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Effect of Soil Properties on the Physical and Nutritional Content of Syzygium Fruits

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ABSTRACT

This study was undertaken to determine the effect of Soil pH, porosity, bulk and particle density, magnesium, manganese, sodium, copper, zinc, and titanium on the physicochemical and nutritional content of *Syzygium cumini* fruits. Multistage sampling was used to select the counties, identify, sample and collect fruit trees. Analysis was done using 40 soil and fruit samples each per county using standard methodologies. Fruit parameters were evaluated by measuring juice pH, total soluble solids, titratable acids, vitamin C, crude fat and fiber, proteins, fruit maturity, carbohydrates, energy, sodium, magnesium, manganese, calcium, iron, copper, and zinc. Results showed that, Syzygium fruits preferred a soil pH from 5.3 to 6.9 which was significantly different between the two counties. Titanium was significantly high in Kwale soil samples giving 57.53±8.37 mg/kg. Particle density caused an increase in bulk density, which in turn increased fruit weight, pH, and ash content. Proteins had a weak positive correlation with soil magnesium, 0.11 and very strongly correlated with carbohydrates, 0.99. Mature fruits had significantly higher protein and carbohydrate contents of 2.96 and 36.1 mg/100 g respectively. The physicochemical and nutritional content of *Syzygium cumini* fruits were highly influenced by soil properties.

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1. Introduction

Syzygium trees grow on various types of soils ranging from a pH of 4.5 to 10.5. Soil is a natural resource consisting of minerals and organic matter that are bound by mineral oxides and charged clay particles. There are spaces between particles that allow the exchange of air and water [1]. The number and size of these pores vary indicating variation in organic matter content, quality, and formation.

Soil properties vary with the variation of soil layers and affect fruit quality namely; Physical, chemical, and nutrition. The properties include; Soil texture, pH, organic matter, porosity, particle density, D_p, bulk density, D_b, and mineral content all indicating both anthropogenic activities and soil processes related to nature. Soil texture affects the exchange of gases, and how nutrients and water are retained in the soil [2]. Soil pH affects chemicals hence determining the variation of flora and fauna in the soil. An increase in soil pH directly increased the absorption of magnesium and molybdenum but reduced the absorption of zinc, copper, manganese, and iron in pepper [3]. [4] reported a negative correlation between the Total soluble solids, TSS of Kiwi fruit and Magnesium and Boron, soluble sugar with magnesium and manganese.

Soil bulk density $D_b = M_s/V_t$ is the ratio of the weight of dry soil, M_s to the bulk volume, V_t, that is solids volume spaces between the pores. It indicates that the soil is healthy and mostly ranges between 1.1 and 1.5 g/cm^3. These values are either higher in sandy soils or lower in soils with high carbon content. Similarly, porosity is the part of soil occupied by spaces [5] and it is greatly influenced by bulk density. Particle density on the other hand is a collection of the solids that make up soil. Most soils exhibit a particle density range of between 2.55 and 2.70 g/cm^3 [6]. A particle density of less than 1.0 g/cm^3 shows the presence of high organic matter. The basic function of soil influences its quality, therefore, environmental sustainability maintains soil quality.

Different studies on soils in Syzygium production sites have shown that potassium balances acid and sugar content resulting in sweeter fruits that can be stored for a long time, and increased fruit size is partly a result of potassium in soils. Generally, fruit quality is a multifaceted attribute with several factors that determine taste, nutritional quality, and market potential [2]. This study, therefore, sought to determine the effect of specific soil parameters such as; pH, soil particle density, bulk density, porosity, and minerals on Total soluble solids, Vitamin C, proteins, carbohydrates, pH, and mineral composition such as; Zinc, Magnesium, Manganese, Copper, Iron, and sodium of Syzygium fruits for two production sites with varying environmental factors.

2. Material and Methods

2.1 Study Area Description

The study was done in Kwale County, Figure 1 located at a latitude of 4° 10′ 0″ S, longitude of 39° 27′ 0″ E, and an altitude of between 382 and 408 m above sea level. The county has a monsoon climate with two rainfall seasons October to December and March to June/July, ranging between 400 and 1680 mm per year. The average temperature is 24.2 ^{o}C. Kwale County soils differ from one site to another. The soils are not well drained, have low pH, and are not fertile therefore unsuitable for cultivation. Most soils have sand, and clay, which is deep and ruby in colour [7].

