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Comparative Studies on Proximate Composition and Phytochemical Screening of Mango, Key lime, African star apple and African pear Seeds as Possible Coagulant Aids for Water Treatment

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Abstract: Many fruits including mango (*Mangifera indica),* key lime (*Citrus aurantiifolia*), African star apple (*Chrysophyllum albidum*) and African or bush pear (*Dacryodes edulis*) are nutritionally valuable as human food, however after consumption of the fruits, their seeds are discarded as wastes since they are of no commercial value and this results in disposal problems. Hence assessment of the constituents of such waste seeds will enable their application to be considered. In this study the proximate composition and phytochemical constituents of the seeds of Duncan mango (*Mangifera indica*), key lime (*Citrus aurantiifolia),* African star apple (*Chrysophyllum albidum: C. acreanum*) and African or bush pear (*Dacryodes edulis*: *D.e.var.edulis*) obtained from southern part of Nigeria have been investigated and compared for the four different seeds. The results obtained from the proximate analyses showed that the major constituent of the seeds are carbohydrates, proteins and fats. The key lime seed was found to contain more protein and fat compared to the other seeds while the African star apple seed was found to contain the least fat and more carbohydrate compared to the other seeds. The phytochemicals detected in all the seeds were tannins, glycoside, coumarins and phenols, however steroids were absent. Only African star apple seed contained saponins and alkaloids. The results further indicated that only the key lime seed was devoid of flavonoid and starch. Tannins in plants have been reported to be among the active agents that bring about coagulation and natural polymers (proteins, carbohydrate (starch) etc.) act as bridging flocculants. Saponins, flavonoids coumarins and phenols have also been reported to posses antibacterial potentials against pathogenic organisms. This study shows that these seeds contain these constituents and they are present in reasonable amount. Therefore it is concluded that these seeds can be investigated as possible coagulant aids for drinking water treatment.

Keywords: Proximate Composition, Phytochemical Screening, Seeds, Fruit Wastes, Nutrients

Introduction

Fruits are important sources of many nutrients and vitamins and they are commercially valuable as human food and are either consumed fresh, dried or processed. Fruit wastes including peels and seeds that are commonly non- edible can amount to as much as 50% of the total fruit weight (Choy *et al*., 2014). These non-

edible portions of fruit wastes are generally discarded into the environment as they are normally considered to be of no commercial value, thus creating disposal problems and the pollution of soil and water sources as a result of possible leachates (Hacker *et al*., 2009). Although these non-edible portions of fruit wastes are generally discarded, it is worthwhile to note that they can have diverse applications. Research have suggested the use of fruit wastes for bio fuel production (Borah and Mishra, 2011), human health (Okpala and Gibson-Umeh, 2013) and livestock treatment (Kordylas, 1990). Most research have focused predominantly on these aspect and hence further uses of fruit wastes have to be explored to access their wide application (Khan *et al*., 2015).

Tens of thousands of plant species are currently been used by humans for multiple purposes such as food, fuel, oil, forage, medicine among others (Tijjani *et al*., 2013). The worth of a plant lies on its quality, hence proximate analysis and phytochemical screening give valuable information and help assess the quality of sample (Nair Lethika *et al*., 2012).

Plant materials such as seeds (example is *Moringa oleifera*) have been identified as a possible lead into the development of natural coagulants for water treatment because they contain certain characteristics. The seed from *Moringa oleifera* which is the most effective natural coagulant (Ghebremichael *et al*., 2005; 2009) have been reported to contain valuable elements such as protein, carbohydrate, lipids and minerals (Ijarotimi *et al*., 2013; Olagbemide and Alikwe, 2015). It has been established that these elements (protein) are responsible for its coagulating capability (Camacho *et al*., 2015; Ghebremichael *et al*., 2005; Sotheeswaran *et al*., 2011). Since this seed is doing well as a coagulant due to its attributes, there is need to assess other seeds for similar attributes in order to investigate their possible use for water treatment.

