Agricultural valorization of sludge compost: the case of the potato

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Abstract– In Morocco, the protection of the public health and of the environment depends of the preservation of resources in water and of ground. The storage not controlled of sludge threatens these resources and constitutes one of the major environmental problems which concern the researchers and the Moroccan authorities.

For this reason, our study aims to produces compost which responds to the standard NFU44-095 and plays the role of fertilizer of ground from co-composting of sludge of the treatment plant of the Fez city with others biodegradable waste and its application on the cultivation of the potato in the conditions of the farmer.

The obtained results showed significant increase parameters of vegetative growth and of potato production amended with the compost with sludge. The results of alimentary quality not attested any change with this type of amendment.

Key words– Sludge, co-compost, fertilizer, vegetative growth, potato, alimentary quality.

1 Introduction

THE estimation of wastewater rejected in Morocco will pass from 600 million of m³ in 2005 to 900 million of m³ in 2020 [1]. These wastewater present risk potential of pollution of resources in water and the ground.

Treat them before their reintroduction in the natural environment became a necessity.

However, their treatment generates quantities of sludge estimated in 2010 to 40000 tons and which is expected to be multiplied around 8 times in 2025 [2]. In absence of legislation on the sludge, they finish often in garbage dump. A forbidden practice in many countries, because of their humidity rate very high, which is not without impact on functioning of the dump and on the production excessive of leachate [3].

In France, many treatments are set in place to limit the volume produced, the odour and the harmfulness of sludge. The three procedures used are: the landfilling (25%), incineration (15%) and the agricultural spreading (60%) [4]. In effect, the incineration contribute to the release of toxic gas, but it can't be a solution feasible because of cost very high of incinerators installations. The landfilling need preliminary operations of stabilization and of dehydration pushed, gradually diminishing its interest for financial reason and juridical. For use agricultural, the direct spreading of sludge not treated is about the hesitation from the farmers, because of the risks associated with the presence of pathogens and odour nauseous [5], despite their wealth in organic matter, nitrogen, phosphorus, trace elements.

In Morocco, the law 10-95 about water forbids any rejection, any spreading, and any waste likely to pollute the waters…) [6]. Thus, in absence of law which regulate the use of sludge, Morocco must be careful by allowing only the spreading of sludge treated beforehand by composting, biomethanisation or thermal drying in order to ensure their stabilization and their hygienisation [7].

This was the objective of a previous work that focused on the recovery of waste sludge from STEPs in the city of Fès through the co-composting sector and the development of sludge compost in the standards of an organic amendment.

The present study is an application of composts produced in the field in order to test our products on the market on the one hand and to share our expertise with farmers and work in their conditions on the one hand. And without agronomic importance and its presence on the market, our choice for this test was the potato. It is among the most coveted vegetable crops in the region of Fez-Meknes “[8].

2. Materials and Methods

2.1 Materials:

2.1.1 Plot of the test:

It is located in SEPT LOUDAYA – Douar KLABA, with an area of 1 ha, his previous crop was tender wheat and his irrigation system is drip.

2.1.2 Amendments used

- Manure (F): procured from farms of Mkansa region.
- C and CB: they are composts, Witness C and with sludge CB, made from sludge and other substrates of nature and of different compositions.

2.1.3 Vegetable material tested

It's about potato of variety ARGOS, considered among variety that adapts very well to the need for little nitrogen fertilizer and tolerates heat well, drought and present a good yield in extreme climatic conditions.

2.2 Methods:

2.2.1 Sampling:

We exploited the systemic random method by square mesh. The surface has been divided into three equivalent portions to have 3 meshes having the same dimensions. Soil samples, with equal masses, were taken from the centre of each mesh which was then mixed, homogenized, to form a single composite sample.

2.2.2 Statistic study

A descriptive statistical study was carried-out for the different results obtained by the univariate linear model. This would allow doing a comparison between the effect of the products on each test and parameter [9].

