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Mineral composition of oil cakes from some unconventional oilseeds from the Democratic Republic of Congo

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ABSTRACT

Description of subject. In Democratic Republic of Congo, a wide range of plants, both domestic and wild, contains fat that can be valued in various areas of life. After extraction of the oil by pressure or by means of solvents, the meal contains minerals with a certain nutritional value. Thus, a study relating to this question was carried out.
Objectives. The objective of the research is to promote the valorization of oil cakes, by-products of unconventional oilseeds with a view to considering their use in the food ration.
Methods. The oil was extracted from ten unconventional oilseed species: *Allophylus africanus* (AA), *Carapa procera* (CP), *Cannabis sativa* (CS), *Coula edulis* (CE), *Hura crepitans* (HC), *Monodora myristica* (MM), *Ongokea gore* (OG), *Moringa oleifera* (MO), *Pentadesma butyraceae* (PB), *Pentachletra eetveldeana* (PE) using petroleum ether as solvent. The oil cakes obtained from the extraction of oil from these oil seeds were analyzed and their mineral composition was determined. The crude ash was obtained after calcining the grain powder in a muffle oven. The composition of major minerals (calcium, magnesium, potassium, phosphorus and sulfur) was determined by X-ray fluorescence spectrometry at CGEA/CERN-K.
Results. The results showed that the meal of *Pentadesma butyraceae* (PB) contained (per 100g of dry matter) the highest amount of Ca (849.80 mg). *Carapa procera* (CP) had the highest K content (925.22 mg). The oil cakes of the species *Hura crepitans* (HC) (59.75 mg), *Ongokea gore* (OG) (59.92 mg) and *Moringa oleifera* (MO) (57.26 mg) gave a higher phosphorus content than the others.
Conclusion. The analysis revealed the presence of five major mineral elements: Ca, Mg, K, P and S. All the oil cakes of the species under study have appreciable quantity of minerals and could be used as food supplements for both man only or for cattle.

Keywords: Oil cake, unconventional oilseeds, mineral elements, DRC.

RESUME

Composition minérale des tourteaux de quelques oléagineux non conventionnels de la République Démocratique du Congo
Description du sujet. En République Démocratique du Congo, un large éventail de plantes tant domestiques que sauvages contient de la matière grasse pouvant être valorisée dans divers domaines de la vie. Après extraction de l'huile par pression ou au moyen de solvants, le tourteau contient des minéraux ayant une certaine valeur nutritionnelle. Ainsi, une étude se rapportant à cette question a été réalisée.
Objectif. L'objectif de la recherche est de promouvoir la valorisation des tourteaux, sous-produits des oléagineux non conventionnels en vue d'envisager leur utilisation dans la ration alimentaire.
Méthodes. L'huile a été extraite de dix espèces oléagineuses non conventionnelles: *Allophylus africanus* (AA), *Carapa procera* (CP), *Cannabis sativa* (CS), *Coula edulis* (CE), *Hura crepitans* (HC), *Monodora myristica* (MM), *Ongokea gore* (OG), *Moringa oleifera* (MO), *Pentadesma butyraceae* (PB), *Pentachletra eetveldeana* (PE) à l'aide de l'éther de pétrole comme solvant. Les tourteaux issus de l'extraction d'huile de ces graines oléagineuses ont été analysés et leur composition minérale a été déterminée. La cendre brute a été obtenue après calcination de la poudre

de grains au four à moufle. La composition en minéraux majeurs (calcium, magnésium, potassium, phosphore et soufre) a été déterminée par spéctrométrie de fluorescence X au CGEA/CREN-K.
Résultats. Les résultats ont montré que les tourteaux de *Pentadesma butyraceae* (PB) contenaient (sur 100g de matière sèche) la plus grande quantité de Ca (849,80 mg). L'espèce *Carapa procera* (CP) a présenté la plus forte teneur en K (925,22 mg). Les tourteaux des espèces *Hura crepitans* (HC) (59,75 mg), *Ongokea gore* (OG) (59,92 mg) et *Moringa oleifera* (MO) (57,26 mg) ont donné une plus forte teneur en phosphore que les autres.
Conclusion. L'analyse a révélé la présence de cinq éléments minéraux majeurs: Ca, Mg, K, P et S. Tous les tourteaux des espèces soumises à l'étude possèdent des quantités appréciables de minéraux et pourraient être utilisés comme suppléments alimentaires tant pour l'homme que pour le bétail.