Bungoma County, Figure 2 on the other hand is located at latitude 00 45′ 00″ N and longitude 34 35′ 00″ E. The altitude is 1385 to 1441 m above sea level. The county has Tropical monsoons and savannahs with two rainfall seasons ranging between 1200 and 1800 mm annually, and an average temperature of 20.3 ^{0}C. Soils are highly acidic to loamy clay.

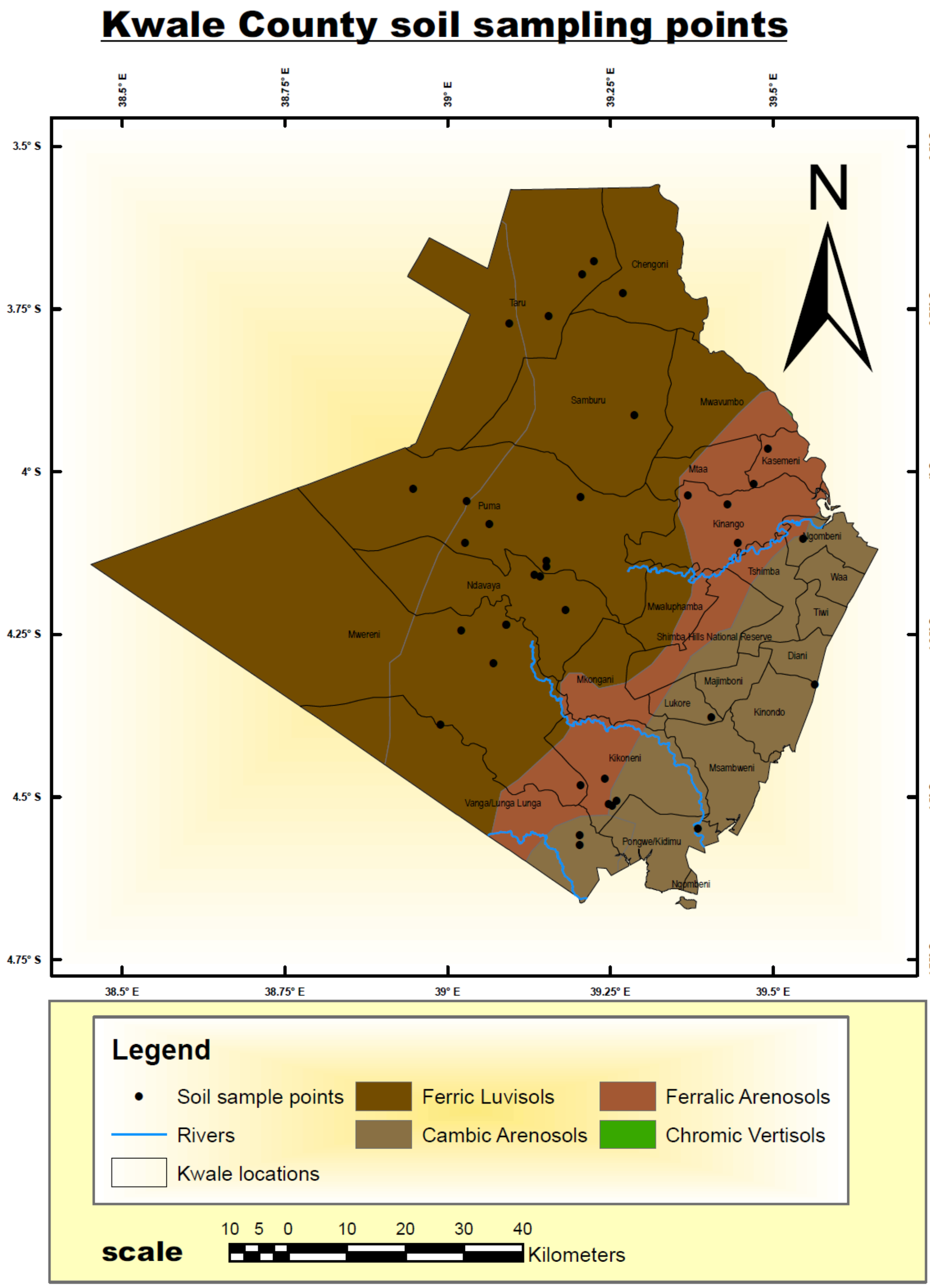

Figure 1. Soil sampling points in Kwale County

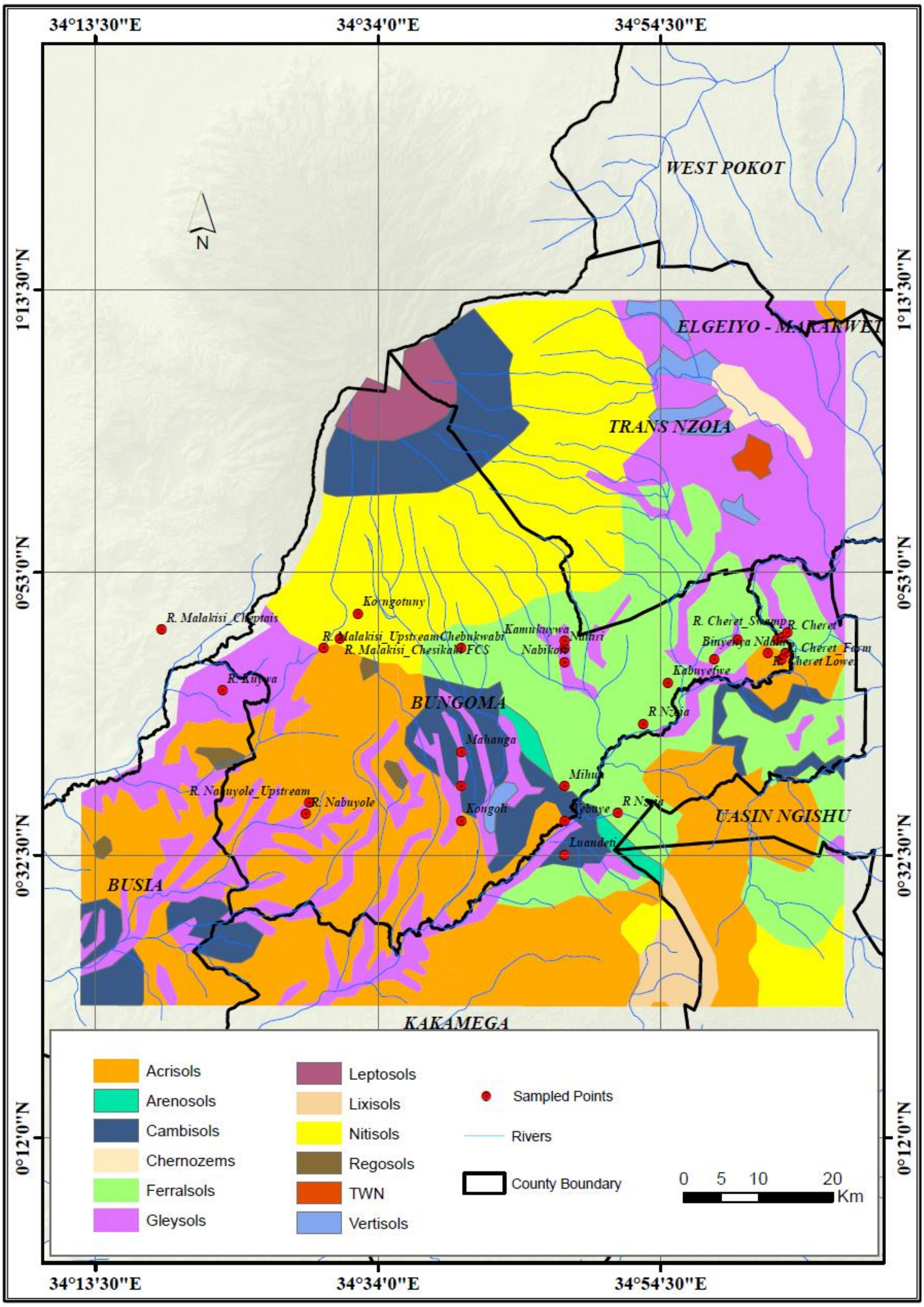

Figure 2. Soil sampling points in Bungoma County**.**

2.2 Experimental design, Soil, and fruit sampling

This study was undertaken in two counties with varying environmental conditions. A mixture of soil samples was taken out of a depth of between 0 and 20 cm using a soil auger. Forty samples were taken from each county. Top soil was removed before sampling the soil which was then mixed to an even composition. This was packed in polyethylene bags, labeled, and transported to the laboratory for analysis. The samples were dried at room temperature for 7 days, ground into powder using a pestle and mortar, then sifted using a 2 mm sieve. About 200 g of each soil mixture was analyzed for; pH, porosity, particle density, bulk density, and mineral composition.