Mango (*Mangifera indica*) seed is encased in a hard compressed fibrous endocarp which contributes to extending their shelf life and the seed kernel is found to contain almost 15% by weight of oil (Nzikou *et al*., 2010). The seeds are used for medicinal purposes (Shah *et al*., 2010) and the seed kernel oil has been found to contain phenolic compounds, hence is widely used in cosmetics industries (Soong and Barlow, 2006). Key lime (*Citrus aurantiifolia*) seeds have been employed in folk medicine for the treatment of diseases and the seed oil is used in cosmetics industries for the production of perfumes (Vekiari *et al*., 2002). African star apple (*Chrysophyllum albidum*) seeds have a shiny hard brown casing which feels like plastic that allows them to be viable for years and used for local games (Akpabio *et al*., 2012). Cotyledons from the seeds are used to treat type two diabetes and as ointment in the treatment of vaginal and dermatological infections in Sub-Sahara Africa (Muanya, 2011). African or bush pear (*Dacryodes edulis*) seeds are surrounded by a pulpy butyraceous pericarp, which is the edible portion consumed either raw or cooked. The seeds are excellent sources of nutrition to consumers, thus encouraging their high rate of production and commercialization for decades (Ogunmoyole *et al*., 2012). The seed oil has been found to have both domestic and industrial potentials (Ajayi and Adesanwo, 2009). All these seeds (mango, key lime, African star apple and African pear) have multiple uses and could be cultivated intensively and help to improve the quality of life of both the rural and urban population.

The proximate composition and phytochemical analysis of fruit wastes for possible potential uses so as to add value to them in order to alleviate their drawbacks (waste generation and disposal problem) is an active area of research. A lot of research has looked at these constituent in relation to human health and livestock treatment, beyond these, there is little or no information relating to their possible application in water treatment. Hence the aim of this work was to carry out a comparative study on the proximate and phytochemical constituent of the four different types of seeds namely; Duncan mango (*Mangifera indica*), key lime (*Citrus aurantiifolia*), African star apple (*Chrysophyllum albidum: C. acreanum*) and African or bush pear (*Dacryodes edulis: D.e.var.edulis*) obtained from Southern Nigeria as possible coagulant aids for water treatment.

Materials and Methods

Collection and Processing of Seed Powders

Fresh ripe fruits of Duncan mango (*Mangifera indica*), key lime (*Citrus aurantiifolia*), African star apple (*Chrysophyllum albidum: C. acreanum*), African or bush pear (*Dacryodes edulis: D.e.var.edulis*) were purchased from a local market (Uselu) in Benin City, Edo State, Nigeria. The fruits were identified and authenticated by a botanist in Plant Biology and Biotechnology Department, University of Benin, Benin City. These fruits were sliced open manually using a clean stainless steel knife to obtain their seeds. The seeds were sun dried for a period of 4 weeks, but after one week of drying key lime seeds were packed in a zip lock bag and stored at room temperature. The seeds of Duncan mango, African star apple and African pear were further shelled manually by stone cracking and hand squeezing to obtain their seed kernels. The seed kernels were further dried for a period of one week after which they were packed in zip lock bags and stored at room temperature. For each dried sample, 30 g was pulverized mechanically using a stainless grain laboratory pulveriser into powder. The powders were then sieved manually to get very fine powders.

Proximate Composition Analysis of the Seed Powders

This analysis was carried out using Association of Analytical Chemist (AOAC) methods to determine major constituents such as moisture, ash, fat, crude protein and crude fibre content in each type of seed, while the Nitrogen Free Extract (NFE) was obtained from their differences and total carbohydrate content was obtained from the addition of nitrogen free extract and crude fibre content.

Moisture Content (AOAC, 1999)

About 2 g of the seed powder was weighed into a petri dish (which was previously washed, dried, cooled and weighed). The sample was then dried in an oven at 105°C for about 5 to 6 h (to constant weight), cooled in the desiccator and weighed. The percentage moisture content was estimated using the equation below:

$$\%Moisture = \frac{Wt,of\ moisture}{Wt.\ of\ seed\ powder} \times 100 \quad (1)$$

Where:
Wt. = Weight
% = Percentage

Ash Content (AOAC, 1999; 2000)

About 2 g of the seed powder was weighed into a pre-heated crucible. The crucible was then placed into a muffle furnace at 400-600°C for about 4 h (or until whitish-grey ash with constant weight was obtained). The crucible was cooled in the desiccator and weighed. The percentage ash content was estimated with the following equation:

$$\%Ash = \frac{Wt.\ of\ ash}{Wt.\ of\ seed\ powder} \times 100 \quad (2)$$

Symbols as in Equation 1 above.