Mots-clés : Tourteau, oléagineux non conventionnels, éléments minéraux, RDC

1. INTRODUCTION

Vegetable oil is obtained from seeds found all over the world. Among hundreds types of oleaginous seeds actually known, a few number has a commercial value. The oilseeds of cotton, groundnut, soybean, maize, sunflower, flax, olive, sesame, castor as well as coconut, palm nut, flop and shea nut, are the conventional one. All vegetable oil extracted from other plant than the commercialized oils are qualified as the unconventional oils.

In DRC ecology, huge amount of wild and domesticate plants contain a lipid that can be valorized in varied sectors of human life, after extraction by pressure or existing solvents. One of the by-product is the meal called cake.

Meals are solid residues or solid by-products obtained after extraction of oil from the seeds or pulps of oil-bearing fruits. They typically account for 50 to 75 % of the seed mass. Meals have a natural outlet as animal and human food supplements. They are the second most important class of food after cereals.

Food contains active ingredients called nutrients, composed with macronutrients (proteins, lipids, carbohydrates) and micronutrients (vitamins, minerals and trace elements) (Cao *et al*., 2000). Mineral elements form complexes with organic molecules and are involved in various biological processes as a "carrier" complex, a charge transfer complex or as cation exchange complex. These complexes participate in the electrochemical functions of nerves and muscles, in the formation of bones and teeth, in the activation of enzymes and in the transport of oxygen, etc. (Gralak, 2002). Some mineral elements are considered essential to human life whereas others are essential for animals. Some such as mercury, cadmium and lead are known to be toxics for humans.

Mineral deficiencies in animal and human diets lead to dysfunctions of certain cellular metabolic pathways which may result in certain pathologies (Wedekind *et al*., 1993). It is therefore important to provide human and animal nutrition with mineral supplements such as oil seeds meals.

Oilseed flours are an important source of minerals. The most widely used are soybean (nearly 70 % of meals consumed in Europe), and groundnut (an important source of calcium, phosphorus and magnesium. Soybean and groundnut meals contain minerals, proteins, carbohydrates and cellulose (Ayoola, 2012) and are given as food supplement to humans or animals.

Recently, it was reported the characterization of vegetable oils from the following unconventional oleaginous seeds plants: *Allophylus africanus* (AA), *Carapa procera* (CP), *Cannabis sativa* (CS), *Coula edulis* (CE), *Hura crepitans* (HC), *Monodora myristica* (MM), *Ongokea gore* (OG), *Moringa oleifera* (MO), *Pentadesma butyraceae* (PB) and *Pentaclethra eetveldeana* (PE) (Mutinsumu, 2015). Herein, the qualitative and quantitative analysis of mineral content was presented on meals obtained after extraction of seed oils using petroleum ether.

Present study aims to valorize the by-products of these unconventional oil seeds. It is expected to determine the mineral contribution of these by-products and describe the relationship between variables and the similitude among studied oleaginous meals so that one can substitute another in food or feed ration.

2. MATERIAL AND METHODS

2.1. Material

Oil seeds of *AA*, *CP*,*CS*,*CE*,*HC*,*MM*,*OG*,*MO*,*PB* and *PE* were collected in the botanical gardens of Eala and Kisantu, Luki reserve and Kikwit in town area), in Democratic Republic of the Congo. Seeds from each vegetable species were authenticated by the INERA Herbarium at the Faculty of Sciences, University of Kinshasa. Meals from the oilseeds were obtained after Soxhlet extraction as described earlier (Mutinsumu, 2015). A little botanical description of the plant species is given as follows:

Cannabis sativa (Chanvre in french; Diamba in Tshiluba, Swahili, Lingala, Kikongo, DRC) belongs to family of Cannabaceae (Pauwels, 1993). It is a plant with average height, generally green but sparse than other varieties. Its leaves are composed with long and narrow blades. Its female flowers are long and fluffy. This allows the free circulation of air around and between the plants, providing a healthy growing and presenting less mould risk in the tropical conditions (Pauwels, 1993) (Bouloc, 2006). *Cannabis sativa* attains the biggest height than other types of Cannabaceae, continuing to go high during the all growing and flowering phases. The female flowers of *Cannabis sativa* appear first on the knots and then extend along the stalk and the ramification. Consequently, female flowers of *Cannabis sativa* are less dense and light than the one of other varieties.

