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Properties of natural adsorbent prepared from two local Sudanese agricultural wastes mango seeds and date's stones and their uses in removal of contamination from fluid nutrient

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Abstract

Background: In recent years, special attention has been focused on the use of natural adsorbents as an alternative to replace the conventional adsorbents, based on both the environmental and the economical points of view. The study aimed to produce natural absorbent (activated carbon) from two local agricultural wastes: mango seeds (MS) and date stones (DS) and their uses in removal of contamination from fluid nutrient. Chemical properties such as ash content, moisture content, carbon content percentage and percentage of methylene blue reduction of the two samples were investigated.

Results: The results of study indicated that activated carbon produced from both MS and DS samples have the same pH value of 7 (neutral).The ash content of activated carbon prepared from mango seeds and date's stones was 9.7 and 9.5%, respectively.Our statistical analysis showed no significant difference ($p \geq 0.05$)for ash determinations, while the moisture content of (19.5 and 19.9%) was found for mango seeds and date's stones, respectively. There was no significant difference at $p > 0.05$ for moisture content of the two samples. A significant difference was observed in carbon contents for mango seeds (61.4%) and date's stones (21.8%) at $p \leq 0.05$). There was no significant difference at $p > 0.05$ for moisture content of the two samples. Statistical analysis showed significance difference ($p \leq 0.05$) for carbon determination for both samples. The results also indicated that there was significant correlation between reduction in methylene blue and percentage of activated carbon.

Conclusions: Activated carbon produced from MS and DS was found to be very effective in color removal and of acceptable quality in pH, carbon content, ash content, moisture content and solubility.

Keywords: Mango seeds, Date's stones, Activated carbon, Methylene blue

Background

Population explosion, haphazard rapid urbanization, industrial and technological expansion, energy utilization and waste generation from domestic and industrial sources have many waters unwholesome and hazardous to man and other living resources.

A number of technologies have been developed over the years to remove organic matter expressed as chemical oxygen demand, (COD) from industrial wastewater. The most important technologies include coagulation/flocculation processor (Amuda et al. 2006; Zahrim et al. 2017), membrane filtration (Galambos et al. 2004), oxidation process (San Sebastián et al. 2003). These

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methods are generally expensive, complicated, time consuming and require skilled personnel. The high cost of coal based activated carbon stimulates search for cheaper alternatives.

In recent years, special attention has been focused on the use of natural adsorbents as an alternative to replace the conventional adsorbents, based on both the environmental and the economical points of view. Natural materials that are available in large quantities or certain waste products from industrial or agricultural operations, may have potential as inexpensive sorbents. Due to their low cost, when these materials end their life time, they can be disposed of without expensive regeneration. The abundance and availability of agricultural by—products make them good sources of raw materials for natural sorbents (Bable and Kurniawan 2003; Bailey et al. 1999).

Adsorption is the process through which a substance, originally present in one phase, is removed from that phase by accumulation at the interface between that phase and a separate (solid) phase.

Activated carbon is broadly defined to include a wide range of amorphous carbon based materials prepared in such a way that they exhibit a high degree of porosity and an extended surface area.

Lu et al. (2020) mentioned that proper granular activated carbon (GAC) selection could improve the performance of biological activated carbon (BAC) filters through a combination of adsorption and biodegradation, while the GACs used in BAC filters are now mainly selected according to adsorption function, ignoring biodegradation.

The use of biologically activated carbon (BAC) in drinking water purification is reviewed. In the past, BAC is seen mostly as a polishing treatment. However, BAC has the potential to provide solution to recent challenges faced by water utilities arising from change in natural organic matter (NOM) composition in drinking water sources—increased NOM concentration with a larger fraction of hydrophilic compounds and ever increasing trace level organic pollutants. BAC can offer many advantages by removing hydrophilic fraction and many toxic and endocrine compounds which are not otherwise removed. BAC can also aid the other downstream processes if used as a pre-treatment (Korotta-Gamage and Sathasivan 2017).

The most common use of activated carbons is in adsoption processes, because the adsorbent presents the necessary physicochemical characteristics that allow it to capture substances that are desired to be removed from systems in gaseous or liquid phases (Dizbay-Onat et al. 2018; Wong et al. 2018).