Three ripe fruits from each tree were randomly picked from forty trees in each of the two Counties. The positions of the trees were marked with a Global positioning system, GPSMAP 65s, USA. The Syzygium fruits once picked, were taken to the laboratory for cleaning, separation of seed from edible portion, and subsequent analysis.

2.3 Reagent and chemicals

98 % Sodium hydroxide**,** 95**%** Phenolphthalein indicator, 35 %hydrogen peroxide, 37 % Hydrochloric acid, 98 % Sulphuric acid, and 34 % Metaphosphoric acid were purchased from Sigma – Aldrich, USA. All chemicals used in this study were of analytical grade.

2.4 Soil analysis

Soil pH-H_20 was obtained from a mixture of 1:2.5 soil/water following the procedure by [8]. Porosity was determined using the saturation method where the soil was put into a graduated measuring cylinder to 100ml and water to the same level. Soil samples oven dried at 105 ^oC were measured for Particle density, *Dp* according to the method by [6]. Bulk density, D_b was calculated according to equation 1;

D_b (g/cm_3) = Dp (g/cm^3) (1 – Porosity) x 100. (1)

Elements; sodium, magnesium, manganese, copper, zinc, and titanium were determined using an Inductively Coupled Plasma – Optical Emission Spectrometer, ICP – OES, as described by [9].

2.5 Fruit analysis

Fruit physical, chemical, and nutritional parameters namely; pH determined following the method by [10], weight following the method by [11], and Total ash determined by burning up the fruit sample in a muffle furnace at a temperature of 550 ^0C according to the method of analysis 930. 05 [12], proteins were determined using the Kjeldahl method of analysis 984 – 13 of [13], crude fat [14], method 920.39, carbohydrates were determined by the difference of Proteins, ash, crude fat, and fiber and recorded as a percentage. Total soluble solids in Syzygium fruits were determined using method 920,151 [15] whereas vitamin C and minerals; zinc, copper, magnesium, calcium, manganese, sodium, cadmium, and chromium were analyzed using High-Pressure Liquid Chromatography , Shimadzu LC20A, Japan and Inductively Coupled Optical Emission Spectrometer, Agilent 5110, CA, USA respectively.

2.6 Statistical analysis

All data were analyzed with R 4.1.1 statistical software. For comparison of means, the students'-tests were employed and the results were presented as means with differences considered significant at *P* = .05. Where extreme values were observed, the Wilcoxon sign rank test was used. This work includes a comparative analysis of the physical, chemical, and nutritional properties of both soils and Syzygium fruits.

3. RESULTS AND DISCUSSION

3.1 Soil properties

Table 1 shows pH, porosity, particle and bulk density, properties of soils from Bungoma and Kwale counties. Further analysis is shown in Figures 3 and 4.

Table 1. Properties of soils from Kwale and Bungoma Counties

Parameter	Bungoma soils (mean)	Kwale Soils (mean)	*t*-value	*P*-value
pH (H_20: Soil)	5.66 ± 0.02	5.27 ± 0.01	1.79	**.04**
Soil porosity (%)	61.5 ± 2	60.08 ± 1	0.54	.29
Soil particle density (g/cm^3)	2.47 ±0.06	2.73 ± 0.05	-6.26	**<.001**
Soil bulk density (g/cm^3)	0.78 ± 0.0	1.17 ± 0.13	-8.46	**<.001**

n's = non-significant, * = significant differences at probability level, *P* = .05

All the analyzed parameters differed significantly at *P* = .05 except soil porosity. Soils from Bungoma were 61.5 % more porous than those from Kwale with 60.08 %. This is probably because the former has soils with more organic matter and sand whereas the latter has more clay due to the difference in altitude [16]. This translated to higher mineral content in Bungoma soils as shown in the box plots in Figure 3. According to [17], bulk density, D_b and porosity are affected by anthropogenic activities.