2.2.3 Characterization of amendments

All materials were characterized by pH, conductivity (EC), organic matter (% MO), Kjeldahl nitrogen (NTK), mineral nitrogen, phosphorus (expressed as P_2O_5), potassium (expressed as K_2O), and report C/N.

2.2.4 Location of the field

In this study, the spatial delineation map for the study area was georeferenced in GIS with Qgis software 8.02, in geographical coordinates Lambert Conic Conform (Merchich Morocco+ the coordinates Lambert coordinate gps: X: –5, 331717 et Y: 34, 266367)

2.2.5 Characterization of soil and irrigation water

Comprehensive soil and water analyzes for irrigation have been carried out by Agrilabo: a specialized laboratory approved by the Ministry of Agriculture and Maritime Fisheries.

2.2.6 Nutritional quality

The nutritional quality of the potato was evaluated by measuring traces of heavy metals by inductively coupled plasma (ICP). Its protein content was tested by the macro-Kjeldahl method [10], its dry matter, and its starch content and in fiber as well as energy value was made by an approved agri-food laboratory.

2.3. Concept of potato planting test

The allocated land was prepared by refinement followed by a reversal of the soil and finally divided into 3 parcels of 33334 m^2 each. Each parcel was amended by one type of amendment (manure, compost C and compost with sludge CB) at a rate of 6 tonnes per hectare.

The plantation was carried out after one week of amendment.

The cultivated field was loosened by the germinated potato on 20 cm deep. The spaces between the seed potatoes are of the order of 30 cm and the rows of 70 cm. These plants, in buttes form, have been gently covered by the earth.

2.3 Planting monitoring

The crop was accompanied by a weekly monitoring controlling the morphological parameters until the day of the harvest. Measurement of all parameters was done three times to ensure reproducibility and repeatability of the results. The value taken into consideration is the average of the three measurements. The measured parameters are: leaf area, the number of stems / plant and the length of the stems / plant.

The day of the harvest, we evaluated: the number of tubers / plant, the yield / plant, size and total efficiency.

3 Results and discussion

3.1 Characterization of the amendments used

The physico-chemical characterization of the amendments F, C and CB (table1) certifies that they carry a high organic load and a low mineral charge. Both composts C and CB are slightly basic and are characterized by total organic carbon, total nitrogen Kjeldahl, of the C / N report, mineral nitrogen, phosphorus and potassium greater than that of manure. What classifies them in ascending order loads in these elements F <C <CB, this seems to be due to the sludge load in nutrients N, P, K [11], [12].

Table 1: Characterization of the studied amendments (CB, C and F)

Products / Settings	CB	C	F
pH	8.15	8.13	7,57
CE (mS/cm)	4.03	2.55	3,44
Dry matter (%)	93.52	92.43	90,56
Organic material (%)	41,67	49,84	38,07
COT (%)	24.17	28.91	20,5
NTK (%)	1.95	2.22	1,45
C/N	12.38	13.02	14,13
Phosphorus (expressed in P2O5) in ppm	1785,95	412,80	367,83
Potassium (expressed in P2O5) in ppm	9914,40	6432,80	5853,23
Azote (expressed in azote mineral) in ppm	55,9	53,70	49,65

3.2 Spatial location of the study area

GIS geographic information system software was used for digitization, the integration, the overlay and the spatial data presentation of the study area (cultivated field of Sebt Loudaya figure 1). Its location was achieved using the global positioning system (GPS) which provides a good accuracy of geographic coordinates.

Figure 1: Delimitation of the field

3.3 Characterization of the soil

The results of the soil analysis, presented in Table 2, shows that it is a heavy textured parcel of clay loam, nope calcareous and at moderately alkaline pH. The plot is low in nitrogen, in phosphorus and organic matter.

The level of organic matter MO is low, this could reduce soil biological activity, limit its water reserves, to make the work of the land difficult "[13]. Therefore, the addition of manure or compost could provide more major nutrients, trace elements essential for growth and a good fruiting. They could also contribute to the improvement of soil quality (permeability and structure) "[14], straighten, to ensure the needs of culture and support soil phosphorus reserves.

