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Diatomaceous Earth Usage in The Agriculture Sector in Uganda And Its Characterization: Current Status and Anticipated Developments

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ABSTRACT

The study was conducted in the districts of Nebbi, Wakiso and Gomba in Uganda to characterize Diatomaceous Earth (DE) from the 3 major deposits in Uganda; explore status of exploitation and usage in agriculture, and anticipate associated effects. DE aka diatomite originated from fossilized remains of diatom shells. In agriculture, it's used in controlling livestock internal and external parasites; post-harvest crop insect pests; and aflatoxins in stored feeds. DE has silica, Ca, Na, Mg, Fe, and other trace minerals making it valuable. Unlike synthetic drugs, DE is safer to consumers. Data collection employed both qualitative and quantitative approaches. Most respondents (94.6%) didn't know of any agricultural DE usage, and the remaining (5.4%) knew it as a remedy against post-harvest weevils in stored grains. Residents in the mining area used DE in painting houses; craved by pregnant women; and relieving diarrhea in humans. Characterization revealed that Ugandan DE deposits were premium for various purposes. No commercial DE exploitation had started however when it's due, the government would guide regulatory framework. Additionally, the socio-economic transformation was anticipated through employment creation; and foreign exchange. Since DE's availability in Uganda is confirmed, more research and programs to promote its exploitation are needed.

Keywords: Agricultural production, Chemical composition, Colour, Commercial exploitation, Diatomite and Uganda.

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INTRODUCTION

Diatomaceous earth (DE) aka diatomite is the fossilized remains of diatom shells. Skeletons of diatoms are made of silica. When diatomite is ground into fine particles, it is called diatomaceous earth or DE. Diatomite is a very porous rock having a fine particle size and low specific gravity. The action of DE on parasites is unclear but there are suggestions that the abrasive action of the powder pierces or scratches the outer protective layer of invertebrates, especially internal and external parasites, which later die as a result of dehydration. This might be the very reason as to why birds frequently take dust baths, most probably to rid themselves of parasites. Some scientists believe that DE is a de-ionizer or de-energizer of worms and parasites. DE, therefore, has a unique physical rather than the chemical mode of action against parasites. This is a very important aspect as far as mammalian safety is concerned since it has negligible toxicity to mammals (Subramanyam and Roesli, 2000). Uganda has DE deposits Pakwach district (this area was recently curved out of Nebbi district) covering most of Alwi and Panyango sub-counties. The benefits of DE in livestock production include: improved general health and appearance of animals; controls internal parasites and external parasites; accelerates growth and production; and improves weight gain and feed conversion (McLean et al., 2005). Additionally, DE controls flies and odour in animal houses; prevents the development of mycotoxins and caking in animal feed and has no withholding period. The contamination of foods and animal feeds with mycotoxins is a big problem worldwide (Kabak et al., 2006). DE has also been used as a vaccine adjuvant (Aw et al., 2013; Nazmi et al., 2017) and when modified with Manganese, DE has been used as wastewater purifier (Walker and Weatherley, 1999).

On the other hand, DE has nutrients for example, silicon (Si), calcium (Ca), sodium (Na), magnesium (Mg), iron (Fe), and many other trace minerals. This attribute makes DE very useful. It is used in neutralizing garbage and manure odours (Bunch et al., 2013). It also has the capacity to eliminate heavy metals from feedstuffs and from bodies of animals; DE is therefore used as a detoxifying agent (Weaver et al., 2013). DE has also been used as a natural dewormer and growth promoter in animals (McLean et al., 2005). Farmers and traders in many parts of the world use DE by adding it to cereal and legume grains to prevent spoilage (Subramanyam and Roesli, 2000). Here, DE plays a very important role in improving food security since over a third of the total grains produced per year globally is lost due to pest attach during storage (Arthur, 1999). This loss affects the farmers' livelihoods, food security, and reduction in the marketability of the grains and it has a negative effect on animal feeds as well (Stathers et al, 2008). DE also keeps food dry and prevents mold growth (Bunch et al., 2013). DE is also used against fleas, lice, mites in animals and bed bugs in houses. When used in controlling pests and parasites, DE uses a physical rather than chemical action against parasites (Subramanyam and Roesli, 2000). In comparison to synthetic drugs, DE is safe, with negligible toxicity to mammals. On the other hand, synthetic drugs impart chemical residues in foods of animal origin and when used during post-harvest handling, synthetic drugs contaminate the foods in which they are applied. The exposure of consumers to drug residues from synthetic remedies is a very big threat since it can lead to chronic illnesses including cancer. On the other hand, consumers are ever more concerned with the safe and ethical production of their food. The demand for organically produced animal products, for example, organic poultry eggs has been steadily increasing (Berg, 2001; Bejaei and Cheng, 2010). This has led to the production of organic poultry in many countries.

