USING TRACE METALS, PEROXIDE, ACID AND IODINE VALUES TO CHARACTERIZE OILS BLEACHED USING CLAYS FROM CENTRAL AND EASTERN UGANDA.
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ABSTRACT

The decrease in content of iron in the bleached oils was highest for all oils bleached. The content of copper showed the smallest change. The decrease in copper content for palm oils decreased from 0.2ppm to 0.1ppm when bleached with both Kajansi and Chelel clays which had be leached in 20% acid.

The content of copper in cotton oils decreased from 0.5ppm to 0.15ppm using Kajansi clay leached in 20% acid yet when Chelel clay leached under similar conditions was used decrease was from 0.5 to 0.1ppm. Similarly, the content of iron in cotton oils bleached using Kajansi clay decreased from 2.5 to 0.2 yet that bleached using Chelel clay decreased to 0.1ppm. The content of iron in sunflower oils bleached using Kajansi clay leached in 20% acid decreased from 1.6 to 0.2ppm yet that bleached with Chelel clay under similar conditions decreased to 0.1ppm.

The acid values showed that the acidity in sunflower oils is largely due to oleic acid as the average value for acids is in the range close to oleic acid, cotton-seed oil corresponded to linoleic acid.

The levels of free fatty acid were found to lie in range from 3.8-3.2 for all clays used showing no significant rise.

The peroxide values of bleached oils lay between 1.2 and 0.8 showing that freshly bleached oils were fit for human consumption.

Key words: Acid, Peroxide, Iodine, Free fatty acids, Iron, Copper content

INTRODUCTION

Sunflower-seed, cotton-seed, Olive, corn, soybeans and all other seed oils fall into the general family of oils known as vegetable oils. Vegetable oil is one of the liquid substances extracted from the vegetables. Vegetable oil is almost entirely made up of the fat of the vegetable. It can be liquid at room temperature, as in the case of corn, cottonseed, soybean, or olive oil. In the case of cocoa butter, coconut, or palm oil, the oil is solid at room temperature. Some vegetable oils are extracted from the seed of the vegetable, as in corn, soybeans, peanuts, hazelnuts, and sunflowers. Some vegetable oils come from the "fruit of the vegetable," as in Olives and palms (*McGraw-Hill,*1997).

There are four basic steps are used to refine oil. These include; neutralization and separation, bleaching and deodorizing (Siddiqui, 1968). When oil is neutralized, sodium hydroxide, also known as

caustic soda, is added to lower the acidity. This neutralizes the bitter taste of the crude oil by combining with the oil to create a sodium salt, which is then separated out from the oil and used for soap stock. The neutralized oil then is ready for bleaching.

 Diatomaceous earth, clays, peroxides or carbon is added to bleach and adsorb the dark colored impurities in the oil in order to give it a clear color. Some of oils may have a color that is objectionable to a consumer. Thus, the oil needs to be bleached to improve its color quality. To this end, a great many oils are commonly treated with bleaching clays to reduce oil color values by adsorptive purification.

Bleaching clays generally improve oil color quality by selectively adsorbing color impurities that are present. Color impurities typically present in oils include, for example, carotenoids, xanthophylls, xanthophyll esters, chlorophyll, tocopherols, as well as oxidized fatty acids and fatty acid polymers (Christidis, et al, 2003; Boki, et al, 1989).

Any off smell that the oil may have is removed through a process known as deodorization. The oil is heated to very high temperatures in a 12-metre tall deodorizer. Vacuum and high heat removes any smell. The result is a clear, odorless, refined vegetable oil. Clays are collectively called alumino-silicates as they contain aluminium oxide and silicon dioxide as universal minerals. Clays were classified into phyllosilicates and layers silicates (Bailey and Brindley, 1979) and have for long been used as clarifying agents for vegetable oils for human consumption (Nutting, 1935; Patterson, 1992; Srasra, 1989; Taylor, 1984; Wiederman, 1981), filling white paper, drilling fluids , geophagy as well as making bricks, tiles, sanitary wares, cups and plates.

