



Application of Compost and Biochar Mixtures to Soils to Produce Parsley Plants Rich in Nutrients and Antioxidant Compounds[†]

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Abstract: Composts and biochar individually or in combination have been used for decades for improving soil quality and health. To date, very few studies have focused on the quality of food produced using compost-biochar mixtures. In this study, the use of biochar to improve the fertilization effect of composts and the quality of greenhouse-grown parsley was investigated by adding biochar to composts made from a mixture of broiler chicken wastes and sugar bagasse, sawdust, urban trees, napier grass, or cotton residues. On average, highest N and P contents were obtained with the bagasse- and sawdust-biochar substrates. The tree-biochar substrate led to increased levels of phenolic compounds in parsley compared to all the other organic substrates.

Keywords: broiler chicken wastes; bioactive compounds; nitrogen; *Petroselinum crispum* Mill; potassium; food quality; phosphorus



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1. Introduction

The term “food quality” is often used to represent all attributes of a food item that are acceptable to the customer; these attributes include the sensory, suitability, and nutritional/health values [1]. Thus, the perception of quality highly affects purchase decisions and dietary patterns. Numerous factors can directly affect the quality of foods before harvesting. Among these are genotypic, soil, and climatic factors [2]. Other factors such as cultural practices (e.g., maturity at harvest) are also important. Before harvest, the quality of crops is predominantly driven by genetic factors and most quality improvement programs in the industry are focused on breeding and/or selecting cultivars of high quality [2,3]. The increase in crop yields observed around the world during the last decades has been achieved in part using inorganic fertilizers and pesticides [4,5], and several studies have investigated the quality of food from crops grown with synthetic chemicals. However, synthetic chemicals used in agriculture pose potential hazards to the environment and human health [5].

Globally, there is increasing interest in soil organic amendments for the sustainable production of food. Several organic media for growing plants have been proposed, including composts, biochar, and peat [6–8]. Biochar is a black carbonaceous, porous, and low-density material that is produced by pyrolysis of various biological residues in the absence of oxygen [8]. Compost is decayed organic material usually produced by aerobic biological decomposition of plant and food wastes [9] Peat is a spongy material formed by

the partial decomposition of vegetation or organic matter in the wet acidic conditions of bogs and fens [6,10].

Systematic analyses of available data show that organic matter from composts, for example, positively affects physical, chemical and biological properties of soils, as well as the physiological development of plants [8,11]. However, the focus in the composting field has been more on the quality of the compost [12] than the quality of food-crops produced using the composts. Besides providing the physical and chemical properties needed for the proper development of plants, organic amendments should ensure the production of crops that are safe and rich in nutrients and bioactive compounds [13,14].

The effect of organic amendments on the quality of foods has recently been an area of great interest [3,9,10,15,16]. In a previous study, we studied the effect of composts obtained from chestnut, red grape, white grape, olive, and broccoli wastes, on antioxidant compounds in lettuce [6]. Our results showed a high accumulation of phenolic compounds in lettuce grown in the white grape-based compost, and in particular quercetin 3-O-glucoside, luteolin 7-O-glucoside, and cyanidin 3-O-(6''-malonyl)- β -D-glucoside; however, all composts led to decreased vitamin C levels [6]. Tortosa et al. [4] evaluated "Alperujo" compost from olive mill wastes as an organic amendment for pepper and found that plants experienced a yield increase and an enhancement of the vitamin C content, which was in contradiction to our study with lettuces. The amendment of biochar and biochar + compost (from several plant leaf residues) significantly increased chlorophyll contents in *Alpinia zerumbet*, an ornamental and medicinal plant primarily used in traditional medicine [8]. In the study by Ngakou et al. [5], the nutrition value of leaves and seeds of *Moringa oleifera* grown using different composts and inorganic chemicals (cow dung compost, goat manure compost, poultry manure compost, chemical fertilizer, mixture of fertilizers, and control) was assessed; results obtained indicated that dried leaves from plants grown with poultry manure compost contained a high total protein content. Growing plants with compost resulted in increasing chlorophyll a and b in leaves, but not vitamin A [5].

The general perception is that studies often have given contradictory results regarding the effects of organic amendments on food quality. The effects appear to have depended on the compost type, the amount applied to soil, and the quality parameter measured. This highlights the importance of formulating different organic amendments for specific plants under specific environmental conditions and cultural management practices. The purpose of this study was to evaluate the impact of five composts made from poultry industry wastes, and added or not with biochar, on the yield and nutritive/health value of greenhouse-grown parsley (*Petroselinum crispum* Mill.). The following parameters were assessed: mineral composition, antioxidant activity, total phenolic compounds, and individual flavonoids.