The soil has a moderately high potassium load which remains insufficient to cover all the needs of the potassium cultivation to reduce the fractional input of potassium fertilizers. The results also show that it is a soil with medium chloride content, low in dissolved salts, without fear of salinization problem and low in trace elements.

Table 2: Soil analysis

Texture du sol						
Argile	Limon fin	Limon grossier	Limon totaux	Sable fin	Sable grossier	Sable totaux
28,99	40,44	19,37	59,81	10,55	0,65	11,2

Statut acido-basique			
pH eau	pH KCl	Calcaire total %	Calcaire actif %
7,65	7,00	32,62	10,58

Paramètres de maturation	
Azote minéral (mg/Kg)	Matière organique %
44,90	1,42

Salinité	
EC mmhos/cm	Sodium échange Na2O
0,204	154,62

Métaux lourds par MS en mg/Kg			
Cuivre	Zinc	Fer	Manganèse
0,50	0,24	6, 32	0,61

Eléments solubles en mg/Kg							
Chlorures Cl-	Calcium soluble Ca++	Magnésium soluble Mg++	Phosphore soluble P+	Sodium soluble Na+	Potassium soluble K+	Bicarbonates solubles HCO3-	Sulfates solubles SO4--
53,20	104,20	9,70	Traces	41, 10	31,60	1073,60	11,40

Based on the results of the soil analysis, a FERTI PLAN (Table 3) has been proposed by the laboratory to improve and maximize the quality and volumes of the harvest. The proposed plan includes soil remediation and adaptation to the needs of the potato as it grows.

Table 3: Ferti plan for potatoes

Contribution period	Nature of fertilizer	Quantity of fertilizer: Unité /Hectare	Quantity of fertilizer: Kg/Ha
Fumure background	Ammonia sulphate 21% TSP% Potassium	30 100 50	150 210 100
Planting - The beginning of tuberculosis (Early appearance of tubers) Every week	Ammonitrate 33,5% TSP 45% Potassium	08 08 09	25 15 20
The beginning of tuberculosis - Early growth of tubers Every week	Ammonitrate 33,5% TSP 45% Potassium	12 10 14	35 25 30
Tuber bulging Every week	Ammoniacale 33,5% TSP 45% Potassium	18 10 23	55 25 50

There is 3 growth stage of the potato. Each stage has its own nutritional needs. According to soil analysis, the plant needs at first 150 kg of ammonium sulphate (21%) which will cover the urea plant's needs, 210 kg of triple super phosphate (TSP) 45% that will provide phosphorus requirements for potatoes and 100 kg of potassium. These quantities should be put as soil fertilizer in the soil before planting. Then, at the time of appearance of tubers, 25 kg of ammonitrate (33.5%), 15 kg of triple super phosphate (TSP) and 20 kg of potassium should be added. These contributions would favour the germination of the plant.

At the time of appearance of tubers, 55 kg of ammonitrate, 25 kg of triple super phosphate (TSP) and 50 kg of potassium should be added, which would ensure a good bulge of the potato.

3.4 Characterization of irrigation water

The results of the irrigation water analysis, testify that they have a moderately alkaline pH and present an electro conductivity content of 1133 µs/cm conferring on them a moderately high load of dissolved salts.

The low total hardness of this water, expresses average levels of calcium and magnesium. The concentration of bicarbonates is high which can lead to chlorosis risks of this calcareous soil. The dominant chemical facies of this water is calcium bicarbonate.

The sodium chloride levels are average. The concentrations of potassium, ammonium, sulphates, phosphates and nitrates are low.