It is on this background of immense diversity of applications that drives the need to study structures, compositions and bleaching characteristics of natural clays in Uganda.

Bleaching of vegetable oils is a very important component of oils production and sales (Proctor, 1978; Boukerroui, 2009). The bleaching of oils for human consumption is efficiently carried out using commercial bleaching earths. Unbleached oils contain pesticide residues, oxidation products and heavy metals which can become harmful when consumed. So it is essential to bleach the oils (Pollard, 1993; Richardson, 1978).

This study has aimed at determining the effects of bleaching sunflower-seed and cotton-seed oils on trace elements, acid, iodine and peroxide values.

Mukwano, BIDCO and Gulu nanak oil factories bleach more than 200 metric tones of oil. The bleaching the oils reduces chances of Ugandans contracting diseases resulting from consumption of heavy metals and pesticide residues in oils.

Whereas kaolinites are rarely used to bleach, acid-leached smectites are widely used to clarify oils. The bleaching of edible oils was accomplished using adsorptive bentonite clays (Richardson, 1978; Wiederman,1981). As early as 1933, the designing and testing procedures for bleaching clays had been published. The designed and tested procedures of bleaching and rating bleaching capacity of acid-leached clay samples were developed using petroleum (Nutting, 1933). Later, (Dandy, 1965; Richardson, 1978) decolorized cotton-seed oil by adsorption of color pigments on acid leached clays of Kajansi and Koki. Cotton-seed oil was bleached by selective adsorption of impurities on sulphuric acid-leached clays from Ghana. (Gadzekpo, and Mensah. 1991, Sabah and Sabri 2005). The adsorption of components of oils like carotenoids and peroxides during bleaching was reported (Toro-Vazquez., 1991).

It has been reported that degumming and bleaching removes gums, trace metals, vitamins, pigments and peroxides (Allen et al 1988; Chiew, 2007; De Greyt, 1999; Leonardis, et al 2000; Mbah et al 2005; Ng, et al , 2004; Rossi, 2001). Oxidation products in the crude vegetable oils (Zchau, 1981) are removed by adsorption on the active surface of the bleaching earth to improve color and stability of the final oil.   The effects of filtering through bleaching media on decrease of peroxide value of autoxidized

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soybean oil were investigated and shown to improve its quality (Bheemreddy, 2002; Shahidi, 1997; Zhang, 1992).

Degumming and bleaching, however, remove minor constituents like carotenes, tocols, phytosterols and squalenes which have nutritional aspects (De Greyt, 1999; Goh, 1991). β - carotenes play a role in the prevention of cancer, cataracts and degenerative diseases (Goh, et al, 1994; Packer, 1991). Similarly, tocopherol and tocotrienols have vitamin E activity in the human body (Matsumoto, 1995; Wang, 1999). Major phytosterols in palm oil include campesterol, stigmasterol and β-sitesterol, have pharmaceutical effects but are removed by bleaching (Chiew, 2007; Hedtmann, 1991; Khor, 1997; 1996).

It was shown that acid activated clay adsorbed carotenes on its active sites by formation of hydrogen bonding with the Broensted sites or coordination bonds with Lewis acid sites forming stable carbonium ions (Christidis, et al 2003; Sarier, 1988). Protonated carotenes have been found to degrade readily (Chen 1994; Mortensen, 2000; Siew-Ling, 2010).

Bleaching removes phospholipids, inorganic phosphates and gums from oils and the reduction in the total phosphorous present was proportional to the quantity of clay used (Kheok and Lim, 1982). They suggested mechanism for phosphorous reduction by adsorption of phosphorous ions on lattice structure of the clay. A review of the industrial bleaching of vegetable oils using clays has been documented by different authors (Kaufmann, 1967; Norris, 1964; 1982).

Whereas vegetable oil bearing seeds are grown widely in Uganda, establishing the composition of fully processed oils sold in Uganda has never been fully studied. It is the aim of this study to establish the effect of bleaching oil on composition of vegetable oils.