In organic farming, the routine use of prophylactic medications is not allowed. It is hence a requirement for a country like Uganda to emulate other countries by practicing organic farming as much as possible so as to access the international market for its livestock and crop products. This, therefore, calls for use of materials like diatomaceous earth which are organic in nature. DE, therefore, has outstanding advantages as compared to synthetic remedies as far as human safety is concerned. Whereas DE has been in existence, well-known and highly utilized elsewhere in the world, the DE deposits in Uganda are not known and have not been put to commercial use. Commercial exploitation of DE would, therefore, be a safer and timely intervention. The current study was conducted between March and June 2017 and was aimed at characterizing the chemical composition and colour of diatomite deposits found in Pakwach district in northern Uganda and to establish the extent of diatomite usage in livestock production in selected districts of Uganda. More emphasis was given to poultry production. This study was a necessary and timely intervention since it was expected to initiate a starting point towards characterization of Ugandan DE chemical composition which may initiate commercial exploitation. The findings would, therefore, serve as a reference point for other intervention which would, in turn, initiate DE exploitation and extensive usage in Uganda and neighbouring countries.

MATERIALS AND METHODS

Study Area

The field part of the study was conducted in the districts of Wakiso and Gomba in central Uganda, and in Nebbi district in northern Uganda (Figure 1). The chemical characterization was conducted at the Directorate of Government Analytical Laboratory, Kampala Uganda.

Data Collection

Field Data Collection

The field part of the study used a multidisciplinary and integrated methodology involving a combination of qualitative and quantitative data collection approaches to explore information concerning DE usage in the target areas. The approaches used were a household survey, focus group discussions and a rapid rural appraisal. A survey was conducted in Wakiso and Gomba districts. Questionnaires were administered to 168 randomly

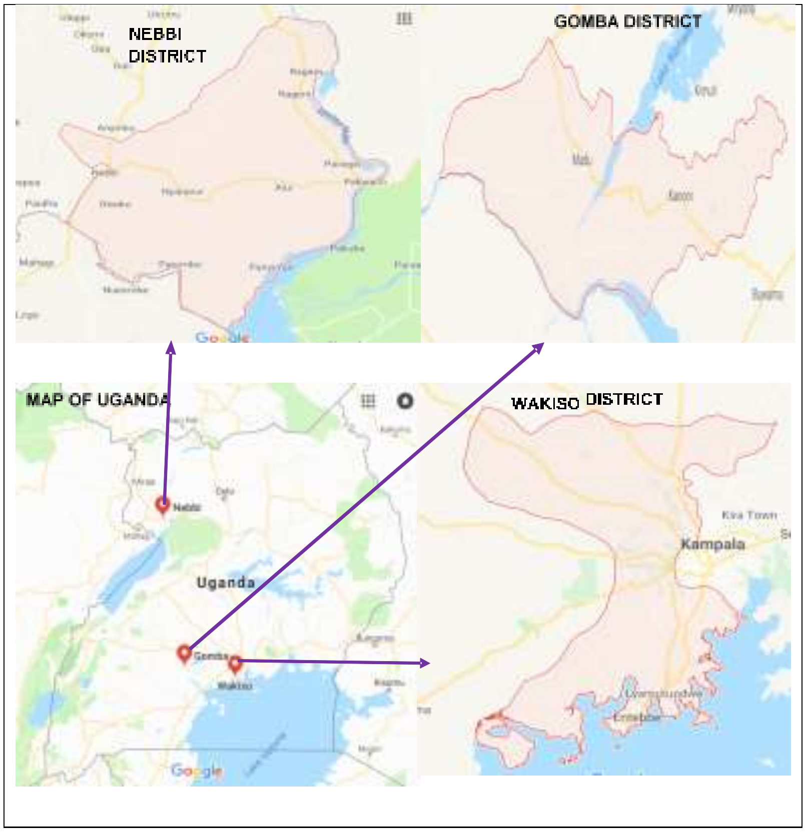

Figure 1. Map of thestudy areas. Source: Google Maps.Accessible on https://www.google.com/maps/search9.8539377,29.4566391,8z.