Depending on the Fraction of Sodium Absorbable SAR, this water is classified in C3 S1. It is water with a high risk of soil salinization and low risk of soil alkalization. This water can be used on a well-laid ground, with good drainage skills and on a crop with a good tolerance for salt as is the case with potatoes

Table 4: The irrigation water analysis

Charge Cationique en mg/l				
Sodium Na^+	Potassium K+	Magnésium Mg2+	Calcium Ca2+	AmmoniumNH4+
99,54	10,27	38,89	68,52	Traces

Charge Anionique en mg/l					
Chlorures Cl^-	Carbonates CO3-	Bicarbonates HCO3-	Dihydrogénophosphate H_2PO_4	Sulfates SO42-	Nitrates NO3-
142,00	00,00	339,16	01,44	66,70	1,50

Alcalinité et salinité				
pH	Conductivité (µs/cm)	Salinité (Teneur en sels totaux)(g/l)	Titre hydrotimétrique (méq/l)	Fraction Sodium Absorbable
7,65	1133	05, 44	0,72	2,63

3.5 Cultivation of the potato

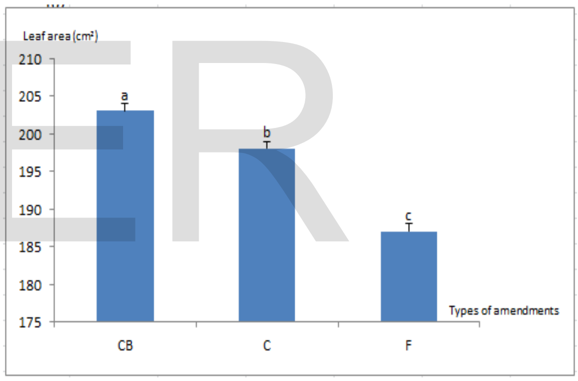
The growth of the potato was monitored by measuring morphological parameters, consisting of: leaf area, the length of the stems and the number of stems, and production parameters corresponding to the measurement of the caliber, yield per plan, the number of tubers per plant and the total yield.

3.5.1 Morphological parameters

3.5.1.1 Leaf area

In botany and agronomy, the specific leaf area (SLA) is defined as the ratio of leaf area to leaf dry weight. It is positively correlated with the photosynthetic capacity of the plant and its production "[15]. The results of the analysis of the variance on the (Figure 2), showed a significant effect for leaf area between the two composts and the manure. This parameter varies from 187.82 cm^2, to 202.96 cm^2 and from 198.16 cm^2, obtained by the manure, compost with sludge and without sludge, an increase of 7,88 and 5,63% respectively compared to the manure. This means that the yield of plots amended by composts is expected to be better. The coefficient of variation is 1.84%.

Figure 2: Leaf area of the potato leaves according to the type of amendment



3.5.1.2 Number of stems per plant

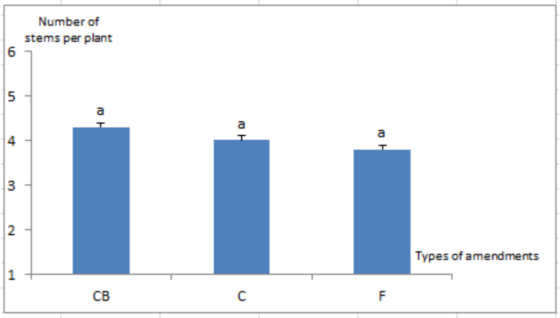
The potato has two types of stems:

- Aerial stems of circular or angular section, on which are placed the leaves and underground stems,
- The stolons, on which the tubers appear [16], [17].

Aerial stems are born from buds present on the tuber used as seed. They are herbaceous, succulent, and may range from 0.6 to 1.0 m in length and vary in number from 3 to 6 main stems [18], [19].

The results of the variation of the number of stems per plant as a function of the type of the amendment are presented in Figure 3. Analysis of the variance shows no significant effect of the amendments on number of stems per plant. This parameter varies from 3 to 4 stems per plant for all applied amendments.