METHODOLOGY

Calcination of clay

Clay (200g) was placed in a furnace operated at the temperatures ranging from 450-500°C for two hours (Puskar and Ridge, 1974; Al-Zaharani and Alhamed, 1996; Foletto et al, 2002).

Leaching of clays

Calcined clay (100g) was mixed with acid (500mL) of appropriate concentrations (5, 10, 20% v/v) in a flask. The mixture was heated at 105°C for 16 hours; then cooled and filtered. The residue was washed to neutrality with distilled water; then dried at 105°C in the thermo-stated oven. The dried leached powders were labeled and stored for future use. The production of bleaching earth from bentonites comprises the reaction with acids at the boiling temperature, washing with water, drying and milling.

Degumming of vegetable oils

Crude oil (100g) was placed in a flask, 85% phosphoric acid (1g) was added, the mixture heated at 90°C while stirring at 900 revolutions per minute for 10 minutes under nitrogen blanket. The oil was filtered under nitrogen. This method was reported by Car (1978) and modified by Saachia (1992).

Bleaching oils

The mixture of degummed neutralised oil (200g) was mixed with acid-leached bleaching clays (5g) was at various temperatures of 40, 50, 60, 70, 80 and 90°C for two hours under nitrogen blanket (Al-Zaharani and Alhamed, 1996, Patterson, 1992). The mixture was then filtered, cooled and the bleached oil was tested for clarity by measuring its absorbance at 550nm. The experiment was repeated to get comparable results.

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Analysis of oils

The bleached oil was analyzed for parameters such as iron and copper content, peroxide value, free fatty acids value, iodine number, refractive index, transmittance and turbidity to find out whether it was suitable for human use. The methods used are outlined below.

Content of iron and copper in bleached oils

The bleached oil (0.2 g, 0.86 mmol) was digested in the perchloric-nitric-hydrofluoric acid mixture (3.0 mL, 0.13 mol) then made up to 25.0mL with distilled water. The absorbance of copper was determined at 580 nm using the atomic absorption spectrophotometer Shimadzu-AA-6200. Similarly iron was determined at 478 nm when ammonium thiocyanate solution had been added to complex the ions (Allen et al, 1998; Leonardis et al, 2000; Hendrickse et al, 1991). An average of three readings was taken.

Peroxide value of bleached oils

Bleached oil (2.0 g, 8.6 mmol) was placed in a 250mL flask. Ethanoic acid (30 mL, 0.43 mol) added together with chloroform (15 mL, 0.24 mol) to give 9.1:5.0 ratios. The mixture was stirred, water (50 mL, 2.7 mol) added and standard potassium iodide (0.5 mL, 0.001 mmol), followed by starch indicator (2 drops) and water (100 mL, 5.4 mol). The mixture was titrated with 0.01M sodium thiosulphate to discharge the blue colour (AOCS, 2001).

Free fatty acid value of bleached oils

Bleached oil (2.0 g, 8.6 mmol) was placed in flask; butan-1-ol (10 mL, 0.12 mol) added. The mixture was titrated with 0.5M ethanolic potassium hydroxide solution to the faint pink phenolphthalein end point (AOCA 94048). The experiment was repeated thrice.

Iodine value of bleached oils

Resublimed iodine (1.3 g, 5.1 mmol) was dissolved in ethanoic acid (100 mL, 1.3 mol) and slight excess chlorine bubbled through it. Oil (0.1 g, 0.43 mmol) was placed in the 250 mL volumetric flask containing chloroform (10.0 mL, 3.1 mmol) excess 0.1M iodine (15.0 mL, 1.5 mmol) was added, stirred and mixture boiled, then cooled. The amount of unreacted iodine was determined by back titration with standard thiosulphate solution (Pockington, 1990).