selected respondents with the aim of capturing farmers' knowledge on the use of diatomaceous earth (DE) in agricultural production putting more emphasis on livestock especially poultry production. Focus group discussions (FGDs) were conducted in Wakiso, Gomba and Nebbi districts, while a rapid rural appraisal (RRA) was conducted in Nebbi district. Each district got one FGD comprising of 8 participants. The FGD participants comprised of district technical staff and leaders; opinion and religious leaders.

The RRA involved a mapping exercise which was aimed at, among other issues, establishing the socio-economic issues associated with DE exploitation and usage.

This included examining the location of DE deposits in relation to the village boundaries; and ways in which it is used by the local population. The RRA employed the following approaches: Reviewing existing data on the use of DE in the area; direct observation; Transect walks and guided field walks; and social resource mapping and triangulation. By using RRA composed of a multi-disciplinary team and studying the social dynamics within the DE mining communities, the team was able to gather information concerning DE usage. Triangulation was used as the main principle during the RRA exercise. This strategy was very important so as to minimize bias from both the researcher and the informant. This enhanced the quality and validity of the gathered information (Freudenberger and Karen, 1999). All strata of the community were involved in the RRA data collection to avoid bias based on gender, socioeconomic status, age and education of the informants.

Secondary Data Collection

These kinds of data were gathered from government policy documents, newspapers and district reports. Information from the aforementioned sources included incidences of occurrence and extent of conflicts associated with ownership and/or access to land which were registered in DE mining communities. Visits to the Ministry of Energy and Mineral Development Ministry which is responsible for all matters of significance in the mining sector in Uganda were also made to collect relevant data on the status of DE exploitation in Uganda.

Chemical Analysis

The chemical characterization was conducted at the

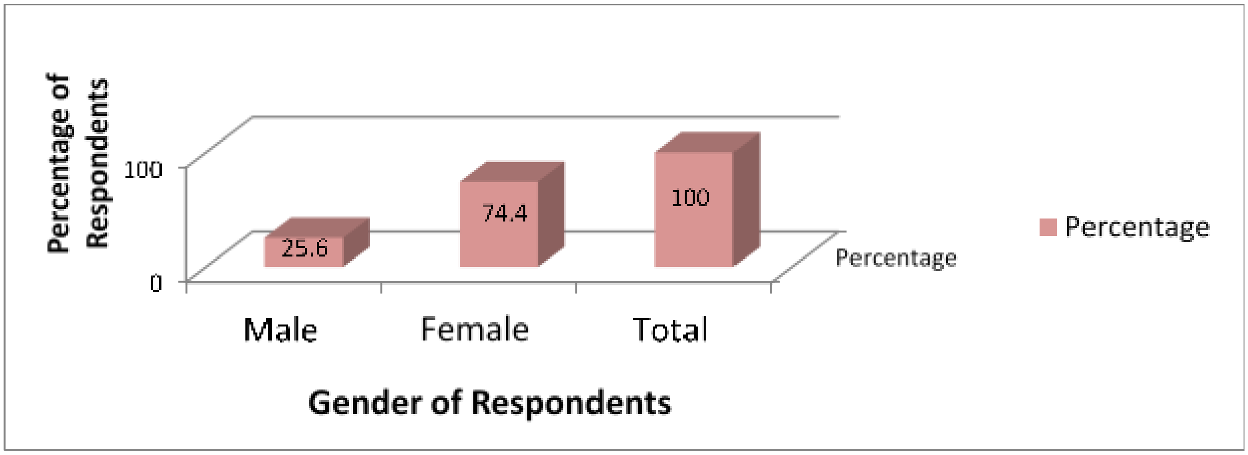

Figure 2. Gender of respondents.