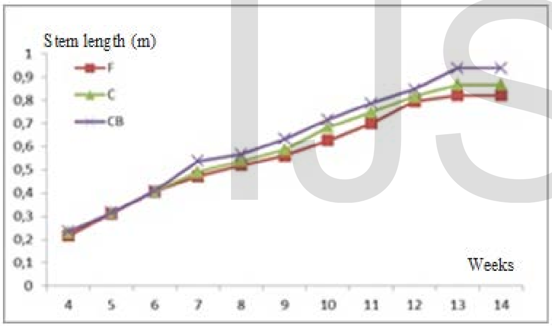
Figure 3: Number of potato stems per plant depending on the type of amendment.



3.5.1.3 Length of stems per plant

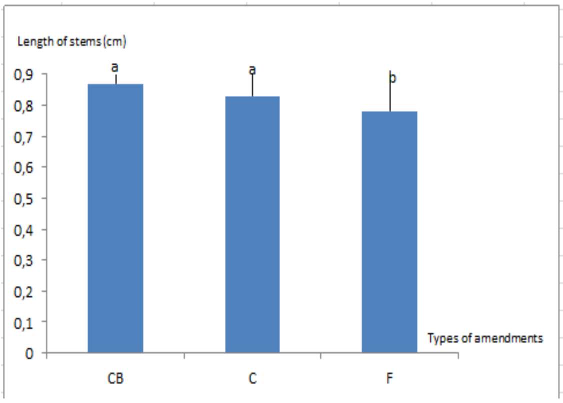
In plants, the rod constituting the axis generally aerial or underground (stem tuber, rhizome), prolongs the root and carries buds and leaves. In Figure 4, the length of the stems has changed since the 3rd week of the appearance of stems. The best stem length is observed in CB-amended potato with a length of 0.9 m. These results confirm those of the small plot of the laboratory "[20]. Thus, the high content of CB in nitrogen was responsible for the development of the green parts of plants and played a vital role in plant growth.

Figure 4: Evolution of the stem length of the potato as a function of time.



The analysis of the variance showed a significant effect by modifying the type of amendment. This length goes from 0.77 m for the manure indicator to 0.91 cm for CB and 0.89 for C, a rate of increase of 17.79 and 15.58% respectively for CB and C compared to manure.

Figure 5: Potato stems length depending on the type of amendment.



3.5.2 Production parameters

The harvesting of the potato was carried out after 3 months of its planting.

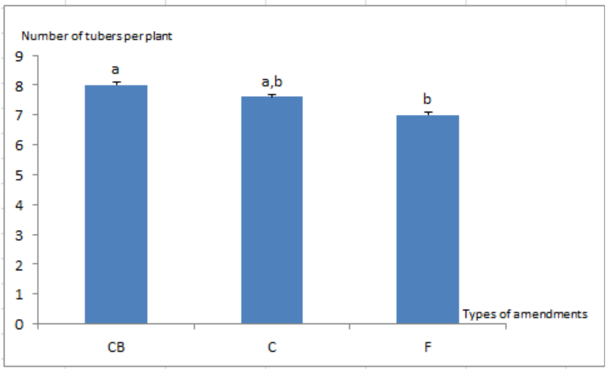
Figure 6: Harvesting the potato.

3.5.2.1 Number of tubers per plant

In Figure 7, the analysis of the variance relative to the number of tubers per plant shows a significant effect of the different types of amendment. The number of tubers is 6 per plant for manure, 7 for C and 8 for CB; an increase of around 14% and 28% respectively for C and CB, respectively, relative to the manure.

Increasing the number of tubers in soils amended by compost C and CB compost can be explained by their high levels of organic matter and nitrogen, which enrich the soil with minerals, thus providing the potato with the nutrients necessary for its reproduction and growth [20], [21], [22].

Figure 7: Number of tubers per plant depending on the type of amendment.