2. Materials and Methods

2.1. Production of Organic Amendments

The following materials were used for the preparation of organic amendments: plant wastes, chicken wastes, and biochar. Plant wastes were collected from a farm and comprised sugarcane bagasse, sawdust, urban tree residues, napier grass, and remnants from the defibrillation of cotton. Different wastes (broiler litter, hatchery wastes, floating sludge, cellulose gut, and charcoal) were collected from a poultry processing company and mixed. Biochar was produced by the slow pyrolysis of eucalyptus woods. Five composts were produced by (i) mixing each of the plant wastes with the same quantity of chicken waste to create piles with a C:N ratio of approximately 30; and (ii) processing the piles in a windrow turner as described in detail in Santos et al. [13]. For parsley cultivation, each compost was mixed with five different amounts of biochar (0, 15, 30, 45, and 60%, weight basis), resulting in 25 organic amendments.

2.2. Greenhouse Experiment

Thirty-day old parsley seedlings were purchased from a local market and planted in pots (1 L) filled with the organic amendments as growing substrates. Parsley plants were grown for 50 days in a non-controlled greenhouse with day/night temperatures of 32/18 °C. At harvest, shoots were weighed, and fresh matter recorded in g pot⁻¹. Dry matter (g pot⁻¹) and moisture content (%) were recorded after freeze-drying the shoots for 18 h.

2.3. Biochemical Measurements

Dried shoots were ground and used for the determination of nutritive and health parameters as described by Santos et al. [13]: total nitrogen (N) was determined using a Kjeldahl analyzer, phosphorus (P) was quantified by UV/vis spectrophotometry, and potassium (K) by flame photometry. Mineral contents were expressed in g kg⁻¹. The phenolic extract was prepared by adding 2.0 mL of 70% methanol to 40 mg of ground shoot. Following incubation at 75 °C for 30 min, the mixture was centrifuged (3500 rpm, 15 min, 27 °C) and the supernatant collected through a 0.45 µm polyvinylidene difluoride filter. The total phenolic content (TPC) of the shoot extract was determined by a modified Folin–Ciocalteu method and quantified at 750 nm using a UV-vis spectrophotometer; TPC was expressed as mg gallic acid equivalent per g (mg GAE g⁻¹). The total flavonoid content (TFC) of the shoot extract was estimated using the aluminum chloride colorimetric method, using catechin (CE) as a standard. Absorbance was measured using a UV-vis spectrophotometer at 520 nm, and TFC expressed as mg CAE g⁻¹. The antioxidant activity of the shoot extract was estimated by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, and results expressed as % sequestration and mg trolox equivalent per g (mg TE g⁻¹). Six parsley flavonoids were separated and identified using High Performance Liquid Chromatography coupled to a diode array detector; levels were expressed as mg apigenin equivalent per g (mg g⁻¹) [13].

2.4. Statistical Analyses

In this experiment, we set up four pots per treatment ($n = 4$) using a completely randomized block design consisting of five composts and five biochar amounts. For each set of compost data, replicate values for all biochar treatments were pooled and used in statistical analyses. The objective of data pooling was to have a global picture of the compost effect, regardless of the amount of biochar added to the organic amendment mixture. A descriptive analysis of the data was carried out to produce means and standard deviations, using SPSS 16.0 (SPSS Inc., Chicago, IL, USA). An analysis of variance (ANOVA) was also carried out to compare mean values. A $p < 0.001$ was considered to indicate differences among means (Duncan test).

3. Results and Discussions

3.1. Yield and Minerals

In this study, we tested the effect of chicken-based composts added with biochar on the yield and mineral composition of parsley. The results are shown in Figure 1. The water content of parsley shoots was not affected by the treatments. Highest yields were obtained with the bagasse and sawdust composts, irrespective of the amount of biochar. The napier compost presented the worst results in terms of fresh matter yield. However, no statistical differences in dry matter yield were found among the napier, tree, and cotton composts. Although we did not include a control treatment (non-amended pots) in this study, our previous data showed higher yields in composted growing media than in non-amended media using some composts [6,11,13]. The application of biochar and composts has also been reported in several studies to increase yields relative to unamended controls [8,10,13]. Highest N and P contents were also measured in plants grown on the bagasse and sawdust composts, and lowest in the napier compost; this pattern agrees with the yield data, although plants grown using the cotton compost also exhibited high N contents. K levels

varied in their response to the organic amendments. In the study by Tortosa et al. [4], macro- and micronutrient levels in pepper leaves from non-amended soils were lower than those obtained from compost-amended soils. However, different results have been reported by different authors [5,9,10,14,17].