Adsorption is a method widely used for the purpose of removing such compounds, due to its low cost of implementation, high efficiency, and easy operational design (Lima and Carmalin 2018). Recent research has shown that this process, when carried out in activated carbon, allows the carbon to adsorb at least 50% of the initial concentration of contaminants present in the water (Sarici-Özdemir and Önal 2018; Kårelid et al.2017).

Fluid nutrients are like water, juices and milk. Water is very important for life. Water should be of an acceptable color, odor and taste for personal or domestic use. Water makes up more than two thirds of the weight of the human body and without it; we would die in a few days. Water is important to the mechanics of the human body. Water serves as a lubricant, it forms the base for saliva, fluids that surround the joints and it also regulates the body temperature, as the cooling and heating is distributed through perspiration. So keeping water save from microbial and chemical contamination is very important to assure the above listed functions and to prevent their borne diseases.

The study aimed to produce natural absorbent (activated carbon) from two local agricultural wastes: mango seeds (MS) and date stones (DS) and their uses in removal of contamination from fluid nutrient.

Methods

Study area

The study was carried out at biomedical research Laboratory of Ahfad University for Women at Omdurman in Khartoum state (Sudan).

Sample collection and preparations:

Two samples of MS and DS were used to carry out these experiments. Mango and date were brought from the local market (Sug El Arabi).

The seeds and the stones were taken from the fruit. They were cleaned, removed from the foreign materials then ground to a powder using an electric grinder to pass a 0.5 mm screen.

The general process to produce activated carbon is based on carbonizing and activating the carbon aqueous precursor or material. Stones of dates and mango seeds are collected and cleaned.The two products as natural as they were, were crushed by mortar and pistil to a fine powder (size 0.5 mm). The powder was put in crucible, and 1 g of zinc chloride was added to it. It was incinerated at 350 °C for not less than 3 h in an oven. It was cooled in a room temperature. The resulting ash was considered as activated carbon. This activated carbon was used in solubility test, pH, carbon content, ash content, moisture content and reduction of methylene blue.

Seventy ml of concentrated HCl was measured and added to 550 ml of distilled water and mixed well, 12.7 g of KOH crystal was taken and dissolved in 250 ml of distilled water, 0.1 g of methylene blue powder was taken and dissolved in 100 ml of distilled water.

A filter paper was used to filter all the mixture of water and activated carbon samples, filter paper and its glass wear set were cleaned well, the filtration was done once time and the clear solution was carefully collected for analysis (Awe et al.2020; Zheng et al.2018).

Physical and chemical methods of adsorbent

The general process to produce activated carbon is based on carbonizing and activating the carbonaceous precursor material. Stones of dates and mango seeds are collected and cleaned.The two products as natural as they were, were crushed by mortar and pistil to a fine powder (size 0.5 mm). The powder was put in crucible, and 1 g of zinc chloride was added to it. Then it was incinerated at 350 °C for not less than 3 h in an oven. It was cooled in a room temperature. The resulting ash was considered as activated carbon. This activated carbon was used in solubility test, pH, carbon content, ash content, moisture content and reduction of methylene blue.

The methods described by Zhang et al. (2005), Chen et al. (2002) and Bernal et al. (2018) were used to measure the physical and chemical properties of the activated carbon produced.

pH

pH was measured by suspending 1 g of carbon from each sample into a 100 ml glass beaker, 25 ml of distilled water was added and boiled on the hot-plate for 5 min. Then cooled the decanted portion to room temperature and measured by using pH meter (HACH 103).

Moisture content

Half gram from activated carbon was weighed into a predried weighing crucible with lid, close and weight at once to the nearest 0.5 g. The lid was removed and placed the container and lid in a preheated forced circulation oven at 105 °C. The oven was closed and dried to constant weight. Cooled in desiccators to ambient temperature and weight.

$$M_n = ((W_w - W_d)/W_w) \times 100$$

in which: M_n = moisture content (%) of material, W_W = weight of the sample before drying, W_d = weight of the sample after drying.

Ash content

The crucible was ignited in the muffle furnace at 650 °C for 1 h. The crucible was placed in the desiccators. It was cooled to room temperature and was weighed out to the nearest 1 g from activated carbon of each sample and was put into ignited separated crucible in muffle furnace at 650 °C. Ashing can be considered complete when constant weight is achieved. The crucible was placed in the desiccators, and cooling was allowed to room temperature. When it was cooled, air was admitted slowly to avoid loss ash from the crucible and was weighed.

$$\text{Ash}\ (\%) = \frac{\text{Final solids weight (g)}}{\text{Initial carbon weight (g)}} \times 100$$

$$\text{Ash},\ \% = (\text{W1}/\text{W2}) \times 100$$

where: W1 = weight of ash, W2 = initial weight of dried sample.