RESULTS AND DISCUSSION

Since vegetable oils are bleached to remove coloring matter, traces of heavy elements, phospholipids, poly-aromatics and oxidation products (Mag 1990) so as to improve the quality and oxidation stability of oils (De Greyt and Kellen 2000) it was found necessary to determine the amount of iron and copper present in the bleached oils as test on quality of oil produced. The data obtained is presented in Figures 1 and 2 as bar charts. The quantity of trace elements in oils has been shown to progressively decrease as the concentration of acid used to leach the clays increased as in Figures 1 and 2, the content of iron and copper in the bleached oils decreased with increase in concentration of the acid used per fixed mass of clay (Boyd, 1988). While the decrease in iron content was highest for all oils bleached, content of copper showed the smallest change. The decrease in copper content for palm oils decreased from 0.2ppm to 0.1ppm when bleached with Kajansi clay which had be leached in 20% acid and a similar change occurred when Chelel clay leached in 20% acid was used.

The decrease in copper content of cotton oils has been observed to change from0.5ppm to 0.15ppm using Kajansi clay leached in 20% acid yet when Chelel clay leached under similar conditions was used decrease was from 0.5 to 0.1ppm(Leonardis et al 2000). This showed that both clays were effective in removing copper. The decrease in copper content in sunflower bleached using Kajansi clay

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leached in 20% acid was from 0.3 to 0.15 and a similar decrease was observed when Chelel clay leached in 20% acid was used. So clays from volcanic sediments and acid-granitoids can effectively eliminate copper from oils.

The content of iron in palm oils bleached using Kajansi clay leached in 20% acid decreased from 3.0 to 0.2ppm yet that bleached under the same conditions using Chelel clay decreased to 0.1ppm. This showed the Chelel clay was better than Kajansi clay. Similarly content of iron in cotton oils bleached using Kajansi clay decreased from 2.5 to 0.2 yet that bleached using Chelel clay decreased to 0.1ppm. The content of iron in sunflower oils bleached using Kajansi clay leached in 20% acid decreased from 1.6 to 0.2ppm yet that bleached with Chelel clay under similar conditions decreased to 0.1ppm.
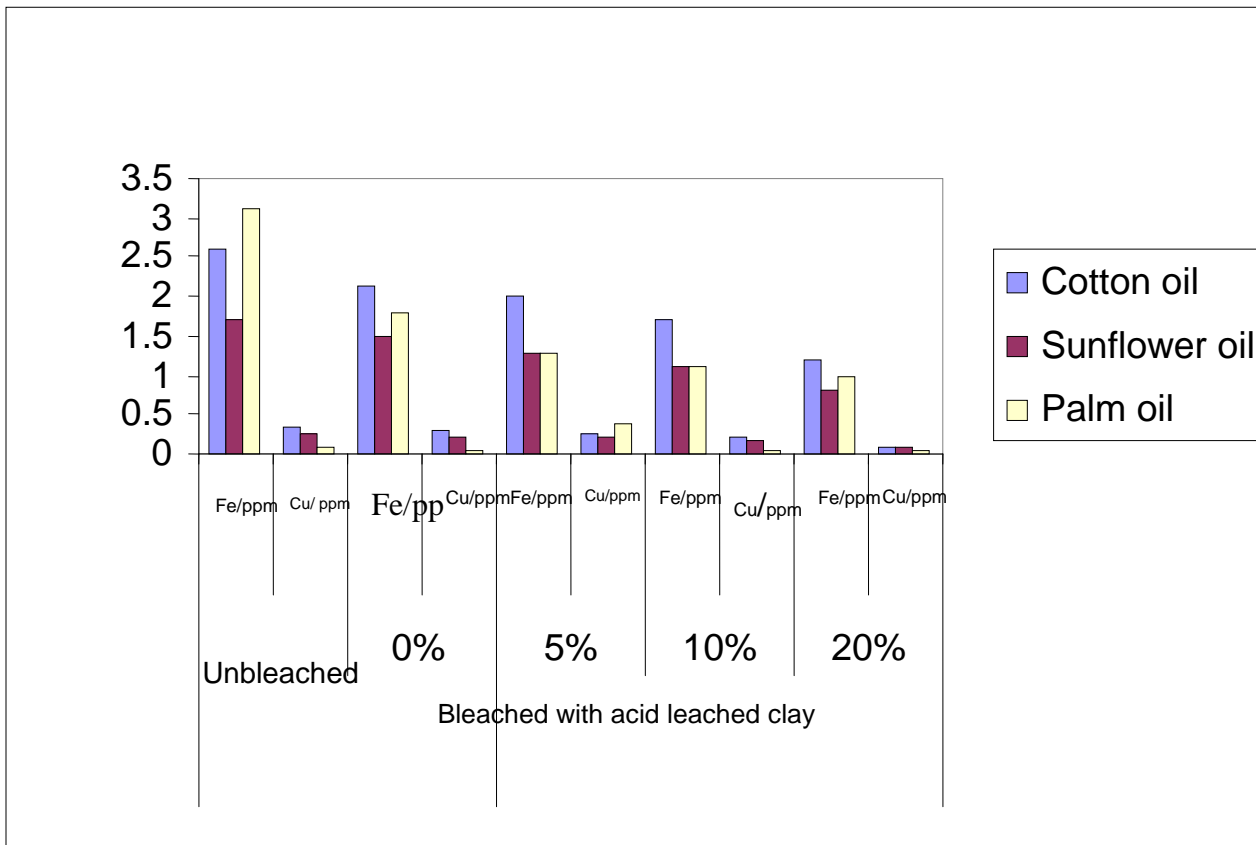

