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EFFECT OF ORGANIC FERTILIZERS ON NUTRITIONAL AND PROCESSING QUALITY OF POTATOES (*SOLANUM TUBEROSUM L.*)

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ABSTRACT: The aim of this study was to determine the effect of different organic fertilizers on the nutritional and processing quality of potatoes. Composting of different materials was done using 12 forumulations and it lasted 6 months. These compost formulations were used to grow potatoes, Kinigi variety, at the rate of 10 tonnes per hectare and control was used as well. Parameters analysed were moisture content, crude protein, crude ash, crude fibers, reducing sugars and total sugars using standard methods. There was a significant difference in parameters analysed for different treatments at $P < 0.05$. Mositure content ranged from 73.05 to 80.44%, proteain from 1.22 to 3.64%, ash from 0.17 to 2.12%, fiber from 3.04 to 4.08%. Analysis of sugars showed that reducing sugars ranged from 1.29 to 2.28% and total sugars from 2.22 to 2.94%. These potatoes are suitable for boiled and mashed products. However, due to high sugar content, they are not suitable for dehydrated and fried products. Controlling maturity and handling should be emphasized in order to reduce the amount of reducing sugars.

KEYWORDS: Compost fertilizers, Nutitional quality, processing quality, potatoes, reducing sugars

INTRODUCTION

Potato *(Solanum tuberosum L.)* is an edible tuber which belongs to the family of Solanaceae and genus Solanum. It is an annual, herbaceous, dicotyledonous and vegetatively propagated plant that can grow as a perennial in selected environments and propagate through botanical seeds commonly known as true potato seed (CIP, 2022). It is the fourth most important in terms of human consumption after maize, wheat and rice. Potato consumption in Rwanda is at 145kg per capita (Rukundo, 2019). It grows well in Northwest part of the country. A good quality of potato is characterized by low moisture content around 80%, uniform shape and size with low reducing sugars. It has become a routine to use fertilizers in order to enrich soils with lacking nutrients which leads to the increase in productivity.

To meet the food requirements of the growing population, the increase of food productivity for arable land is crucial. Nutrition of the plant is an important factor to control the productivity. Continiuous use of agricultural land deplates nutrients in soil which leads to poor productivity (Savci, 2012). To mitigate this, people have adopted the use of fertilizers to increase productivity. Fertilizers are added to the soil to improve its physical, biological, and chemical properties. A physical property is related to soil friability, porosity and absorption (Sharma and Chetani, 2017). Biological properties are related to the

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microorganisms living in the soil (Sharma and Chetani, 2017). The chemical properties encompasses the soil pH (acidity level) and the availability of nutrients to the plants for absorption (Sharma and Chetani, 2017). Fertlizers contribute to rapid growth of the plant with bigger and healthy crops which leads to more food production. Use of mineral fertilizers has contributed to food security in many nations though it has left other many unsolved problems.

During industrial revolution which was followed by green revolution, the world adopted the use of inorganic fertilizers to increase production per unit area. Inorganic fertilizers comprise nitrogen fertilizer, potash fertilizer, phosphorus fertilizer, and compound fertilizers (Sharma and Chetani, 2017). Some of the minerals which are used in food production accumulate in the environment and lead to the environmental pollution. Excessive use of nitrogen in inorganic fertilizer leads to the leaching and accumulation of nitrate in drinking water and rivers (Savci, 2012). It was reported that around one third to one fourth of applied nitrogen fertilizer is lost as ammonium and nitrous oxide gases to the atmosphere or as nitrates to the surface or ground waters and they are associated with the environmental and health problems (Bahar *et al.,* 2019). Use of inorganic fertilizers was also reported to negatively affect the soil. Fertilizers containing sodium and potassium deteriorate soil structure and increase its acidity (Savci, 2012). Inappropriate application of inorganic fertilizer can lead to the emission of different gases which threaten the environment. These gases include carbon dioxide, methane, hydrogen sulfide with chloro-fluoro hydrocarbons like halon gases (Savci, 2012). Inorganic fertilizers contribute to the deterioration of the ecosystem.