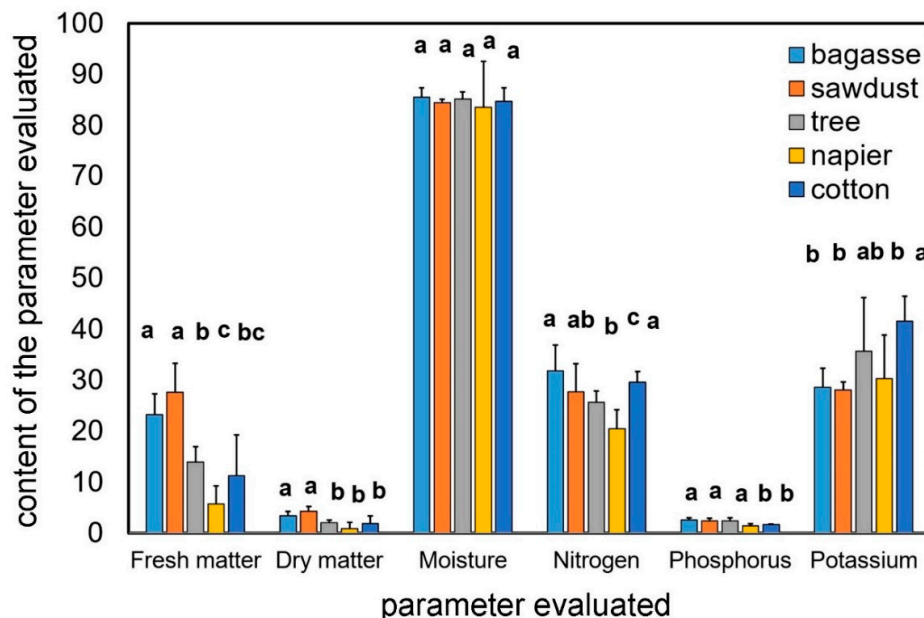


Figure 1. Growth (dry and fresh matter in g pot^{-1} , moisture in %; y -axis) and mineral content (N, P, K in g kg^{-1} ; y -axis) in shoots of parsley plants grown in medium composed of bagasse–chicken compost + biochar, sawdust–chicken compost + biochar, tree–chicken compost + biochar, napier–chicken compost + biochar, and cotton–chicken compost + biochar. Biochar was added to the composts at five inclusion rates (0, 15, 30, 45, and 60%, weight basis) and the average values used in statistical analyses. Error bars represent standard deviations. For each parameter, bar values followed by the same letter are not statistically different ($p < 0.05$; ANOVA Duncan post-hoc test).

3.2. Antioxidant Compounds

In agreement with yield and N, P contents, TPC was highest in plants grown using the bagasse, sawdust, and tree composts (Figure 2). Generally, the treatments did not affect the TFC content, except for a low TFC for plants grown using the napier compost. However, there seems to be no relationship between TPC/TFC and DPPH. The antioxidant activity of shoot extracts revealed that parsley plants grown using the napier and cotton composts exhibited increased DPPH activities, despite low yields and low TPC; these latter plants also tended to exhibit high TAC. It can be concluded that the napier and cotton composts induced a nutritional stress in plants. The plants responded to the oxidative stress by activating their antioxidative system. Therefore, increased DPPH antioxidant activities might not be related to phenolic compounds only, but also to other antioxidant compounds such as glutathione and ascorbate [4,8,16]. Overall, levels of bioactive compounds in foods depend on the type and amount of composts used as growing substrates [7,10,13]. For example, Zawadzińska et al. [10] found that tomatoes grown in a medium consisting of 25% compost, 30% high peat, 15% low peat, 20% pine bark, and 10% wood fiber reached the highest TPC and vitamin C levels.

3.3. Flavonoids

Flavonoids are a vital group of bioactive compounds in plants [18]. At the plant level, these compounds play a crucial role in regulating reactive oxygen species [8]. At the human level, flavonoids have various biological activities including anti-inflammatory, anti-cancer, and anti-depression properties [19]. The results from our study indicate that composts can enhance flavonoid levels in parsley (Figure 3). The synthesis of flavonoids

was highest in tree compost-grown plants, followed by sawdust, cotton, and bagasse-grown plants. The napier compost represented an exception with very low levels of flavonoids. This behavior was particularly notable for apigenin-7-apiosylglucoside, apigenin-malonyl-apiosylglucoside, and diosmetin-malonyl-apiosylglucoside.