Directorate of Government Analytical Laboratory, Kampala Uganda. Three sediment samples about 0.5 kg each were collected from 3 diatomite deposits in Alwi and Panyango sub-counties in Pakwach district, Northern Uganda. To determine the chemical composition of each of the DE samples, Atomic Absorption Spectroscopy (AAS) method was used in accordance with García and Báez (2012). Each of the samples was analyzed in quadruplicate.

Data Management and Statistical Analysis

Data were coded and entered into Microsoft Excel spreadsheets and analyzed using Statistical software for Social Scientists (SPSS) version 16.0.

RESULTS AND DISCUSSION

Findings from Household Survey

Socio-economic characteristics and ownership of poultry in surveyed households of the 168 farmers visited, 125 (74.4%) of the respondents were female while 43 were male (25.6%) (Figure 2). The responses showed that in majority of the households (60.1%), poultry was entirely owned by adult females while in 38.7% household's poultry was owned by male adults while 1.2% of responses showed that poultry was owned by children. While 55.4% of the respondents owned not more than 50 birds; only 34.5% of the respondents owned more than 100 birds. Poultry management was mainly carried out by adult females (78.0%); followed by male adults (20.8%), and children (1.2%). The low number of birds owned by most respondents as suggested from the survey results was an indicator that poultry farming in the target area was practiced mostly at the subsistence level. Additionally, poultry was in majority of households owned and managed by adult females, that is, by women. This implies that interventions aimed at promoting poultry production could create a big impact as far as improving incomes and livelihoods of the women were concerned. These findings were in line with those by Okitoi et al. (2007). The findings showed that access to veterinary extension services was very difficult, therefore enhancement of alternative remedies especially indigenous traditional knowledge (ITK) was a necessity.

Frequency of Access to Agricultural Extension Services

About 28.6% of the respondents had not accessed agricultural extension services within the previous one year; while 11.2% accessed only once the year, and 41.7% accessed 2 to 5 times in the year; 17.9% 6 to 12 times in the year and only 0.6% accessed veterinary extension services more than 12 times in the year (Figure 3). Agricultural extension service delivery was therefore found to be very low in all study areas. This implied that methods aimed at improving agricultural production using natural products, for example, DE could create a big impact when introduced in such areas. This is because wherever such products are utilized, they are safer, affordable and accessible. In the case of DE, this applies to areas near the mines.

Cause of Losses in Poultry in Surveyed Households

Majority of the respondents (91.7%) mentioned other diseases rather than ectoparasites as the major causes of losses in poultry. Other cause of losses mentioned in reverse order of importance included poor feeding (22.6%), predators (20.8%), adverse weather (13.7%), ectoparasites (9.5%) and accidents (6.5%) (Figure 4).