Accumulation of chemical wastes in soil, water and air imparts a continuous toxicity to the marine and land ceatures. Chemical wastes accumulates in the water bodies and when it is used in soil during irrigation, its continuous use degrades the soil health and quality hence causing the soil pollution. As a results environment and ecosystem are greatly destroyed. Accumulation of nitrogen in water leads to eutrophication which threatens marine life, while nitrosamines resulting from nitrates was reported to be carcinogenic (Bahar *et al.,* 2019). The adverse effect of these synthetic chemicals on human health and environment can only be reduced or eliminated by adopting new agricultural technological practices such as shifting from chemical intensive agriculture to organic agriculture which include the use of organic inputs such as manure, bio fertilizers and nanofertilizers that would improve the human health as well as environmental and ecosystem protection. Opting to organic farming will create a healthy natural environment and ecosystem for the present as well as future generation.

Organic fertilizer which consists of use of compost has been found to be more useful. Compost is a soil amendment produced through the metabolism of an organic substrate by aerobic microbes under controlled conditions. It is an ancient agricultural technology with important applications in modern cropping systems. In organic cropping systems, compost provides a primary source of nutrients to the crops (Seyedbagheri, 2010). It is an organic fertilizer that can be made at farm level and it consists of decomposed organic matter, such as crop residues or animal manure, most of these ingredients can be easily found around the farm (Seyedbagheri, 2010; Sharma and Chetani, 2017). A good compost is made up with five main components such as greens, browns, water, air and soil (Seyedbagheri, 2010). It can also be a mixture of organic residues like manure, animal carcasses, straw, etc, that have been piled, mixed and moistened to undergo thermophilic process where microorganisms can feed on the organic components and convert the piled organic material to fairly stable nutrients rich soil amendment

Organic farming tends to be better for the environment by reducing pollution, conserving water and water health, reducing soil erosion, increasing soil fertility and health, and using less energy (Sharma and Chetani, 2017). Organic farming also creates healthy soil that does not need much water which results in growing healthy food. On the other hand, treating soil with harmful chemicals makes the soil dependent on these unnatural substances. Inorganic fertilizer is loosing popularity for both environmentalists and consumers.

Due to the increasing perception of consumers on the negative effects of synthetic fertilisers which have dominated agriculture of potatoes in Rwanda, and due to the high consumption rate of potatoes in Rwanda, it is worthwhile to increase potato production while using agricultural inputs which will protect environment with less or no heath threatening effects. Therefore, the current research was conducted to evaluate the contribution of different organic fertilizers on chemical composition of potatoes.

MATERIALS AND METHODS

Area of study and composting

The experiment was conducted in Northern province, Musanze district, Busogo sector, UR-CAVM farm and laboratories. It is geographically located at 1°33′26′′ S and 29°32′39′′E with altitude of 2221.00 m. The site is characterized by Andosol due to volcanic soil. The average temperature is 17.9°C with average annual rainfall of 1420 mm (Climate-Data.Org, 2021). different composts were utilised for potato cultivation in the period of May to October 2021 and Kinigi variety was used. Each composting treatment had 3 m for length, 2 m for width and 1.7 m of height. The composting lasted 6 months. Mixing was done every month while 40 liters of cow urine or 40 liters of pig urine were applied every two weeks in case it did not rain in that period. Fertilizer application was at the rate of 10 tonnes of compost fertilizer per hectare. Details of compost fertilizers used are described below.

T1: Eucalyptus (fresh+ dry) + cow manure +cow dung+ soil

T2: Cyprus (fresh+ dry) + cow manure +cow dung+ soil

T3: Alnus (fresh+ dry) + cow manure +cow dung+ soil

T4: Eucalyptus (fresh) + Cyprus(fresh) + Alnus (fresh+ dry) + cow manure +cow dung+ soil

T5: Eucalyptus (dry) + Green plant + cow manure +cow dung+ soil

T6: Cyprus (dry) + Green plant+ cow manure +cow dung+ soil

T7: Alnus (dry) + Green plant+ cow manure +cow dung+ soil

T8: Eucalyptus (dry) + Cyprus (dry) + Alnus (dry) + Green plant+ cow manure +cow dung+ soil

T9: Eucalyptus (dry) + Cyprus (dry) + Alnus (dry) + Human hair+ Green plant+ cow manure +cow dung+ soil

T10: Human hair + Green plant+ soil + cow dung

T11: Cyprus (dry) + Green plant + pig manure + soil + pig dung

T12: Human hair + Green plant + soil from Alnus + cow dung

T13: No compost fertilizer was used

Proportions used:

