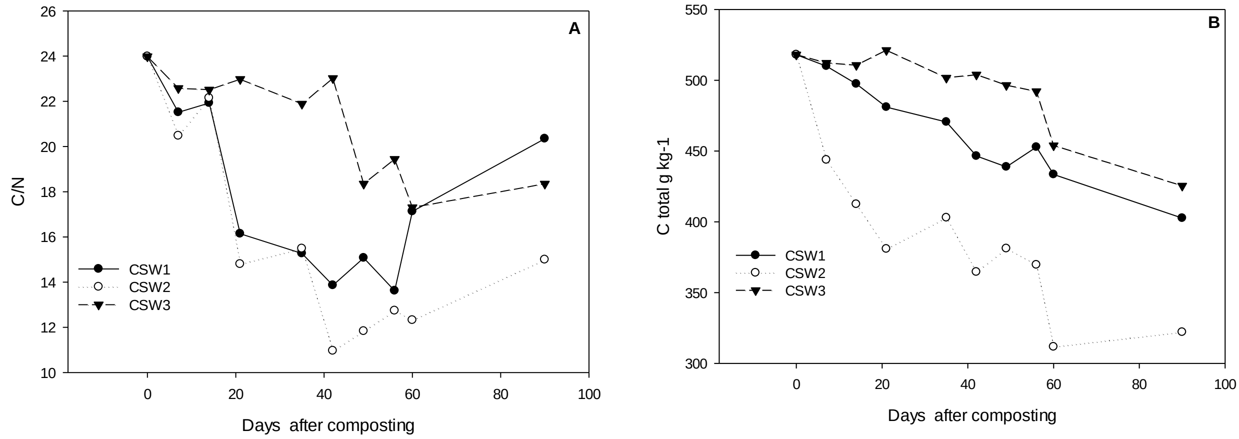

Fig. 2: Changes in total C/N ratio (A) and C (B) of slaughterhouse wastes during the composting. CSW1: Slaughterhouse waste (SW) only; CSW2: SW + Dolomite (20 kg t^{-1} of waste); CSW3: SW + Urea (12 kg t^{-1} of waste).

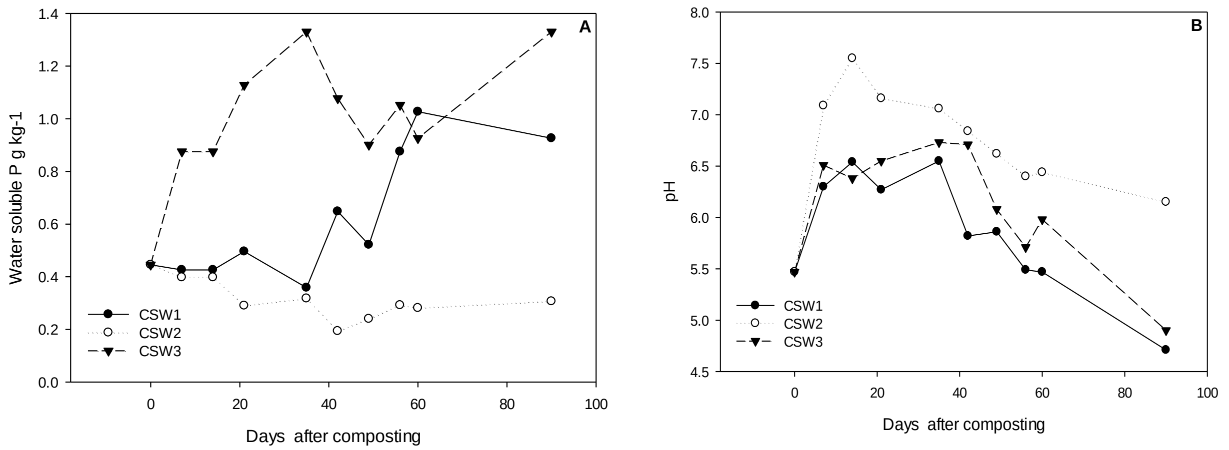

Fig. 3: Changes in water soluble P (A) and pH (B) of slaughterhouse wastes during the composting. CSW1: Slaughterhouse waste (SW) only; CSW2: SW + Dolomite (20 kg t-1 of waste); CSW3: SW + Urea (12 kg t-1 of waste).

organic amendment (Nunes *et al.* 2014) requiring a high acidic condition to be solubilized. Obviously this solubilization was not possible in our vegetable sites in light of the alkaline soil conditions. A composting of these SW would be an option to allow increasing the solubility of P for its further use by the plants. It would also allow thanks to the temperature increase during the composting to reduce the pathogen organisms which are remarkably important in the slaughterhouse wastes (Asemota *et al.* 2016) and thereby provide healthy organic material for the soil fertility improvement.

We did not observe main differences in lettuce yields probably because of the application of high rates of urea leading to increased biomass production within the 5 to 6 weeks of growth. However, the lowest lettuce biomasses exhibited the lowest P contents indicating that P might be a limiting factor for the vegetables in this site. This situation was probably created by the unbalanced mineral fertilization leading to unbalanced N:P ratio which can negatively affect plant biomass, leaf area and tissue nutrient concentration (Luo *et al.* 2016).

Composting to improve the agronomic values of the SW

The decrease of the C:N ratios after 3 months attests an operational composting while the increase of C:N ratios between 60 to 90 days is probably due to N losses via denitrification. The increase of pH till 20 days of composting is related to the degradation of organic acid usually occurring during the first weeks of composting (Compaoré and Nanéma 2010). The addition of dolomite allowed limiting a decrease of soil pH which probably created more favorable conditions for the decomposition of the organic matter as attested by the important decrease of the C:N ratio. Indeed, it is known that the acidity can reduce the microbial growth and decomposition rates (Malik *et al.* 2018). The addition of the urea led to a reduced C:N ratio and then to a high loss of nitrogen via volatilization (Kumar *et al.* 2014) and finally to a low decomposition of the organic matter. The addition of dolomite led to a retention of P (Xu *et al.* 2014) and therefore to a low water available P. However, this retention does not prevent the P to a further uptake by plant when the compost will be applied to the soil because of the possible acidic conditions of the rhizosphere. Indeed, our results of the pot experiment showed an increase of lettuce total biomass induced by the application of the composts and also a highest increase of lettuce root biomass with the application of the compost produced with the dolomite probably because of an important release of P.

Conclusion

The SW are potential and trusted source of organic amendement for the vegetable farmers just like the manure. Their use is determined by the socio-economic status of the farmers such as education level and the farm size. Because of their low P availability their long term application without a water soluble P source may lead to P deficiency in soils which can be detrimental to the vegetables production. The composting allows improving the P availability of the SW and therefore to improve their agronomic efficiency. The installation of composting pits at the slaughterhouses of the cities would be an option to provide better organic resource to the farmers and also to provide energy trough anaerobic composting. An awareness rising is needed to increase the level of knowledge and use of this organic material by the farmers.

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