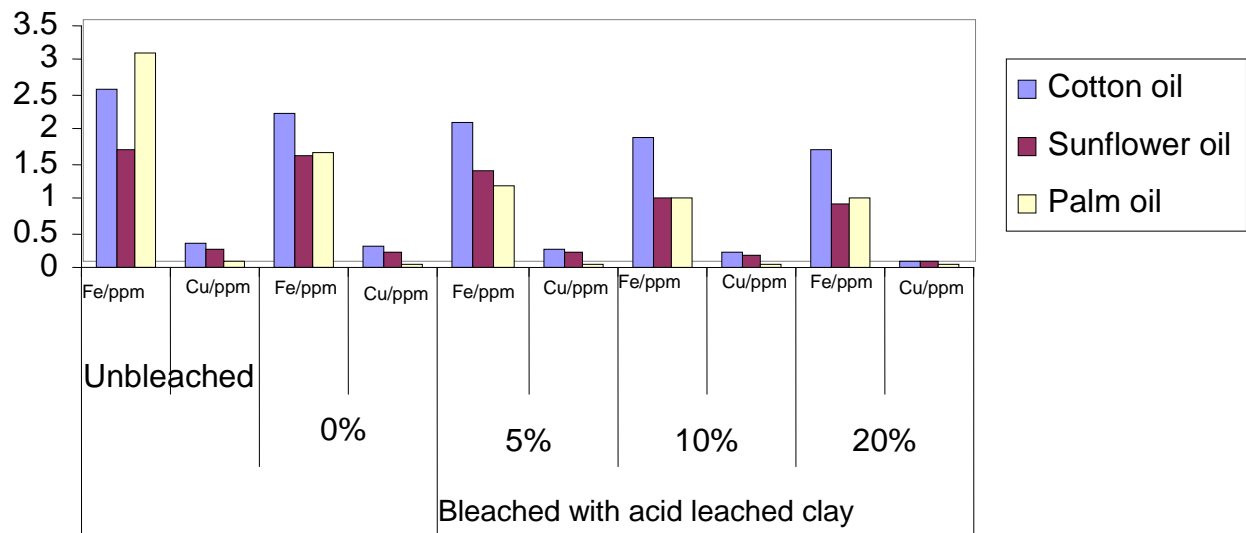**Figure 1: Percentages of metals in bleached oils using Kajansi clays**

Figure 2: Percentages of metals in bleached oils using Chelel clays

Degumming and bleaching removed trace metals like copper and iron. Presence of these elements is known to increase ease of oxidation of oils, so their removal must increase the shelf life of the bleached oils (Wei P C, 2004). Clays are known to adsorb metal ions like Cd^{2+}, Pb^{2+}, Ni^{2+}, PO_4^{3-} (Bhattacharyya, 2006; Sen Gupta and Bhattacharyya, 2006). Similarly, acid-activated sepiolite adsorbed phosphorus from rapeseed oil (Sabah and Mehmet Sabri 2005; Sabah, 2009).