Fat Content (AOAC, 1999)

About 100 mL of an anhydrous petroleum ether (of boiling point of 40-60°C) was transferred into a round bottom flask (250 mL). About 5 g of the seed powder was weighed and placed inside a thimble made from thick filter paper which was loaded into the main chamber of the soxhlet extractor. The soxhlet extractor was placed onto the flask (on the heating mantle) containing the extraction solvent. This was then connected to the condenser; the heating mantle was switched on for refluxing of the solvent in the flask to take place. The extraction was continued for at least 8-10 h. After the extraction has been completed, the flask was disconnected and placed in the oven at 650°C for about 4 h, it was then cooled in the desiccator and weighed. The percentage fat was estimated with the following equation:

$$\%Fat = \frac{Wt.\ of\ fat}{Wt.\ of\ seed\ powder} \times 100 \quad (3)$$

Symbols are as in Equation 1.

Crude Protein Content (AOAC, 1995; 2000-Kjeldahl Method)

Digestion

About 2 g of the seed powder was weighed into a kjeldahl flask and 25 mL of concentrated sulphuric acid, 0.5 g of copper sulphate, 5 g of sodium sulphate and a speck of selenium tablet were added. The mixture was then digested, at first heat was applied in a fume cupboard slowly to prevent undue frothing, then digestion was continued for 45 min until the solution become clear pale green. It was left until completely cooled before 100 mL of distilled water was added rapidly. The digestion flask was rinsed about 2-3 times and the rinsing was added to the bulk.

Distillation

The distillation apparatus was set up and about 10mls of the digested solution was added into the apparatus via a funnel and it was allowed to boil. Sodium hydroxide (10 mL) was added using a measuring cylinder (so that ammonia is not lost) and 50 mL of boric acid (2%) containing screened methyl red-methylene blue indicator was then distilled into it.

Titration

The alkaline ammonium borate formed was titrated directly with 0.1 M hydrochloric acid. The titre value (which is the volume of acid used) was recorded. The percentage crude protein was estimated with the following equation:

$$\%Crude\ protein = \%N\ x\ 6.25 \quad (4)$$

Where:
% = Percentage
N = Nitrogen

Crude Fibre Content (AOAC, 2000)

About 1.3 g of defatted seed powder was weighed and transferred into a flask/beaker and 200 mL of pre-heated sulphuric acid (1.25%) was added and the solution was boiled gently for about 30 min (maintaining constant volume of acid by adding hot water). A funnel

was placed on top of the flask, it was then fitted with a cheese cloth and pre-heated by pouring hot water into the funnel. The boiled acid sample mixture was then filtered through the funnel under sufficient suction. The residue was then washed several times with boiling water (until the residue was neutral to litmus paper) and transferred back into the beaker. Then 200 mL of pre-heated sodium hydroxide (1.25%) was added and the mixture boiled for another 30 min. An empty what man no 1. equivalent filter paper (previously weighed) was used to filter the mixture. The residue together with the filter paper was dried in the oven at 600-650°C for about 4 (till constant weight). It was then cooled in the desiccator and weighed. The percentage crude fibre was estimated using the equation below:

$$\%Crude\ fibre = \frac{Wt.\ of\ crude\ fiber}{Wt.\ of\ seed\ powder} \times 100 \quad (5)$$

Symbols are as in Equation 1 above.

Nitrogen Free Extract (Mathematical Calculation Method)

The Nitrogen Free Extract (NFE) was determined by mathematical calculation. It was obtained by subtracting the sum of percentages of all the nutrients already determined from 100. It is expressed as follows;

$$\%Nitrogen\ Free\ Extract\ (NFE) = 100 - \begin{pmatrix} \%Moisture + \%Ash + \%Fat \\ +\%Crude\ protein + \%Crude\ Fiber \end{pmatrix} \quad (6)$$

Total Carbohydrate Content (Mathematical Calculation Method)

The total carbohydrates content was determined by mathematical calculation. It was obtained by adding the sum of percentages of Nitrogen Free Extract (NFE) and Crude Fibre (CF). It is expressed as follows;

$$\%Carbohydrate = \%\ Nitrogen\ Free\ Extract(NFE) + \%Crude\ Fibre \quad (7)$$

Phytochemical Screening of the Seed Powders

Qualitative phytochemical screening of each type of seed powder was carried out using standard methods of analyses (Trease and Evans, 2002) to determine secondary metabolites (such as tannins, glycosides, saponins, alkaloids, flavonoids, coumarins, steroids, phenols and starch) in the seed powders.