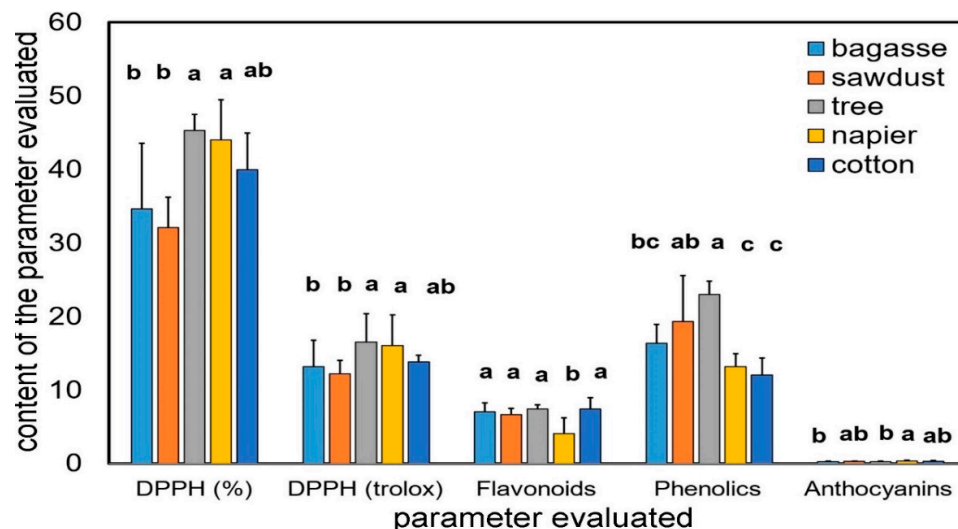


Figure 2. Antioxidant activity (DPPH in % and mg TE g⁻¹; y-axis), total flavonoids (mg CE g⁻¹; y-axis), total phenolics (mg GAE g⁻¹; y-axis), and total anthocyanins (mg CGE g⁻¹; y-axis) in shoots of parsley plants grown in medium composed of bagasse–chicken compost + biochar, sawdust–chicken compost + biochar, tree–chicken compost + biochar, napier–chicken compost + biochar, and cotton–chicken compost + biochar. Biochar was added to the composts at five inclusion rates (0, 15, 30, 45, and 60%, weight basis) and the average values used in statistical analyses. Error bars represent standard deviations. For each parameter, bar values followed by the same letter are not statistically different ($p < 0.05$; ANOVA Duncan post-hoc test).

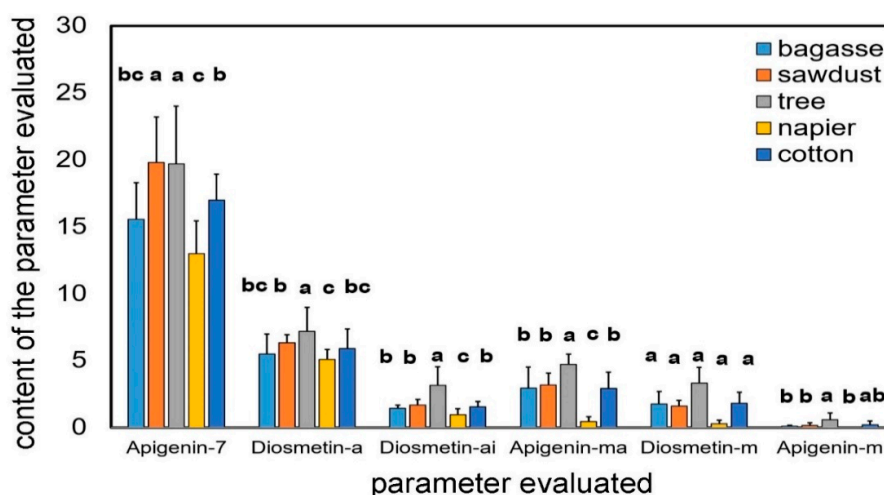


Figure 3. Flavonoid composition (apigenin-7-apiosylglucoside, diosmetin-apiosylglucoside, diosmetin-apiosylglucoside isomer, apigenin-malonyl-apiosylglucoside, diosmetin-malonyl-apiosylglucoside, and apigenin-malonylglucoside in mg g⁻¹; y-axis) in shoots of parsley plants grown in medium composed of bagasse–chicken compost + biochar, sawdust–chicken compost + biochar, tree–chicken compost + biochar, napier–chicken compost + biochar, and cotton–chicken compost + biochar. Biochar was added to the composts at five inclusion rates (0, 15, 30, 45, and 60%, weight basis) and the average values used in statistical analyses. Error bars represent standard deviations. For each parameter, bar values followed by the same letter are not statistically different ($p < 0.05$; ANOVA Duncan post-hoc test).

4. Conclusions

Our study shows that organic amendments can greatly affect the nutritive and health value of foods. Composts were manufactured using piles of broiler wastes and sugarcane bagasse, sawdust, urban tree debris, napier grass, or cotton residues. All the compost-biochar mixtures tested in this study had various effects on mineral and phenolic compounds in parsley. The bagasse and sawdust composts led to the highest N and P levels and yields. Highest phenolic levels were measured in plants grown with the tree compost. The napier compost generally did not cover the nutritional requirements of the plants.

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