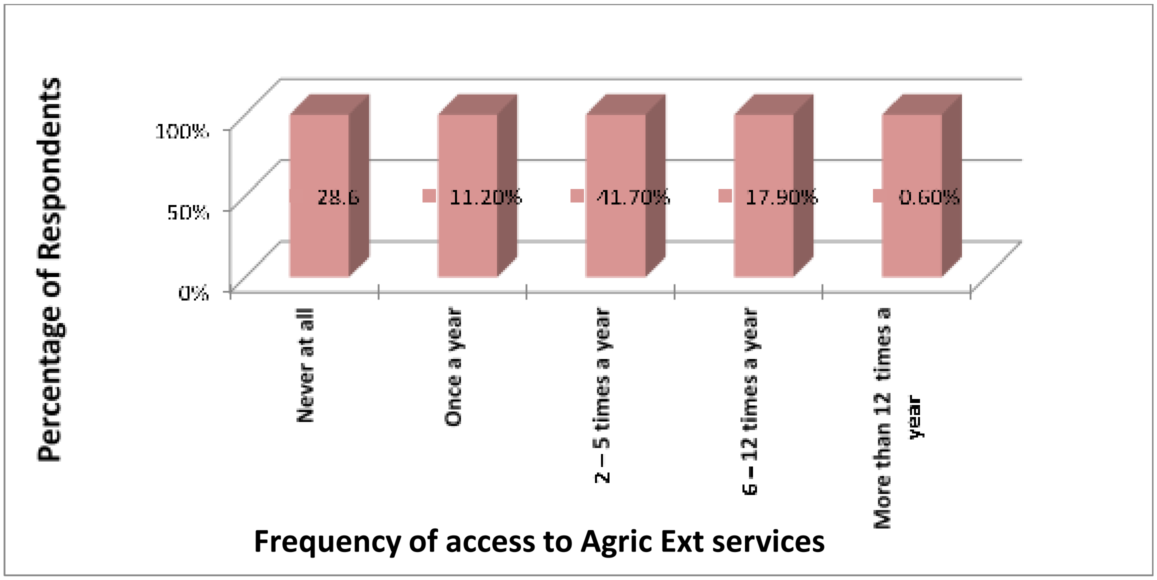

Figure 3. Frequency of access to agricultural extension services.

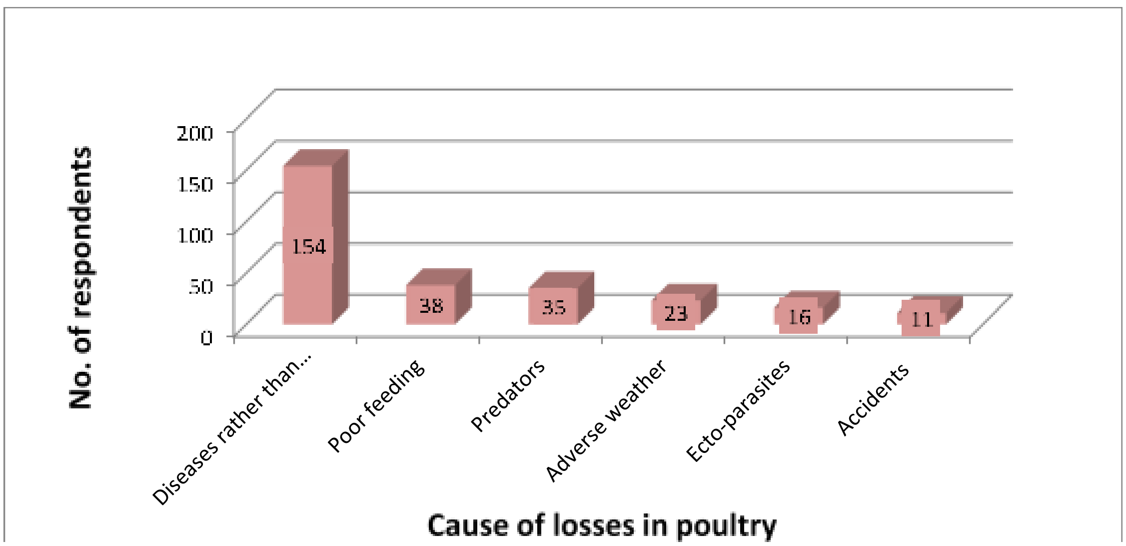

Figure 4. Common cause of losses in poultry.

Alternative Methods Used for Treatment of Poultry Diseases

As alternatives to conventional medicines, the farmers interviewed used a number of ITK in controlling worms in poultry. Such remedies included use of red pepper, *Aloe vera*, *Vernonia amygdalina, Cyphostemma adenocaule*, while some used ashes. These remedies were used mainly in controlling poultry diseases and worms. The remedies used in controlling ectoparasites in poultry included petroleum jelly; paraffin; tobacco; cooking oil and smoking dry banana leaves. 59.4% of the respondents preferred traditional veterinary medicine as compared to modern acaricides in controlling ectoparasites on poultry saying the later was affordable; accessible and more eco-friendly. These findings concurred with those got one other author (Isabirye and Mecleod, 2015).

Findings from Focus Group Discussions and Rapid Rural Appraisal

Land Tenure System

It was also found out that land tenure in the DE mining communities was mainly communal. In each village, there existed a forum of elders which was tasked to come up with modalities followed during natural resource exploitation. The elders convened whenever required to make decisions on the potential clientele of DE among other natural resources. Each village had a chief whose role was to allocate land for the various activities to his subjects and to handle land disputes. A fee commensurate to the amount of DE bought was collected from every client by an elder assigned the role of revenue collection. The fund developed through these means was channeled to development projects and supporting underprivileged groups in the population, for example, paying school fees for orphans. Although communal land ownership can be a source of conflicts in a community, no major conflicts, associated with land ownership and access or issues of land deprivation, in the recent past were mentioned. The research team also discovered that the institutions made up of chiefs and elders ably managed any possible conflicts well. The land around the mining area was used mainly for growing of food crops and cattle rearing among other activities.