Tannins (Lead Acetate Test)

Aqueous extract of the seed powder was prepared (0.5 g of the seed powder was weighed and transferred into a beaker, then 25 mL of distilled water was added to the beaker and the mixture boiled for about 5 min, the solution was allowed to cool and then filtered, the volume of the solution was adjusted to 25 mL). After this, 10 mL of water and 2 to 10 drops of 1% lead acetate solution was added to 1 mL of the extract and a precipitate was formed. A confirmatory test was carried out by adding 10 mL of water and 2 to 10 drops of 1% ferric chloride solution to 1 mL of the extract. The colour was noted (brownish green and blue black colouration indicate the presence of tannins-hydrolysable and condensed tannins).

Glycosides (Fehling Test for Reducing Sugars)

About 0.2 g of the seed powder was weighed into a beaker, 5 mL of dilute hydrochloric acid (HCl) was added and the mixture was then heated on a water bath for about 2 min and allowed to cool and was filtered. The filtrate was made distinctly alkaline by adding 2 to 5 drops of 20% sodium hydroxide (NaOH) and tested with a litmus (pH) paper. Then, 1 mL of Fehling's solutions B and A were added to the filtrate and heated for about 2 min. The quantity and colour of precipitate produced was noted (formation of brick-red precipitate indicate the presence of reducing sugar).

Saponins (Froth Test)

Aqueous solution (extract) of the seed powder was prepared (0.2 g of the seed powder was weighed and transferred into a beaker, then 15 mL of distilled water was added to the beaker, the solution was transferred into a test tube and shaken vigorously, it was then filtered). The filtrate was shaken again (a froth which does not break readily on standing indicates the presence of saponins).

Alkaloids (Dragendorff Test)

About 0.5 g of the seed powder was extracted with ammoniacal alcohol (ammonia and ethanol in 1:9 ratio), filtered and the filtrate was evaporated to dryness. The residue was extracted with 1% sulphuric acid (H_2SO_4), filtered and then dilute ammonia (NH_3) solution was added to the filtrate to render it distinctly alkaline. It was shaken with chloroform ($CHCl_3$), the chloroformic extract was separated and the chloroform was evaporated off. The residue was then dissolved in 1% sulphuric acid (H_2SO_4) and one drop of Dragendorff's reagent was added. Formation of orange red precipitate indicates the presence of alkaloids.

Flavonoids (Ammonia Test Method)

Aqueous solution (extract) of the seed powder was prepared (0.2 g of the seed powder was weighed and transferred into a beaker, then 15 mL of distilled water was added to the beaker and then filtered). A strip of

filter paper was dipped into the liquid extracts, dried and exposed to ammonia solution. The appearance of an intense yellow indicates the presence of flavonoids. A confirmatory test was also performed by exposing the strip of filter paper to dilute hydrogen chloride (yellow colour disappear).

Coumarins (Ammonia Test Method)

Chloroform extract of the seed powder was prepared (0.5 g of the seed powder was weighed and transferred into a beaker, then 25 mL of chloroform was added to the beaker, the chloroformic extract was separated and then filtered). 5 mL of the extract was evaporated to dryness. The residue was then dissolved in hot distilled water, allowed to cool and divided into two test tubes labelled test tube A and B. 0.5 mL of 10% ammonia solution was added to test tube A and test tube B was used as a control. Test tube A was then observed under UV light and the occurrence of a fluorescence colour was noted (intense bluish green indicates the presence of coumarins).