- Layer of 30 cm of fresh mulch (when used alone)
- Layer of 20 cm of fresh mulch (when used with dry mulch)
- Layer of 10 cm of dry mulch (where it was applied)
- 45 kg of the cow manure compost
- 60 kg of the topsoil
- 20 liters of cow urine or pig urine
- One basin of human hair

Sample preparation

From each treatment 1 kg of potato of processing size was taken. Selected potatoes were fresh, free from disease and damage. They were transported carefully to UR-CAVM laboratory for further preparation and analysis. Selected potatoes were washed in tap water and spread at room temperature to dry off adhering water. They were thereafter sliced, dried in oven at 45°C until dried. They were then ground into flour and kept in refrigerator at 4°C for further analysis.

Determination of moisture content

Moisture content was determined using standard method (AOAC 2000). About 2 g of potato powder were weighed into a crucible dish and placed in heating oven at 105°C for 2 hours. The moisture content was computed as follows:

$$\text{Moisture content } \% = \frac{\text{Weight of wet sample-weight of dried sample} \times 100}{\text{Weight of wet sample}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Determination of crude protein

Crude protein was determined using kadjeldhal standard method (AOAC, 2000). About 2 g of finely ground flour were used. conversion factor (CF) used was 6.25

$$\text{N } \% = \frac{\text{ml acid for sample-ml acid for blank} \times \text{morality HCl} \times \text{DF} \times 14 \times 100}{\text{Weight of sample in mg}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$\text{Crude protein } \% = \%\text{N} \times \text{CF} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3$$

Determination of ash content

Crude ash was determined using(AOAC, 2000) method. About 2 g of sample of potato powder were weighed and added into the crucibles and placed in muffle furnace at 550°C for 4 hours. The ash content was computed as follows:

$$\text{Crude ash } \% = \frac{\text{Weight after ashing} \times 100}{\text{Weight of the sample}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 4$$

Determination of crude fiber content

The method used by (AOAC, 1995) was adopted. The reagents consisted of 1.25% of sulfuric acid and 1.25% of sodium hydroxide. About 5 g of finely ground flour were weighed into a graduated glass beaker and 100 ml of hot water was added before adding 25 ml of sulfuric acid. The volume was increased to 200 ml with hot water and the contents were boiled for 30 minutes. Timing started onset of boiling and the volume was kept at 200 ml by constantly adding hot water with gentle boiling. After 30 minutes, they were vacuum filtered using the filter sticks packed with glass wool and washing was done three times with hot water. Thereafter, about 100 ml of hot water was added before adding 25 ml of 1.25% sodium hydroxide and the volume was increased to 200 ml with hot water and kept constant during boiling by adding hot water. The filter sticks were allowed to remain in the solutions with residue and boiled for 30 minutes. After they were removed, filtered, and washed three times with hot water. Residues and glass wool were transferred in 75 ml porcelain dish. The beaker of all residues were washed using hot water into the dish while filtering. Further washing was done and filtrates were collected in clean and dry crucible. The crucible with contents were dried in oven set at 105°C overnight, cooled in desiccator and weighed accurately. They were thereafter placed in the furnace set at 550°C for 4 hours to ash and then allowed to cool to about 100°C and then continue cooling in a desiccator to room temperature and weighed.

$$\text{Crude fiber \%} = \frac{\text{(Weight of oven dried sample- weight of ashed sample)} \times 100}{\text{Weight of fresh sample}} \quad ....5$$

Determination of reducing sugars

The Lane and Eynon titration method using Fehling's solution was used for determination of reducing sugars (RS) and total sugars (TS) (AOAC, 2000) no 925.35. About 10 g of sample were homogenized in 100 ml distilled water to dissolve all suspended particles followed by filtration with Whatman filter paper in a 250 ml volumetric flask. From filtrate, 10 ml of diluted HCl was added and boiled for 5 min. The obtained solution was allowed to cool at room temperature and neutralized with 10% NaOH using 3 drops of phenolphthalein as an indicator. It was there after made up to volume in a 250 ml volumetric flask with distilled water. The solution was titrated with Fehling's solution using 3 drops of methylene blue as an indicator and readings were recorded at the brick red end point and calculation used the formula below:

$$\text{Reducing sugars \%} = \frac{4.95 \text{ (factor)} \times 250 \text{ (Dilution)} \times 100}{\text{Weight of the sample} \times \text{Titre} \times 1000} \quad ....6$$

$$\text{Total sugars \%} = \frac{4.95 \text{ (factor)} \times 250 \text{ (Dilution)} \times 2.5 \times 100}{\text{Weight of the sample} \times \text{Titre} \times 1000} \quad ....7$$

Data analysis

Analysis of Variance was done using Minitab17 statistical software at 5% level of significance. Means separation was done using Tukey's HSD.