3.5.2.2 Tuber size

The results of the variance study shown in Figures 8 and 9 show that the compost with sludge has significantly improved the size of the tubers. The difference is significant compared to manure and compost without sludge. We conclude then, that compost with sludge has improved the development of tubers during bulging due to its high potassium content. Potassium deficiency extends over a period of 30 to 40 days [23], [24]. It manifests itself, especially at the beginning of the appearance of tubers when the need for potassium reaches its peak. Normally potassium increases the average size and proportion of tubers. Archer demonstrated that the proportion of marketable tubers was 84.4% with 0 kg K_2O / ha; 85.6% with 188 kg K_2O / ha and 86.6% for the 282 kg K_2O / ha dose “[25].

Figure 8: Foliar tuber diameter according to types of amendment

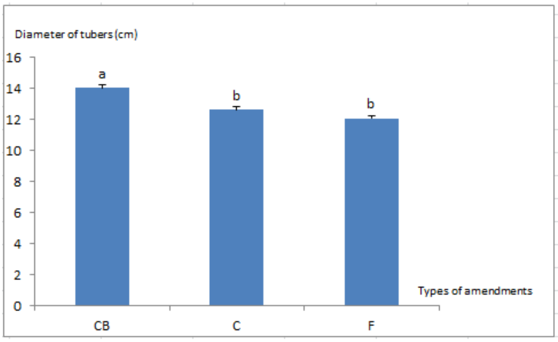
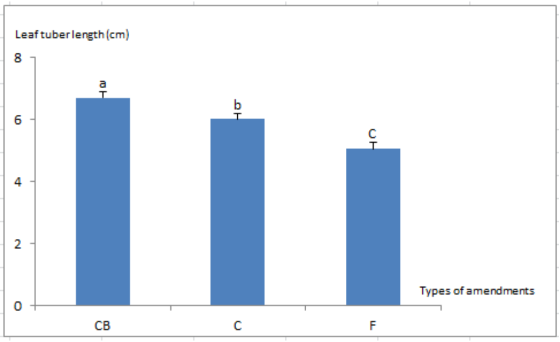


Figure 9: Leaf tuber length according to types of amendment



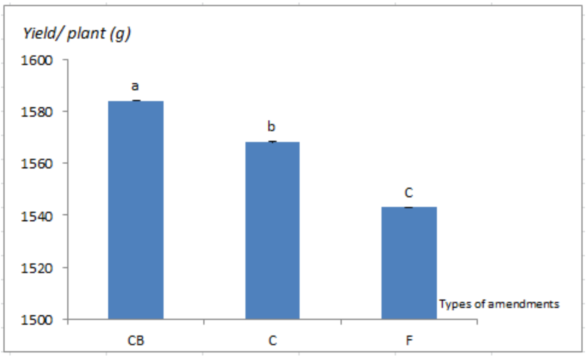
3.5.2.3 Yield per plant

The yield per plant was significantly influenced by the soil amendments. The difference in this yield can be explained by the contribution of the organic matter and nitrogen of potassium and phosphorus by the amendments used. The products have provided the potato with more necessary elements that promote its reproduction and maturation. According to previous studies, the physical characterization of bio-waste shows that the latter contain more than 95% of organic matter. The chemical composition shows that the bio-waste contains a major content of elements (N, P, K ...) allowing their use in horticulture. The experiment showed its efficiency by increasing the yield compared to the unmodified ones [26], [27].

Variance analysis showed a highly significant effect on tuber weight per plant. This goes from 1543 g in manure soils to 1568.2 g in compost without sludge and 1584.26 g in compost with sludge. The rate of increase is of the order of 14.51 and 5.5% respectively for compost with sludge and without sludge.

The coefficient of variation is 1.088%.