Steroids (Salkowski and Liebermann-Burckhardt test)

Chloroform extract of the seed powder was prepared (0.5 g of the seed powder was weighed and transferred into a beaker, then 25 mL of chloroform was added to the beaker, the chloroformic extract was separated and filtered), the filtrate was then divided into two test tubes labelled test tube A and B. About 5 mL of concentrated sulphuric acid was added to the extract in test tube A carefully down the side of the test tube to form a lower layer. The colour at the interface was observed (a reddish brown/cherry red indicates presence of steroids). A confirmatory test was also performed by adding acetic anhydride and then concentrated sulphuric acid to the extract in test tube B carefully down the side of the test tube to form a lower layer. The colour at the interface was observed (bluish colour shows that steroids are present).

Phenols (Ferric Chloride Test)

Aqueous solution (extract) of the seed powder was prepared (0.5 g of the seed powder was weighed and transferred into a beaker, then 25 mL of distilled water was added to the beaker and the mixture boiled for about 5 min, the solution was allowed to cool and then filtered, the volume of the solution was adjusted to 25 mL). Then, 10 mL of water and 2 to 10 drops of 1% ferric chloride solution was added to 1ml of the extract. The colour of the precipitate formed was noted (dark green indicates presence of phenols).

Starch (Iodine test)

About 0.5 g of the seed powder was weighed and transferred into a petri dish, then 2 to 3 drops of iodine solution was added to it and the colour of the solution was observed (blue black colouration shows the presence of starch).

Results

The results of the proximate analyses and phytochemical screening of Duncan mango, key lime, African star apple and African pear seeds are presented in Table 1 and 2 respectively.

Table 1. Proximate analyses of Duncan mango, Key lime, African star apple and African pear seeds

	Duncan Mango Seed (DMS)		Key Lime Seed (KLS)		African Star Apple Seed (ASAS)		African Pear Seed (APS)	
Components	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Moisture (%)	8.19	-	4.59	-	5.73	-	6.54	-
Ash (%)	3.78	4.10	4.66	4.88	3.89	4.13	4.30	4.60
Fat (%)	14.41	15.51	25.13	26.75	4.83	5.15	15.74	16.93
Crude Protein (%)	10.67	11.51	19.94	20.96	11.67	12.42	10.62	11.19
Crude Fibre (%)	1.76	1.85	24.42	21.37	1.95	2.03	3.48	3.63
NFE (%)	61.89	67.80	25.59	26.84	69.95	74.23	60.02	64.25
Total Carbohydrate (%)	63.81	69.57	46.23	48.42	71.90	76.30	63.54	67.68

Table 2. Phytochemical screening of Duncan mango, Key lime, African star apple and African pear seeds

Phytochemical	Duncan Mango Seed (DMS)	Key Lime Seed (KLS)	African Star Apple Seed (ASAS)	African Pear Seed (APS)
Tannins	+	+	+	+
Glycosides	+	+	+	+
Saponins	-	-	+	-
Alkaloids	-	-	+	-
Flavonoids	+	-	+	+
Coumarins	+	+	+	+
Steroids	-	-	-	-
Phenols	+	+	+	+
Starch	+	-	+	+

Discussion

Results of proximate analyses (moisture, fat, crude protein and carbohydrate) of Duncan mango seed are closer to the values reported by Okpala and Gibson-Umeh (2013) while the crude fibre content is closer to the value reported by Elegbede *et al*. (1996), although different mango varieties were analysed by the authors. The entire proximate analyses is closer to the values reported by Fowomola (2010) for mango. The results of fat, crude protein, crude fibre and carbohydrate obtained for African star apple are closer to the values reported by Akpabio *et al*. (2012) and that of African pear seed excluding carbohydrate(and including moisture) are closer to the values reported by Onuegbu *et al*. (2016). Results (Table 1) shows that the seeds consist majorly of moisture, ash, protein, fat and carbohydrate

It was observed that, generally the seeds (Duncan mango, key lime, African star apple and African pear) has low moisture content. The moisture content of Duncan mango seed (8.19% wet basis) was significantly higher compared with those of the other three seeds. *Moringa oleifera* have been used extensively for water treatment because it has certain characteristics, therefore the seeds were compared with it and other natural coagulants that have been scientifically identified. The seeds from *Moringa oleifera* was reported to have moisture content value of 9.97% by Olagbemide and Alikwe (2015) and 10.60% by Ijarotimi *et al*., (2013). The results of the current study show that the moisture content of the Duncan mango compares quite well with that of *Moringa oleifera*. The low value of moisture content in *Moringa oleifera* seed was considered advantageous because that was considered to reduce microorganism activity and increase the shelf life of the seed. Hence dry seeds of Duncan mango, key lime, African star apple and African pear can be stored for a long time.