RESULTS AND DISCUSSION

Moisture content of potato

Moisture content of analysed potatoes was significantly different at ($p<0.05$). The moisture content ranged from 73.05 (T8) to 80.44% (T12) as presented in Table 1. Norell *et al.* (2016) reported moisture content of 75 to 85% which aligns with this study. Moreover, these results agree with a study done on eleven cultivars in India showing a range from 78.10% to 84.85% of moisture content for fresh potatoes and from 77.2% to 83.7% after cold storage of six months (Pal *et al.*, 2008). Based on this study the moisture content for treatment (T12) was the highest,

Table 1 Nutritional compostion of potatoes in percentage of fresh weight

Treatment	Moisture%	Protein%	Ash%	Fiber%
T1	75.18±0.014^{h}	2.27±0 ^{cd}	0.32±0.11^{fg}	3.15±0.02 ^{i}
T2	73.70±0.015 ^{j}	2.68±0.2 ^{b}	0.23±0 ^{g}	3.67±0.02 ^{g}
T3	80.34±0^{b}	2.56±0.2 ^{bc}	0.45±0 ^{defg}	3.56±0.13 ^{f}
T4	78.77±0.012 ^{d}	1.92±0.02 ^{de}	0.4±0.01 ^{efg}	3.29±0.04 ^{h}
T5	76.3±0.013 ^{g}	3.61±0.1^{a}	0.17±0.06 ^{g}	3.81±0 ^{d}
T6	77.44±0.012 ^{e}	2.15±0.1 ^{d}	0.4±0.01 ^{efg}	3.36±0.02 ^{g}
T7	74.57±0.014^{i}	1.28±0.1 ^{gh}	2.12±0.01 ^{a}	3.56±0.01 ^{f}
T8	73.05±0.015 ^{m}	1.69±0.1 ^{3f}	0.77±0.05 ^{cde}	4.08±0.01 ^{b}
T9	73.11±014^{l}	1.51±0.1^{fgh}	0.94±0.11 ^{bcd}	3.24±0.01 ^{h}
T10	73.31±0.015 ^{K}	1.57±0.3 ^{efg}	1.26±0.12 ^{b}	3.93±0.01 ^{c}
T11	76.7±0.013 ^{f}	1.22±0 ^{h}	0.92±0.04^{bcd}	3.04±0.03 ^{j}
T12	80.44±0.001 ^{a}	2.74±0.1^{b}	1.1±0.06^{bc}	3.42±0.02 ^{e}
T13	78.92±0.015^{c}	1.75±0.14^{e}	0.762±0.18^{cdef}	3.49±0.03^{f}

Means followed by the same letter in the column do not differ by Tukey's test at 5%

while treatment (T8) was the lowest and many treatments performed better than the control. Potatoes are classified based on their moisture content. Potatoes for dehydrated products, French fries and crisps should have moisture content of 80% and below, while the ones for canning should have moisture content above 82% (Marwaha *et al*., 2010). T3 and T12 are slight higher in moisture content and the remaining are suitable for processing of fried and dehydried potato products and compost used can be adopted in potato production for different purposes.

Protein content of potato

Protein content of analyzed potatoes was significantly different among 13 treatments at ($p<0.05$). Protein content ranged from 1.22 (T11) to 3.64% (T5) as shown in Table 1. The potato protein was reported to range from 1 to 5% (Rodriguez, 2011). Based on this study the protein content for treatment (T5) was the highest, while treatment (T11) was the lowest. The average protein content of potato was reported to be 2.57% (Liu, 2013. Protein content of some potatoes is above average. Potato protein is rich in essential amino acids with high biological value. Potatoes with high protein content are of paramount important due to their high biological value. Compost T5, T3, T2 and T1 can be recommended where high amount of protein is needed. However, free amino acids should be low as their contribute to browning and acrylamide formation in fried potatoes.