Anticipated Socioeconomic Developments in Uganda

This study revealed that a number of benefits in terms of socio-economic transformation where anticipated from commercial DE exploitation. People's involvement in DE related jobs would enhance socio-economic development and transformation of the communities involved through employment creation. Many activities would be attracted around the mining and processing areas leading to improved livelihoods of the surrounding communities. Many categories of people including private investors, farmer and the general were expected to benefit from commercial DE exploitation the study revealed. It was also anticipated that the general public, especially the consumers of agricultural products, will benefit by accessing livestock products and grains which have reduced amounts of drug residues, hence reducing on chances of acquiring chronic illnesses, while the farmers will have access to a readily available and eco-friendly product for use in their farming systems. An opportunity of exporting DE to neighbouring countries especially in East, Central and Southern Africa, particularly those countries in the East African Community was also anticipated.

The benefits anticipated include Employment and livelihood improvement. Input dealers; miners; transporters; DE processors and exporters. Another benefit to the government would be earnings got in form of taxes accrued from activities associated with DE exploitation in the mining and surrounding areas. Such activities would include for example mining, processing, transportation and sales of DE. Other developments would include businesses attracted to the area as a result of increased population, for example, housing, the supply of foods; and delivery of social services, for example, schools and health facilities. Many activities would, therefore, be attracted around the mining and processing areas. Hence, leading to improved livelihoods of the surrounding communities and such communities would act as a reliable tax base for the government. It was however pointed out that DE exploitation might lead to poverty among the smallholder farming communities. This fear was attributed to the issue that the poor tenants in the DE mining area might not have the capital to get engaged in the wide range of commercial activities due to lack of capital. These findings concurred with Collier, (2010) where it was found out that the large-scale mining of oil, gas and other mineral resources mostly benefited the elite and had little contribution to the sustainability of economies.

Anticipated Environmental and Social Challenges

Environmental challenges facing mining communities as anticipated by this study where mainly land and water degradation as a result of digging the ground surface. Also anticipated was an increase in incidences of malaria cases. This comes as a result of an increase in the number of breeding grounds for mosquitoes due to pits left behind after digging the DE. For sustainable development of the DE mining sector in Uganda, the above-anticipated challenges should be looked into and appropriate mitigation measure instituted accordingly. This is in line with the Mining Policy for Uganda (The Draft Mining and Mineral Policy for Uganda, 2018).

Findings from Characterization of Diatomite

Chemical Characterization

Based on the data gotten from chemical analyses, the samples were composed of a significant amount of silica. Using classification similar to that used in Eldernawi et al. (2013), constituents by percentage chemical composition of the DE sediments found in Northern Uganda can be classified into 3 categories as major, secondary and minor constituents. Silica (SiO_2) makes the major component of diatomite sediments while the secondary constituents are magnesium, iron, potassium, calcium and phosphorus; and the minor constituents are cobalt, zinc, manganese, sulphur and molybdenum (Table 1).

Classification of DE Deposits Found in Northern Uganda

Generally, diatomaceous earth deposits may be found close to either current or former bodies of water. Depending on their source, iron and crystalline silica

Table 1. Results from chemical analysis of diatomite from 3 different deposits.

Test/Parameter	Units	Result		
Sample ID		A	B	C
Phosphorous	%(w/w)P_2O_5	2.05%	2.24%	2.32%
Calcium	%(w/w)CaO	4.74%	4.74%	4.77%
Magnesium	%(w/w)MgO	12.28%	10.98%	12.58%
Iron	%(w/w)Fe_2O_3	9.53%	9.15%	8.01%
Zinc	%(w/w) $ZnCO_3$	0.21%	0.27%	0.25%
Cobalt	%(w/w) Co_2AlO_4	0.26%	0.14%	0.57%
Potassium	%(w/w)K_2O	8.89%	9.36%	9.55%
Manganese	%(w/w)MnO	1.29%	1.26%	1.24%
Molybdenum	%(w/w)MoS_2	0.01%	0.008%	0.006%
Sulphur as sulphate	%(w/w)SO_3	0.05%	0.54%	0.39%
Silicon	%(w/w)SiO_2	67.49%	60.59%	74.13%
Colour of diatomite sample		Pearl white	Cream	Grey