The values of the ash content of the seeds were not significantly different from each other and are within the range of values of 3.87 and 4.77% obtained for *Moringa oleifera* seeds as reported by Olagbemide and Alikwe (2015; Ijarotimi *et al*., 2013) respectively. It is well known that ash content is related to the presence of inorganics with different charges. The presence of multi-charged ions in plant seeds extract has been reported to possibly aid coagulation process in water treatment and studies have proven that the addition of ions can help to reduce residual turbidity (Bokil *et al*., 1976; Okuda *et al*., 1999).

The seeds were also found to contain appreciable amount of crude protein (10.62-19.94% wet basis). Key lime seeds contain significantly higher values of crude protein on both wet and dry basis (19.94 and 20.96%) compared with Duncan mango seed (10.67 and 11.51%), African star apple seed (11.67 and 12.42%) and African pear seed (10.62 and 11.19%) samples. The coagulating agent in *Moringa oleifera* seed has been reported to be a soluble protein (Gassenschmidt *et al*., 1995; Ghebremichael *et al*., 2005; Sotheeswaran *et al*., 2011; Camacho *et al*., 2015). The crude protein content in *Moringa oleifera* seed is 35.97% (Olagbemide and Alikwe, 2015) which is a higher value compared with the ones obtained in the seeds under study. Although not all proteins are soluble, studies have reported that soluble proteins (which are active coagulating agent) were extracted from *Moringa oleifera* seed using sodium chloride (salt) solution because a salt increases protein-protein dissociation and protein solubility as the salt's ionic strength increases (Okuda *et al*., 1999). Therefore salt solution can be added to the seed extracts in order to increase their protein-protein dissociation and protein solubility. This will greatly improve coagulation process due to the salt aggressiveness in separating the plant cells or tissues (Alfred and Bridgeman, 2015).

The fat contents value of key lime seed on both wet and dry basis (25 and 26%) were significantly higher compared with those of Duncan mango seed (14.41 and 15.51%), African star apple seed (4.83 and 5.15%) and African pear seed (15.74 and 16.93%) samples. Although *Moringa oleifera* seed has also been reported to contain higher fat content of 38.67% (Olagbemide and Alikwe, 2015), but studies have also shown that high fat content in the seed tends to hinder its coagulation capability and that the crude extract from defatted *Moringa oleifera* seed powder was more effective as a coagulant in water treatment than the crude extract from the non-defatted seed powder. The seeds with lower fat content should therefore be more desirable for water treatment. Therefore, the seeds (key lime, Duncan mango and African pear seeds) with higher fat content may need to be defatted before use in water treatment.

Carbohydrates in mucilage of cactus (*Opuntia*) have been reported to greatly influence its coagulation capability (Saenz *et al*., 2004). The crude fibre content (both wet and dry basis) of Duncan mango seed (1.76 and 1.85%), African star apple seed (1.95 and 2.03%) and African pear seed (3.48 and 3.63%) were not significantly different from each other, while key lime seed has high values (24.42 and 21.37%). For the first three types of seeds, the crude fibre contents are not far from the value (2.87%) reported for *Moringa oleifera* seed (Olagbemide and Alikwe, 2015), although crude fibre (insoluble carbohydrate) has not been reported to enhance coagulation process, lower values in seeds could be better as its not soluble in water, hence might not have impact on coagulation process. Nitrogen Free Extracts (NFE) representing the soluble carbohydrate (starch and sugar) are higher on both wet and dry basis in Duncan mango seed (61.89 and 67.80%), African star apple seed (69.95 and 74.23%) and African pear seed (60.02 and 64.25%) compare with the values of key lime seed (25.59 and 26.84%). However, starch has

been reported to be the coagulation agent in *oryza sativa* (Thakre and Bhole, 1985) and *Zea mays* (Sotheeswaran *et al*., 2011) using adsorption and inter-particle bridging mechanism, hence high nitrogen free extracts in these seeds implies that this constituent (starch and sugar) are present in them and could be advantageous to coagulation process (as the number of active sites available for particle adsorption will be increased). The nitrogen free extract together with the crude fibre amounted to higher values of the total carbohydrate content (both wet and dry basis) of Duncan mango seed (63.81 and 69.57%), African star apple seed (71.90 and 76.30%) and African pear seed (63.54 and 67.64%) compared with the values of key lime seed (46.32 and 48.42%). This constituent in the seeds implies that the extracts from these seeds can enhance turbidity removal in coagulation-flocculation process of water treatment.