The results in Figures 1 and 2 depicted that for a fixed mass of clay, both iron and copper were increasingly removed with progressive increase in the mass percent of the acid used. The decrease in content of iron and copper in the bleached oils was greatest for the acid leached clays from Chelel possibly because it had the highest smectite content, so the clay acquired high capacity to adsorb metal ions from oils during the bleaching process. Unleached raw clays studied showed reduced adsorptive capacity for metal ions due to availability of very few adsorption sites in the matrix and would be adsorption sites are occupied by exchangeable ions in the interlayers. So the silicon skeleton left after acid-leaching of a clay is very important in the adsorption of metals. The fact that raw clays had a significant effect on the content iron and copper in the bleached oils underscored the importance of clays in removing heavy metals from the environment.

Bleaching vegetable oils with acid activated clays may lead to increased acidity of the oils as solid acids may catalyze hydrolysis of fats by water present in oils or clays (Mag1990). So it has been found necessary to determine the amount acid present in the bleached oils. The data obtained is presented in Table 1.

The bleached oils were subjected to testing for acid value by titrating portions of the bleached oil (0.4g) which were dissolved in ethanol – ether mixture to make $150cm^3$ of solution with 0.1M ethanolic

potassium hydroxide solution using phenolphthalein indicator. The titres obtained were used to calculate the acid values in Table 10 for the clays used.

Table 1: The average acid values

Acid value	Raw clay	5% leached	10% leached	20% leached
Cotton oils	270-279	275-278	280-283	279-285
Sunflower oils	281-282	283-286	284-287	283-287

The calculated acid values showed that the acidity in sunflower oils is largely due to oleic acid as the average value for acids is in the range close to the molar mass of 282 for oleic acid. The calculated acid values for cotton-seed oil correspond to average value for linoleic acid, molar mass 279. The acid values for the raw and bleached oils are almost constant showing that bleaching did not cause the triglycerides to hydrolyze and this is not a new phenomenon because the bleached vegetable oils' acid values were not affected by the bleaching procedure although a slight shift in the absorption maximum of the bleached cottonseed oil was observed (Falaras, et al 1999; Adel Girgis; 2005). Efficient bleaching required determination of peroxide value, free fatty acid content, iron concentration, and conjugation values (Mag, 1990).

Bleaching of vegetable oils at elevated temperatures and in presence of water normally leads to significant rise in levels of free fatty acids because the triglycerides are hydrolyzed by the water present in clays or oils or significantly dissociate when heated at temperatures as high as $200^{\circ}C$ (Mag, 1990). Basing on this, it often necessary to determine the free fatty acid content of vegetable oils bleached with acid-leached clays. The data obtained in experiments to deduce the level of acidity of bleached clays has been presented in tabular form in Table 2.

The bleached oils were subjected to free fatty acids (FFAs) content of oils to investigate the effect of bleaching on fatty acid levels in oils. The data tabulated in Table 2; showed that bleaching sunflower, cotton and palm oils had no significant changes on the free fatty acid content of bleached oils as compared to unbleached oils.

Table 2: Percentages of FFA in bleached vegetable oils

Oil	Percentage of FFA cotton	Percentage of FFA in sunflower oil	Percentage of FFA in palm oil
Unbleached oil	3.5	3.7	3.3
Raw clay	3.3-3.6	3.7-3.8	3.4-3.5
5% leached	3.6	3.7-3.9	3.4-3.7
10% leached	3.6-3-8	3.7-3.9	3.5-3.8
20% leached	3.7-3.9	3.8-4.0	3.7-3.8