Solubility

0.1 g of activated carbon from each sample was weighed and dissolved in each solution of Chloroform, Ethanol, benzene, acid, base and water.

Instrumentation and standard solution

Standard solution of methylene blue was prepared by dissolving 1 g of reagent in 100 ml distilled water then a single beam spectrophotometer with wave length 390 nm (wave length accuracy ± 0.1 nm) was used to measure the absorbance of each solution before and after the addition of already prepared adsorbent. The difference in the concentration of absorbance reading in each sample of water was measured using the formula:

$$\frac{\text{Abs of unknown}}{\text{Abs of the standard}} \times 100 = \%\ \text{reduction (remove of color)}$$

Data analysis

Data were analyzed using Statistical Packages for Social Sciences (SPSS).

Results

Physical and chemical properties of adsorbent

Percentage solubility of activated carbon prepared from MS and DS in different solvents is shown in Table 1. Solubility of AC is important property when carbon is chosen for some industrial and nutrition application.

Table 2 show pH, parentage of carbon, Ash and moisture of both MS and DS in relation to standard adsorbent.

Table 3 shows the reduction % of methylene blue by AC from different concentration of MS and DS.

Regarding the correlation between removal of the color of methylene blue and the amount of activated carbon. Statistical analysis showed significance correlation ($p \leq 0.05$) for two samples. Reduction in color by AC prepared from MS gave significant correlation (Fig. 1). The reduction depends on the concentration of activated carbon. This result indicates that activated carbon can be

Table 1 The solubility test (0.1% of activated carbon) in different solvents

Solvents	% of solubility of activated carbon prepared from MS	% of solubility of activated carbon prepared from date's stone AC	Remarks
Distilled water	0.00	0.00	Insoluble
Potassium hydroxide (KOH)	4.69	4.70	Slightly soluble
Hydrochloric acid (HCl)	8.47	8.50	Moderate soluble
Chloroform	7.0	6.74	Slightly soluble
Benzene	11.40	11.40	Highly soluble
Ethanol	14.0	12.67	Highly soluble

Table 2 pH, % of carbon, ash % and moisture % AC from seeds

Parameter	MS (solid)	DS	**Standard adsorbent
pH	7	7	7.37–8.3
% of carbon*	61.4	21.8	13–65
Ash %*	9.0	9.5	4–9.32
Moisture %*	17.5	19.9	2–10

*An average of triplicate reading

**Commercial activated carbon from plant sources

used in systems that need to remove color such as food processing and textile**.**

Discussions

Results from the experimental work showed that mango activated carbon (MAC) have not dissolve in water, approximately 1 g of the product showed a very high degree of solubility in ethanol and benzene. They have solubility greater than that obtained from chloroform, acid and base solvents. The polarity network of carbon and other is affected by attraction force and side charge of the other elements associated with it (Mohammad-Khah and Ansari 2009). However, the result indicated high solubility of AC of both samples in ethanol and benzene was found to be 11.40% and 12.67%, respectively, while moderate solubility of AC was observed in acid (HCl) was found to be 8.47%. Therefore, AC was highly soluble in organic solvents.

pH

The pH was found to be neutral (Bansal and Goyal 2005) for both samples. The result was found to be nearer to that obtained by Ekpete and Horsfall (2011) of value was 6.70 but it is lower than that obtained by Rajesh Mohan et al. (2015), its value was 8.33. Activated carbon pH may influence color by changing the pH of the solution. Such a change affects the pH-sensitive fraction of solution colorants, causing unreliable color measurements (Haimour and Emeish 2006). Moreover, acid carbons, for example, may be a better decolorizer (Bento 2009) and a distinctly alkaline carbon may cause color development through alkaline degradation of organic impurities.