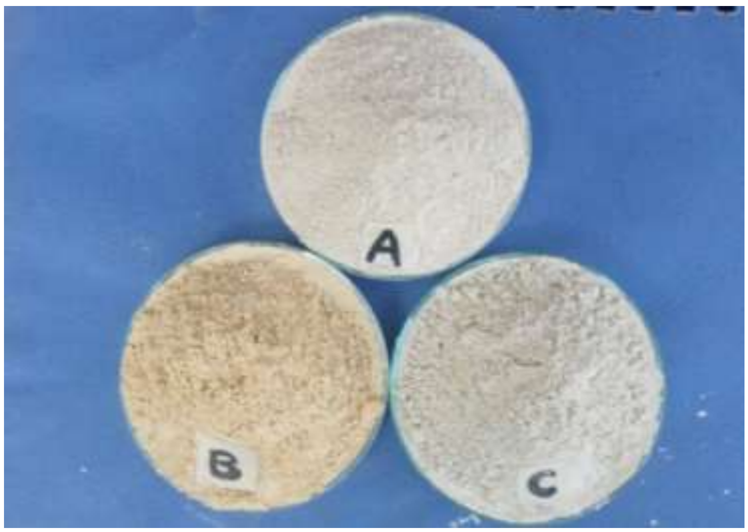

Figure 5. Appearance of DE samples from each of the 3different deposits.

content, DE deposits worldwide are usually divided into two categories: freshwater and saltwater. Freshwater diatomaceous earth is generally mined from dry Lake beds and may be described as having low crystalline silica content and high iron content. This distinguishes it from saltwater diatomaceous earth which is generally extracted from oceanic areas and may be characterized as having high crystalline silica content and low iron content (WIPO, 2010). The DE deposits found in Northern Uganda may, therefore, be classified as freshwater DE deposits.

Colour Description of Ugandan DE Deposits

Findings on DE characterization in terms of appearance revealed that each of the 3 DE deposits found in northern Uganda produced DE having a distinct colour from one another. The colours were pearl white; cream and grey (Figure 5). Results from the chemical analysis showed that the cream DE had the highest percentage of sulphur (0.54%) while the yellowish green had moderate sulphur (0.39) while the pearl white DE had the least sulphur composition. The dark-colored diatomaceous earth contains calcium montmorillonite (aka calcium bentonite) which is naturally occurring clay in the deposits (Kurkura et al., 2012). The white DE contains only diatomaceous earth containing other traces of additional elements. Based on the research conducted on the raw material from these DE deposits, it can be concluded that they represent SiO-diatomite of high quality suitable for various purposes. The DE can be applied in a variety of agricultural and industrial uses (Reka et al., 2014).

Layer Transition of The DE Deposits

The DE deposits were found to have a somehow uniform pattern of layer transition when compared to one another. The DE deposits tended to be found between 3 to 4 feet above the ground. They each formed a layer of 3 to 6 feet deep with an average of 5 feet below which no more DE could be found. Some of the deposits crossed the Pakwach-Arua road. The research team discovered that these DE deposits were responsible for the turbulent that are characteristic to this stretch of the road. It was amazing to note that the DE layers were naturally separated from the soil at the point of intersection without the soil getting admixed with the DE or vice-versa. General findings on agricultural usage of diatomite in the study area. The study findings revealed that 94.6% of respondents were not aware of any agricultural activity whereby DE was utilized. All those who had ever heard about DE agricultural usage (5.4%) knew it as a remedy in controlling post-harvest weevils. These findings were in line with Nikpay (2006). There were no taboos associated with the use of DE mentioned in the study area. This was an indicator that DE might be socially acceptable in the target area. Many respondents (49.4%) preferred traditional remedies as compared to modern acaricides in controlling parasites in poultry saying the latter was expensive, inaccessible and required some knowledge on prescription before usage by farmers. This, therefore, gives hope to the introduction of DE in the area because it will likely be acceptable for use by many people. Agricultural usage of DE was not encountered or mentioned at all during the study. It was, however, observed that animals preferred drinking water from pits left behind after mining of DE as compared to water found elsewhere in that area.