The levels of free fatty acid did not rise significantly because most of the clay matrices are themselves acidic enough to disfavor dissociation of the triglycerides. It is likely that the surface acidity of the clay matrices greatly retarded dissociation of the triglycerides to give free fatty acids. The slight increase in level of free fatty acids has been attributed acid activated hydrolysis of the triglycerides as the clays used were acidic. As the oils feebly ionized in the acidic clay matrices, free fatty acid levels increased insignificantly in the bleached oils because the oils lacked water or the clays lacked water to cause the

triglycerides in vegetable oils to hydrolyze and the temperature at which bleaching was performed was low so the triglycerides could not dissociate to give free carboxylic acids (Mag1990). The rise in acidity was automatically checked by the exchange capacity of the clays so it was not significant. The slight rise in free fatty acids with increase in mass percent of acid used to leach the clay is in agreement with the se results reported by Adel Girgis (2005); Morgan et al. (1985) and Hoffmann (1989) who reported that free fatty acids increase in the bleached vegetable oils with acid bleaching earth.

Vegetable oils always contain oxidation products that impart unpleasant odors. Bleaching with activated clays eliminates oxidation products and other impurities from oils. (Mag1990; Topallar 1998) thus improving the quality shelf life of the oils (De Greyt and Kellen, 2000). It is therefore necessary to determine the quantities of peroxides that may be still present to find out if bleaching effectively eliminated them. The data obtained on these experiments has been summarized in table 3.

The titres obtained during the titration of the iodine liberated when the peroxides in the bleached oil (0.1gm) reacted with potassium iodide in presence of acid were summarily used to calculate peroxide values given in Table 3 for clays used to bleach cotton oils and sunflower oils. The values of the peroxide values were computed using the formula:

$$PV = \frac{1000M(A-B)}{W}$$……………………………………………………………..…………(4.7).

Where A is titre obtained with sample of sodium thiosulphate/cm^3.
B is blank titre of sodium thiosulphate/cm^3.
M is molarity of sodium thiosulphate.
W is mass in g of test portion.

The resulting ranges of peroxide values have been summarized in Table 3 below.

Table 3: Peroxide values for oils bleached at 90^oC

Acid strength	Raw	5% leached	10% leached	20% leached
Peroxide value	1.2-2.25	1.1-2.1	1.0-1.9	0.8-1.7

As shown in Tables 3 above, the values are negligibly small showing that freshly bleached sunflower and cottonseed oils are fit for human consumption. The reductions found in peroxide values of the cotton and sunflower seed oils after their bleaching with the different kinds of bleaching earths developed in this study agree with those presented by Adel Girgis (2005), Young (1987), Boki et al. (1989) and Mag (1990) who showed that oxidation levels are reduced by the breakdown of hydroperoxide primary oxidation product on the adsorbent surfaces such as bleaching earth. Boki et al. (1989) suggested that a decrease in peroxide value is due to the decomposition of peroxides by the strongest acid on the surface of bleaching earth. However, it is expected that peroxide values would be higher if the oils were stored for long to encourage rancidity. The primary oxidation products got removed significantly to lower levels as the concentration of the leaching medium increased. The efficiency of adsorption of oxidation products is increased by increase in mass percent of the acid used to leach the clays for all the studied bleached vegetable oil samples investigated (Boyd, 1988; Khor, , 1997; Wei , 2004). As the acid used to leach the clays was low, satisfactory removal of vegetable oil oxidation products was achieved in a manner similar to results adduced when medium activation of the clay (treatment of Ca-montmorillonite with 4 N H_2SO_4) and was found the most effective in bleaching the cottonseed oil, resulting in the best color index and the lowest peroxide value (Falaras, et al 1999). To evaluate efficiency of bleaching required measurements peroxide value, free fatty acid content, iron concentration, and conjugation values (Mag, 1990).

Vegetable oils are unsaturated containing double C=C bonds. The level of unsaturation of the oils may be expressed by the iodine numbers. Iodine numbers of bleached oils have been presented in table 4

and used to identify the dominant acid in the oils. To test the efficiency of bleaching, determination of iodine value or number for conjugation values of the bleached oils was essential (Mag, 1990).