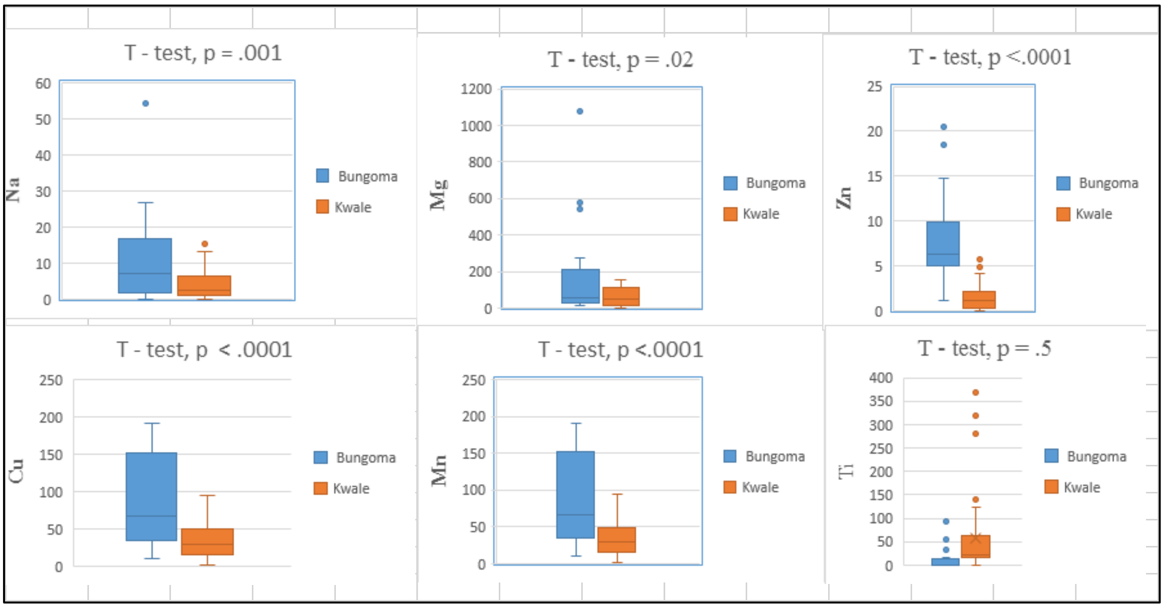

Figure 3. Box plots of soil minerals articulated as median. Results are expressed as mg/kg.

Outliers are dots above the boxes, top and bottom box edges of the boxes show upper and lower quartiles, the upper and lower whisker shows extreme values whisker.

Zinc and copper content of 8.27±0.12 and 0.92±0.15 mg/kg in Bungoma, 1.43±0.09 and 0.6±0.1 in Kwale soils, is an indication that the county is has industrial and agricultural activities compared to Kwale, these results are in agreement with those of [18], who reported that zinc and Copper levels in soils are increased by environmental changes, industrial pollution, and agricultural practices. Due to Titanium mining in Kwale County, mean titanium levels in soils from Kwale, 57.53 mg/kg were five times higher than levels in soils from Bungoma, 12.44±0.13 mg/kg. The availability of this natural resource base, explains the setting up of a Base Titanium factory in Kwale County.

Soil minerals; Na, Mg, Mn, Cu, Zn and Ti values ranged as follows; 0.01 – 54.2, 2.02 – 1075, 10.86 – 190.77, 0 -1.88, 0 – 20.7 and 0 - 369.23 respectively within the counties. The median values for all elements varied significantly, P = .05 between soil samples, and were higher in Bungoma soils samples than in Kwale, except 0.585 mg/kg, and 22.74 mg/kg, dry weight from Bungoma and Kwale soils samples respectively. Soils from Bungoma had a higher concentration of minerals which were also distributed widely within the collected fruit samples. Interquartile ranges, IQR from the Bungoma samples were higher than those from Kwale except for Ti where Kwale had a significantly higher IQR of 41.5 against 5.6 mg/kg. This was an indication that Ti is widespread in most soil samples from Kwale.