Carbon content:

The average of carbon content in MS and DS was calculated and found 61.4% and 21.8%, respectively. Result was found lower than that obtained by Rajesh Mohan et al. (2015), and the value was 76.50%. For activated carbon to have the desired properties, the temperature of carbonization must be well controlled. The temperature must be sufficiently high to dry and volatilize all non carbon substances during carbonization. If the temperature of carbonization is too high it greatly affects the activity of the carbon produced. The same applies to the temperature at which the carbonized product is activated. The temperature of carbonization and activation influences the molecular architecture of the carbonized material leading to increase in surface area and internal pores. The

Table 3 % Reduction in methylene blue by different concentration of AC from MS and DS in wavelength 390 nm

Conc. of AC in grams	Abs of methylene blue after addition of AC from MS	Abs of methylene blue after addition of AC from DS	Methylene blue reduction % by AC from MS	Methylene blue reduction % by AC from DS
0.01	1.94	1.92	1.02	2.04
0.02	1.93	1.91	1.53	2.55
0.03	1.92	1.89	2.04	3.57
0.04	1.90	1.86	3.06	5.10
0.05	1.85	1.83	5.61	6.63

Absorbance of methylene blue = 1.96

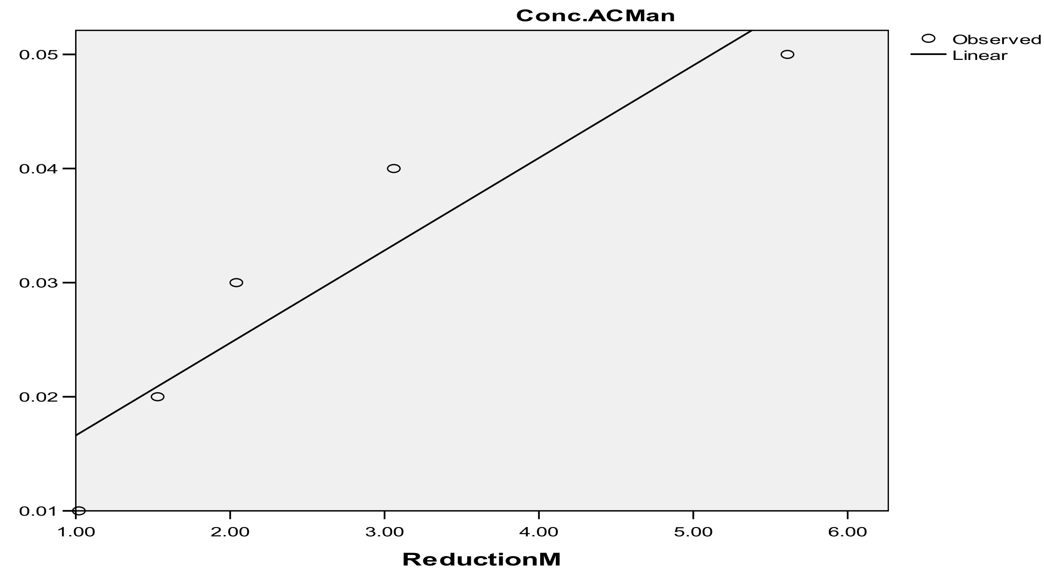

Fig. 1 Correlation between conc. of AC from MS and percentage reduction in methylene blue in wave length of 390 nm

statistical analysis shows significance difference ($p \leq 0.05$) for carbon determination.

Ash content

The average of ash content in AC of MS and DS revealed a value of 9.0% and 9.5%, respectively. Our result indicates higher than that found by Rajesh Mohan et al. (2015), the value was 3.63% and lower than that found by Ekpete and Horsfall (2011), the value was 22.38%. Ash content is a measure mainly derived from the carbon precursor of the minerals as impurities in the carbons Alumina, Iron, Silica and other noncombustible impurities contained in coal and left after its burning. Ash content is measured as a percent by weight of coal and negatively affects its value. Ash content of a carbon is the residue that remains when the carbonaceous materials is burned off. As activated carbon contain inorganic constituents derived from the source materials and from activating agents added during manufacture, the total amount of inorganic constituents will vary from one grade of carbon to another. The inorganic constituents in a carbon are usually reported as being in the form in which they appear when the carbon is ashed. Statistical analysis shows no significance difference ($p \leq 0.05$) for ash determination.

Moisture %

The average of moisture % in activated carbon was found 17.5% and 19.9% for MS and DS, respectively. Our result was found to be similar to that obtained by Ekpete and Horsfall (2011), and the value was 19.5%. It is higher than that obtained by Rajesh Mohan et al. (2015), the value was 2.60%. High moisture content indicating that the particle density is relatively moderate and that the biomaterial should be an excellent raw material for adsorbents to be used in different application such as water and fluid treatment, reduction in microbial load.