The titre values for the blank and iodine solutions generated when iodine solution (25.0 cm^3) was added to bleached oil sample (1.0g) which had been dissolved in trichloromethane (15.0 cm^3) and the resulting mixtures separately titrated with 0.1M sodium thiosulphate solution after adding water and potassium iodide solution and labeled basing on oil bleached. Using the average titres obtained from titration and applying the formula below, the iodine values (Iv) were calculated and summarily tabulated in Table 4 as shown below.

Iodine value is given by:

$$Iv = \frac{12.69T(V3-V4)}{M}$$ …………………………………………………………….. .….(4.8).

T is exact molarity of sodium thiosulphate = 0.1M.
V3 is   number of cm^3 of $Na_2S_2O_3$, used on blank test.
V4 is   number of cm^3 of $Na_2S_2O_3$, used on test portion.
M is mass of test portion in grams.

Table 4: Iodine values for oils bleached at $90^{\circ}C$

Strength of acid	Raw	5% leached	10% leached	20% leached
Iodine values	109.5-128	109-127	108-127	110-127

The iodine values for the vegetable oils bleached with raw and acid leached clays are low and are in same range showing that the structures of oils change negligibly as a result of bleaching.

The data adduced in this study compares very well with the internationally published data on iodine values of oils by journal of American oil Chemists in which the iodine value for cotton-seed oils lies in the range 108-110 and for sunflower oils it is in 109-135 range. This data has been deduced to indicate that the acid of formula $CH_3 (CH_2)_7CH=CH(CH_2)_7COOH$, oleic acid is dominant in cotton oils yet the acid of formula $CH_3CH_2(CH=CHCH_2)_3 (CH_2)_6COOH$, linolenic acid is dominant in sunflower oil (Firestone, 1993; Firestone D, 1993). The data in Table 4 lacks molecular masses 232 and 270 and so it gives similar inferences those reported by Adel Girgis (2005), Morrison (1975), Hoffmann (1989) and Topallar (1998) who cited that bleaching increases the level of conjugated trienes and reduces the content of conjugated dienes as these have molar masses lying in range of 232 and 270.

CONCLUSION

The decrease in content of iron in the bleached oils was highest for all oils bleached. The content of copper showed the smallest change. The decrease in copper content for palm oils decreased from 0.2ppm to 0.1ppm when bleached with either Kajansi or Chelel clay which had been leached in 20% acid. This showed the clays effectively removed iron and copper from oils bleached under different conditions.

The decrease in copper content of cotton oils was from 0.5ppm to 0.15ppm using Kajansi clay leached in 20% acid yet when Chelel clay leached under similar conditions was used decrease was from 0.5 to 0.1ppm. The content of iron in palm oils bleached using Kajansi clay leached in 20% acid decreased from 3.0 to 0.2ppm yet that bleached under the same conditions using Chelel clay decreased to 0.1ppm. Similarly, the content of iron in cotton oils bleached using Kajansi clay decreased from 2.5 to 0.2 yet that bleached using Chelel clay decreased to 0.1ppm. The content of iron in sunflower oils bleached using Kajansi clay leached in 20% acid decreased from 1.6 to 0.2ppm yet that bleached with Chelel clay under similar conditions decreased to 0.1ppm. So Chelel clay was better at removing trace elements from oils than Kajansi lay (Mbah et al 2005).

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The acid values showed that the acidity in sunflower oils is largely due to oleic acid as the average value for acids is in the range close to oleic acid; cotton-seed oil corresponded to linoleic acid. So the bleached oils contain different free fatty acids.

The levels of free fatty acid were found to lie in range from 3.8-32 for all clays used showing no significant rise in acidity resulted from bleaching.
The peroxide values of bleached oils lay between 1.2 and 0.8 showing that freshly bleached oils are fit for human consumption.

Recommendations

As Chelel is located on the slopes of the Elgon, a volcanic mountain, studying of clays from Chelel should be continued to locate Uganda's bentonite. As Kajansi is a Kaolinite, there is need to analyze this kaolinite which binds impurities in oils to nearly the same level as smectites.

ACKNOWLEDGEMENT

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