Using a correlation matrix in Figure 4, the best positive significant correlations were obtained between the minerals Mn and Zn, 0.95, Na and Zn ,0.91, Mg and Ti, 0.94, Mn and Na, 0.85 though [19] showed the antagonistic relationship between the two minerals. Bulk and particle density also correlated positively, 0.85, Mn and soil pH, 0.81, and Soil porosity with Na, 0.86. Mn, 0.96, and Zn 0.93. A strong negative correlation was obtained between soil porosity and bulk density, - 0.97 of the soils in both counties. Bulk density increases with decreasing pore spaces, and correlated negatively with soil pH [20,21].

	Na	Mg	Mn	Cu	Zn	Ti	Soil pH	Bulk density	Particle density	Soil porosity
Na	1.00									
Mg	-0.43	1.00								
Mn	**0.85**	-0.58	1.00							
Cu	0.10	-0.32	0.36	1.00						
Zn	**0.91**	-0.55	**0.95**	0.27	1.00					
Ti	-0.40	**0.94**	-0.56	-0.34	-0.53	1.00				
Soil pH	0.72	-0.56	**0.81**	0.30	**0.79**	-0.53	1.00			
Bulk density	-0.82	0.78	-0.92	-0.35	-0.90	0.77	-0.78	1.00		
Particle density	-0.68	0.71	-0.79	-0.21	-0.71	0.72	-0.67	**0.85**	1.00	
Soil porosity	**0.86**	-0.69	**0.96**	0.34	**0.93**	-0.67	0.79	-0.97	-0.86	1.00

Figure 4: Correlation matrix for the soil parameters.

3.2 The physicochemical and nutritional content of *Syzygium cumini* fruits

The physicochemical and nutritional properties of *S. cumini* fruits from Bungoma and Kwale counties are presented in Figure 5**.** Fruit breadth was the only parameter that showed significant differences between the two counties. However, the mean fruit weight of Kwale fruits, 4.56 ± 0.69g was higher than those of Bungoma, 4.09 ± 0.8 g. Kwale fruits could probably be first-generation or sampled from superior germplasm [22]. TSS in the Bungoma fruits were 13.35 ^{o}Brix while Kwale fruits presented 9.37 ^{o}Brix. This implies the fruits from Bungoma were sweeter than those from Kwale. Vitamin C was remarkably higher in Kwale; these results are in agreement with the high % TA. This agrees [23] in the report on the ripening of traditional tomatoes. The mineral composition of *S. cumini* fruits from the two counties is seen in Figure 5

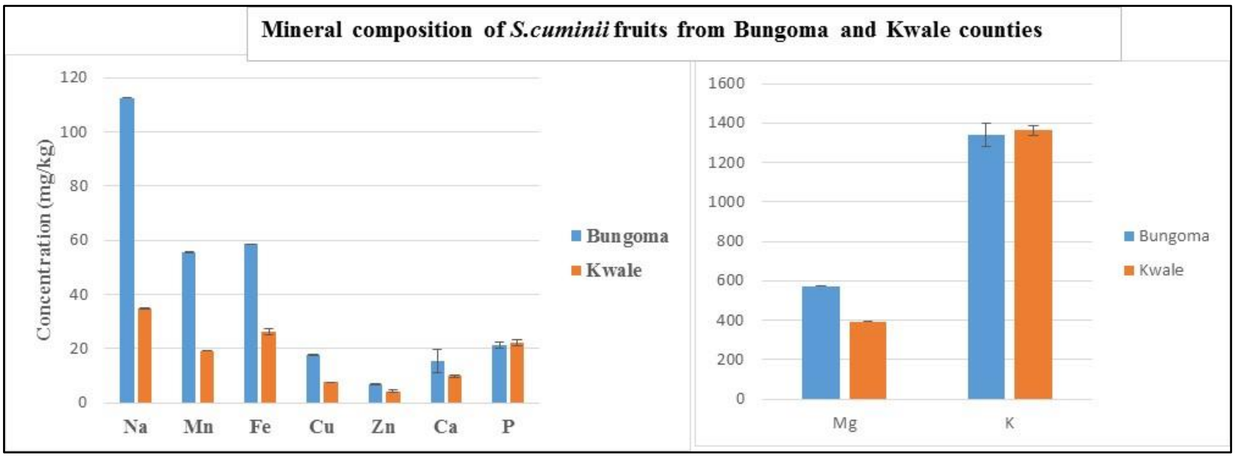

Figure 5. Mineral composition of *S. cumini* fruits from Bungoma and Kwale counties articulated as mean ± Standard error