The result agreed with the findings of Babatunde et al. (2014) that suggest some activated carbons when stored under humid conditions will adsorb considerable moisture over a period of month. They may adsorb as much as 25to 30% moisture and still appear dry. For many purposes, this moisture content does not affect the adsorptive power, but obviously it dilutes the carbon. The statistical analysis shows no significance difference ($p \leq 0.05$) for moisture determination for the two samples.

Results revealed that the reduction in percentage of methylene blue increases as the concentration of AC of both samples increases. The methylene blue value gives an indication of the adsorption capacity of an activated carbon for molecules having similar dimensions to methylene blue it is method for comparing different batches of activated carbon of the quality. Volume of methylene blue test solution in ml that is just decolorized is the methylene blue value of the activated carbon and the two samples had the ability to absorb color of the methylene blue to color less.

The amount of colorants that can be removed from a solution by activated carbon depends on factors such as contact time, carbon dosage, temperature, concentration or viscosity of the solution and the intrinsic features of the carbon itself. These factors were controlled in a

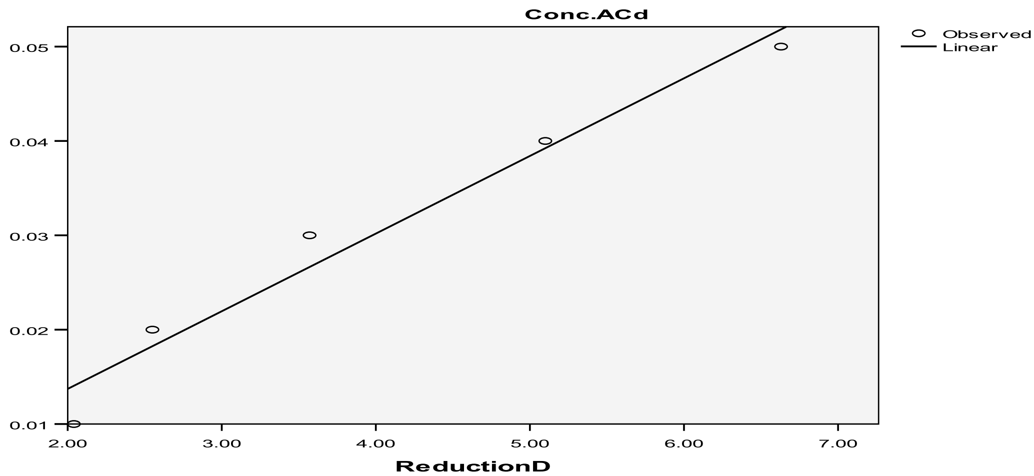

Fig. 2 Correlation between conc. of AC from DS and percentage reduction in methylene blue in wave length of 390 nm

standardized batch test that was designed to allow direct comparison of the decolorization efficiency among the experimental carbons and reference carbons. From all of the above factors, carbon dosage is particularly important because it determines the extent of decolorization and may also be used to predict the cost of carbon (Johns et al. 1999; Mohammad-Khah and Ansari 2009). Our statistical analysis shows significance difference ($p \leq 0.05$) for two samples.

Reduction in color by AC prepared from DS gave significant correlation (Fig. 2). The reduction depends on the concentration of activated carbon. This result indicates that activated carbon can be used in systems that need to remove color such as food industry and textile.

Conclusions

Activated carbon produced from MS and DS was found to be very effective in color removal and of acceptable quality in pH, carbon content, ash content, moisture content and solubility. Reduction in methylene blue was increasing in linear relation to the addition of concentration of both MS and DS activated carbon. The solubility of both samples was higher in ethanol and benzene and moderate soluble in HCl (acid), chloroform and potassium hydroxide (base). It was insoluble in water. The pH of both samples was neutral. The study recommends further research with more sample size.

Abbreviations

AC: Activated carbon; BAC: Biological activated carbon; COD: Chemical oxygen demand,; DS: Date stones; GAC: Granular activated carbon; HCl: Hydrochloric acid; KOH: Potassium hydroxide solution; MAC: Mango activated carbon; MS: Mango seeds; NOM: Natural organic matter; SPSS: Statistical Packages for Social Sciences.

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Authors' contributions

NAE and NAW conceived the design and carried out the experiments. AAI obtained, analyzed and interpreted the data. SKW and SIAE wrote and revised the manuscript. AAI provides financial support for all experiments. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

Authors declare that they have no competing interests.

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