Figure 10: Tuber yield per plant according to types of amendment

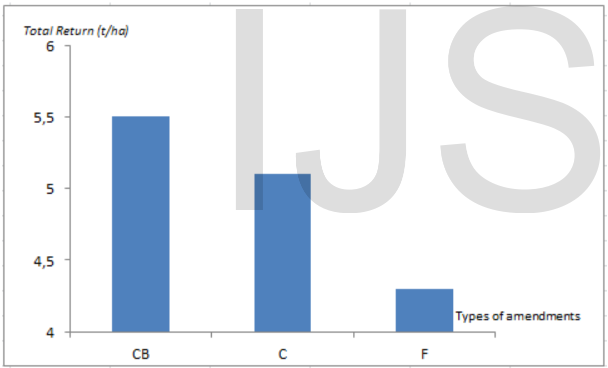


3.5.2.4 Total yield

The total yield was significantly influenced by the change in soil amendments. A significant increase in yield was obtained with the plots amended by the compost in comparison with those amended by the manure. The total harvest was 4.3 t / ha, 5.1 t / ha and 5.5 t / ha of potatoes in the amended parcels respectively by manure, compost without sludge and compost with sludge. An increase of 18, 6% and 27, 9% respectively for C and CB.

The results show that CB compost is of better quality than compost C and manure. This corroborates with the results obtained by the plots of the laboratory without fertilizer where the increase was 7% for C and 34% for CB compared to manure "[28]. Therefore, CB compost provided the potato with more elements necessary for its germination, reproduction and maturation. This confirms that in the presence or absence of fertilizers, compost with sludge has improved crop yield. The variability of the increases can be explained by the textural difference of the soil or by the variety of potatoes used in both trials.

Figure 11: Total yield of the potato according to the type of amendment.



3.6 Nutritional quality of the potato

The potato has a varied nutritional profile. It has all the assets of a starch, but also fibers, vitamins and minerals. A dietary food that also fits in low calorie diets "[29].

To evaluate the nutritional quality of potatoes grown, they were compared to marketed potatoes procured from the market. The results of the analyzes in Tables 5 and 6 show that potatoes obtained from land amended by both composts C and CB have the same nutritional value as those grown with manure or those marketed. The results thus found join those of Ambroise Martin "[30], [31] who concludes that the potato produced is rich in water (80% water). Dry matter consists of 80% starch, 7% fiber, 3% protein and 10% minerals and vitamins with an energy content of 19 g carbohydrates, 2 g protein, 0.1 g fat and 85 Calorie kcal.

Table 5: Nutritional quality of cultivated potatoes

Analyses / Potatoes	Trace heavy metals	Protéines (%)	Amidon (%)	Fibres (%)
Potato with sludge	Negative	3	80	7
Potato of land without sludge	Negative	3	80	7
Potato with manure	Negative	3	80	7
Potato of land marketed	Negative	3	80	7

Table 6: Energy values of cultivated potatoes

Energy values / Potatoes	Glucides (g)	Protides (g)	Lipides (g)	Calorie (Kcal)
Potato with sludge	19	2	0,1	85, 03
Potato of land without sludge	19,01	2	0,1	84,76
Potato with manure	19	2	0,1	85,03
Potato of land marketed	18,97	2	0,1	85,00

These results show that the soil amendment improves crop yield and soil quality and confirms the work of Chuimika Mulumbati Magnifique who has shown that bio-waste, sanitation products, is potentially a good fertilizer "[32]. They can either mitigate the thorny problem of low soil productivity by their contribution; reduce the cost of production due to the use of manure, which in most cases requires prior treatment. But in this case, it does not influence the nutritional quality of the potato.

CONCLUSION

Applying the three types of amendments for potato planting reveals:

- a significant increase in production and vegetative parameters;
- the same nutritional quality of the potato as those marketed
- an improvement in soil quality in organic matter, namely carbon, trace elements, nitrogen, potassium and phosphorus
- a good development of foliage of the potato
- good formation and bulging of tubers

The best results for the morphological and productive parameters of the potato were recorded for the amendment CB (compost with sludge). These results further confirm the important role that sludge plays in soil fertilization and the value of sludge upgrading in the composting and agricultural sectors in order to increase crop yields.

Therefore the use of composts appears as a palliative solution to the double problem of unsanitary Moroccan soil and lack of foodstuff following soil infertility.

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