This preference might be attributed to the presence of minerals and trace elements available in DE, a factor desired in improving animal wellbeing McLean et al. (2005). It was also discovered that no commercial exploitation of DE was taking place in the area where this mineral was found. However, small portions of the DE deposits had been exploited and used by the local people. The major activities for which the mineral was put to use was painting houses; craved by pregnant women; it was also used as a remedy for diarrhea in human beings. On the other hand, sacks packed with DE were lined up on the roadside for sale. No information was available as to where the DE was being taken and for what purpose. It was however mentioned that the clients were always destined for Kampala. During the focus group discussions and rapid rural appraisals, held in the mining areas, the different stakeholders emphasized the modalities that were to be followed before mining of DE. An overview of the Mining Act and the environmental issues anticipated in the event of commercial exploitation of DE were mentioned. It was however realized that since no commercial activity was to be executed by the research team among other stakeholders, the environmental issues could not apply at that time and would only be applicable if commercial exploitation, as opposed to research activities, was being conducted in the area.

CONCLUSION

Basing on the findings of this study, it was discovered that the farmers in the target area had little knowledge on diatomaceous earth especially as regards its use in agricultural production. While little usage for DE in agriculture had been documented in Uganda, literature indicated that DE was being used in many countries worldwide in agricultural production. This called for interventions leading to commercial exploitation of this important natural resource to explore the wide range of benefits by farming communities in Uganda. DE has very many agricultural benefits and advantages as compares to synthetic drugs. Literature emphasizes that DE is natural, safe, eco-friendly and has low mammalian toxicity. Commercial exploitation is the main approach through which Uganda can explore this wide range of benefits. In case of commercial DE exploitation was to be effected, a number of benefits in the form of socioeconomic transformation were anticipated. They include the creation of employment through DE related jobs; many activities would be attracted around the mining and processing areas leading to improved livelihoods of the surrounding communities in particular and Uganda in general. Results from the research, especially characterization, suggest that diatomite mined in Uganda is found to be a very important raw material for making various products for use in agricultural production and industrial purposes.

The results of this investigation will, therefore, act as a starting point towards intensive exploration leading to commercial exploitation of DE deposits found in Northern Uganda. Due to a global increase in organic farming, arising from the demand for organic livestock edible products by consumers and food safety campaign programs, diatomaceous earth is gaining attention from scientists and commercial farmers. Its use has however not yet been adopted in most countries, particularly in sub-Saharan Africa, Uganda inclusive. There are, however, relatively few studies investigating the potential of diatomaceous earth in agricultural production especially in the field of livestock. There is, therefore, need for adequate scientific information and infrastructure to produce and continuously supply a naturally-occurring substance such as diatomaceous earth, for improving livestock and crop production locally and internationally. Basing on the findings and conclusions of the study, the following recommendations are forwarded: Commercial exploitation of DE can contribute to Socio-economic transformation of Uganda. The obvious benefits being creation of employment;

making available a natural, safe and eco-friendly product for use in agriculture on both the Ugandan and export market; and enlarging the tax collection base for the country. It is also assumed that by enhancing livestock productivity as well as minimizing post-harvesting losses, farming communities would greatly improve from DE exploitation.

The major impact in this would be improving food security and poverty eradication in the farming communities in Uganda. Since DE exploitation and consequent usage in Uganda is lacking and therefore overdue, strategies aimed at promoting this endeavour are highly advocated for. Policy should target the promotion of DE usage in agriculture so as to make maximum use of this important resource. This can be achieved mainly through vigorous DE awareness campaigns and programs for both farmers and consumers to promote DE usage in the livestock industry and crop sector are needed.

More research on DE is needed to motivate for the broader potential of diatomaceous earth as a means of improvement in both crop and livestock production sectors. In this context, DE would move to another level in agricultural production and food safety for the benefit of future generations. Additionally, a social environmental impact assessment (SEIA) of DE mining is needed before commercial DE exploitation can ensue in those places where the mineral is found. This aspect was beyond the scope of this study.

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