All minerals were significantly and remarkably higher in Bungoma fruits as opposed to Kwale fruits, this is a result of the high concentration of the same minerals in the soils, Figure 1.
A correlation matrix of the different fruit and soil parameters is shown in Figure 6 below;

	Na	Mg	Mn	Cu	Zn	Ti	Soil pH	Bulk density	Particle density	Soil porosity	Fruit weight(g)	Breadth	pH	% Ash	TSS:TA	CHO	Protein
Ti	1.00																
Mg	-0.43	1.00															
Mn	**0.85**	-0.58	1.00														
Cu	0.10	-0.32	0.36	1.00													
Zn	**0.91**	-0.55	**0.95**	0.27	1.00												
Ti	-0.40	**0.94**	-0.56	-0.34	-0.53	1.00											
Soil pH	0.72	-0.56	0.81	0.30	0.79	-0.53	1.00										
Bulk density	-0.82	0.78	-0.92	-0.35	-0.90	0.77	-0.78	1.00									
Particle density	-0.68	0.71	-0.79	-0.21	-0.71	0.72	-0.67	**0.85**	1.00								
Soil porosity	0.86	-0.69	**0.96**	0.34	**0.93**	-0.67	**0.79**	-0.97	-0.86	1.00							
Fruit weight(g)	-0.72	0.68	-0.85	-0.26	-0.76	0.67	-0.67	**0.87**	**0.80**	-0.88	1.00						
Breadth	0.22	0.33	0.11	-0.10	0.16	0.34	0.07	0.06	0.14	0.02	0.04	1.00					
pH	-0.74	**0.79**	-0.82	-0.21	-0.78	0.78	-0.69	**0.90**	**0.81**	-0.88	**0.96**	0.09	1.00				
% Ash	-0.72	0.67	-0.77	-0.11	-0.72	0.68	-0.65	**0.84**	**0.79**	-0.84	**0.94**	0.09	**0.94**	1.00			
TSS:TA	-0.29	0.14	-0.30	-0.44	-0.33	0.10	-0.41	0.27	0.05	-0.24	0.18	-0.34	0.18	0.14	1.00		
CHO	-0.28	0.10	-0.29	-0.42	-0.31	0.05	-0.43	0.24	0.03	-0.22	0.14	-0.29	0.14	0.11	**0.98**	1.00	
Protein	-0.30	0.11	-0.29	-0.46	-0.31	0.07	-0.39	0.25	0.06	-0.23	0.14	-0.25	0.14	0.11	**0.97**	**0.99**	1.00

Figure 6. Correlation matrix for the physicochemical and nutritional content of *Syzygium cumini* fruits with soil parameters.

Analyzed data, 95 % correlated positively; Fruit pH was highly influenced by soil particle density, 0.96 and bulk density, 0.81. Fruit weight was highly influenced by; soil bulk density, 0.87, and soil particle density, 0.87. Ash content was highly influenced by bulk density, 0.84 and particle density, 0.79. There was a weak positive correlation between TSS: TA or fruit maturity and soil Mg, 0.14, this was also reported by [24] who stated that the TSS of kiwi fruits correlated with both magnesium and manganese in the soil, and [7] reported that Zinc and copper were the main factors that contributed to the Total soluble solids in pepper.

4. Conclusion and Recommendations

Soil pH affected the bio availability of minerals in both the soils and fruits. Though higher pH of 5.66 ± 0.02 promoted availability of 144.05±0.41mg/kg magnesium in Bungoma County, it seemed to inhibit availability of zinc, copper and manganese in the fruits. Higher levels of soil porosity, 61.5 ± 2, bulk density, 0.78 ± 0.0 mg/kg, and particle density, 2.47 ±0.06 mg/kg in Bungoma caused an increase of minerals in Syzygium fruits. The physicochemical and nutritional content of *S. cumini* fruits are highly influenced by soil properties. It is recommended that age of tree be determined and effect on fruits assessed.

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Competing interests

The authors declare that there were no competing interests.

Authors' contributions

All the authors wrote the protocol, first draft, read and approved the final manuscript. The corresponding author in addition, designed the study and performed the statistical analysis.

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