Ash content of potato

Ash content of analyzed potatoes were significantly different among 13 treatments at ($p<0.05$). Ash content ranged from 0.17 (T5) to 2.12%(T7) as shown in Table 1. Stone *et al.* (2011) reported total ash of four potato varieties from four different areas of Japan to range from 0.88 to 1.03%. Based on this study the ash content for treatment (T7) was the highest, while treatment (T 5) was the lowest. The high amount of ash content means the presence of high amount of minerals. Minerals play vital role in humans due to their contributions to the human metabolism. Therefore, Treatment T7, T10 and T12 can be recommend due to their high ash content.

Fiber content of potato

Crude fibers content of analyzed potatoes were significantly different at ($p<0.05$). Fiber content ranged from 3.04 (T11) to 4.08%(T8) as presented in Table 1. Fiber content of potato was reported to range from 0.17 to 3.48% (Lister and Munro, 2000). The average of fiber content was reported to be 2.5% Liu (2013). Fiber content was influenced by organic fertilizer application and some potatoes had fiber content above the average. It is recommended to consume 14 g of fibers for every 1000 calories (Madhu *et al*., 2017). Fibers contribute to the bulk of feces, bind undesirable materials such as mutagenesis, carcinogen, and helps in digestion by creating a conducive environment for valuable microflora in the intestine (Visvanathan *et al*., 2016; Madhu *et al*., 2017). Compost used increased fiber content of potatoes which in return have heathy effect on consumers. High fiber content is desired in our routine diet and potatoes in this study are highly recommended due to their high fiber content.

Reducing sugars and total sugars of potato

Reducing sugars and total sugars are important for determination of the processing quality of potatoes. The experiment showed that the results of reducing sugars and total sugars were statistically significantly different at ($p<0.05$). Reducing sugars ranged from 1.29 to 2.28% and total sugars from 2.25% to 2.94% as presented in Table 2. Reducing sugars were reported to range from 0.10 to 0.20% and total sugar from 0.26 to 0.55% of fresh weight (Bhattacharjee *et al.* 2014). Moreover, Leonel reported reducing sugar content to range from 0 to 2%. Sugar content is linked to the variety and maturity of potatoes. It was suggested that reducing sugars should be 0.25% for dehydrated products, 0.15% for French fries, less than 0.1% for crisps and 0.5% for canned potatoes (Marwaha *et al.*, 2010). Due to high amount of reducing sugars and total sugars, these potatoes should not be used for dehydrated and fried products. However, they can be boiled or mashed. It is very important to allow potatoes to mature to the level where haulms become fully dried which allows translocation of nutrients to the tubers and conversion of simple sugars into starch.

CONCLUSION

The world is facing unprecedented challenge related to the reluctancy of consumers on some food. Use of inorganic fertilizers has gained momentum but nowadays people are concerned with their use in food production and environment. The emphasis is being shifted to the use of organic fertilizer which seems to have less effect on the ecosystem. The use of compost to grow potatoes revealed that dry matter of potatoes produced was within acceptable range of potato for processing. However, both reducing and total sugars were high. Produced potatoes are not suitable for production of dehydrated and fried products due to high content of reducing sugars. However, they can be used for boiled and mashed potato products. High amount of these sugars might have been caused by early harvesting time. Haulm should be allowed to dry naturally which might diminish reducing sugars content and improve processing quality of potato.

Table 2 Reducing sugars and total sugars in percentage of fresh weight of potato

Treatments	Reducing sugars %	Total sugars %
T1	1.29±0.4[ef]	2.27±0.53 [ab]
T2	1.60±0.31[cde]	2.61±0.51[ab]
T3	1.93±0.52[cb]	2.94±0.16[a]
T4	1.69±002[cde]	2.67±0.17[ab]
T5	1.82±0.45[bcd]	2.8±0.93[ab]
T6	2.04±0.31[b]	2.59±0.1[ab]
T7	1.64±0.6[cde]	2.65±0.83[ab]
T8	1.98±0.16[bc]	2.62±0.13[ab]
T9	1.36±0.17[def]	2.36±0.18[ab]
T10	2.28±0.41[a]	2.38±0.03[ab]
T11	1.74±0.31[cd]	2.34±0.25[ab]
T12	1.51±0.8[def]	2.25±0.24[ab]
T13	1.42±0.3[def]	2.16±0.28[b]

Means followed by the same letter in the column do not differ by Tukey's test at 5%

CONFLICT OF INTEREST

The authors confirm that this manuscript has no conflict of interest.

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