Table 2 shows results of qualitative phytochemical screening of Duncan mango, key lime, African star apple and African pear seeds. The results showed that tannins, glycosides, coumarins and phenols are present in all the seeds and that all the seeds samples were devoid of steroids. Tannins are forms of natural high molecular weight polysaccharides (like starch and cellulose) and molecules having high molecular weight are useful coagulating agents as they contribute to coagulation process by increasing the number of active sites available for particle adsorption (adsorption and inter-particle bridging mechanism), hence tannins have been reported to enhance turbidity and colour removal from water sources owing to the use of weakly basic polymer which is formed by reacting tannins with formaldehyde and amino ethanol (Bolto and Gregory, 2007). Tannins are polyphenol compounds and tannins in plants are safe (USEPA, 2006), although contradictory effects on human health have been reported when large quantities of tannins are consumed (Chung *et al*., 1998). However, acceptable daily intake for tannins is yet to be established (FOA, 1970). Phytochemical screening results also showed the presences of saponins and alkaloids in only African star apple seed while they are absent in Duncan mango, key lime and African pear seeds. Additionally, flavonoids and starch are present in Duncan mango, African star apple seed and African pear seed while they are absent in key lime seed. As discussed earlier starch has also been reported as a major component that enhances turbidity removal (using adsorption and inter-particle mechanism) in coagulation-flocculation process of water treatment. The presence of phytochemicals (including saponins, flavonoids coumarins and phenols) in plant may suggest that they possess antibacterial potentials against human pathogens (Nwokonkwo, 2014) because studies have linked these compounds to various bioactivities (Ajaiyeoba *et al*., 2003; Nwokonkwo, 2009; 2013). Hence, these compounds could also be effective on pathogenic organisms that may be attached to suspended particles in water that cause turbidity, implying that these seeds might also have disinfecting ability. Although steroids and alkaloids have been reported to exhibit anti-inflammatory activities (Enzo, 2007), till date it has not be reported if they are among the adhesive agents that bring about coagulation by plant materials, therefore their absence from some of the seeds might not hinder the ability of the seeds to aid coagulation and disinfection. Both the proximate analyses and the phytochemical screening of these seeds (Duncan mango, key lime, African star apple and African pear seeds) indicate that they contain natural constituents, hence the potentials of the seeds extracts to enhance water treatment will pose no threat to life. Some of the phyto-constituents of Duncan mango (tannins, glycosides and flavonoids), African star apple (tannins, saponins, flavonoids and alkaloids) and African pear seeds (tannins, flavonoids and phenols) are in agreement with those reported by Kaur *et al*., (2010; Egharevba *et al*., 2015; Nwokonkwo, 2014).

Conclusion

This study has shown that Duncan mango, key lime, African star apple and African pear seeds are rich in constituents including the active components (tannins and natural polymers such as proteins, starch) which have been reported to bring about coagulation and others (including saponins, flavonoids coumarins and phenols) that possess antibacterial potentials against pathogenic organisms. Therefore, beyond using the seeds for human health and livestock treatment, their extracts could be further investigated as possible coagulant aids for water treatment. This can play a vital role for people in rural areas of poor developing countries where it is difficult to access inorganic chemicals (coagulants and disinfectants) for water treatment.

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Authors' Contributions

Animetu Seghosime: Conceived the study, designed and performed the experiment and prepared the draft of the paper.

Johannes Akpabla Mawuli Awudza: Supervised the work and edited the manuscript

Richard Buamah: Supervised the work and edited the manuscript

Sampson Oduro Kwarteng: Supervised the work and edited the manuscript

Conflict of Interest

The authors declare that they have no conflict of interest.

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