Allophyllus africanus P. Beauv is a shrub belonging to the family of Sapindaceae (Pauwels, 1993). His stalk is short, 2-8m high; her branches are skirt around and somehow and erected. The bark is smooth, grey to very brown with thin, yellow to pink branches, sometimes becoming brownish. Leaves are alternate, trifoliate, elliptic to obovate shape, with rounded teeth edge, and sometimes as a hook and about glandulous. His flower is white to greenish, on short pedicels, with overlapping and hairless sepals, bearing 4 tiny petals, of 2 mm of diameter. Fruit is bulging berry, of 6-8 mm of diameter, red orange to maturity, having at top a vestige of style.

Ongokea gore is a plant in the family of Olacaceae (Pauwels, 1993), his big height can attain 40 m high. The stalk is straight and cylindrical devoid of branches at 20m high, with 100-150 cm of diameter, without buttress, but sometimes with important swelling of roots. The surface of bark is gray to brown or black, slightly cracked; it can detach in thin and irregular scale. The bark has 1-2 cm of thickness, smoothly granular, yellow brown. His pyramidal top is open with some big branches, and the secondary branches are laterally compressed. Leaves are alternate, simple and entire, without stipules; thin petiole of 0.5 - 1 cm long, with groove at the top, ending in thin edges along the branch, the limb is elliptic, 4-12 cm with rounded base or cuneiform; apex is shortly acuminated, papyrace, hairless, pennantinerve with 6-10 pairs of lateral nervures. Inflorescence is axillar panicle and can attain 15 cm long, compose with umbel cymes with numerous flowers. The flowers, bisexual or functionally unisexual, are regular, greenish, with a thin pedicel, of about 6 mm long, bent, having a disk with 4 lobes and a tube composed with stamina. Fruits are bulging drupe of 2 - 4 cm of diameter, surrounded by a widen calices, except its apical portion; slightly acuminated, with a single grain during the fructification. Fruits strew the soil in a big quantity; a fleshy exocarp ferments rapidly and spread a characteristic acid smell. Grains are bulging with about 1.5 cm of diameter.

Pentadesma butyraceae (Nzibu in Kikongo, DRC) belong to the family of Guttiferae (Kabele, 1975). It is a tree of average to big height, attaining 35 m high. His stalk is cylindrical, attaining 100 - 150 cm of diameter, sometimes with the small contreforts or stilt roots. The bark is rough and scaled; his internal bark is red brown to brown, thinly cracked, exsuding a yellow bright sap. Branches are angular or cutlet, brown to black. Leaves are opposed, in dense terminal tuft, simple and entire, stipules are absent, they have a petiole of 2.5 cm long, stocky and a limb is obovate to oblong, lanceolate, measuring 9 - 25 cm. Flowers are bisexual, regular, yellowish to white greenish; the pedicel measures 1 - 4 cm long, mostly arched. Sepals are free, oval, attaining 5 cm long, unequal, tough and the petals are free, oblong, merged to the base (Avocevou, 2005). Fruit is a berry ellipsoidal to ovale, 9 - 15 cm with the base surrounded by the calice. Stamina and glands of disk are persisting, apex is pointed and the partition is crude, brown and coriace, containing 5 - 15 grains (Avocevou, 2005). Pyramidal grains have flattened sides or irregular, 3 - 4 cm long. The brown seedling has a hypogeal germination with a redish epistyle, 10 - 30 cm long and first leaves opposed of 6 - 16 cm (Ouattara, 1999).

Carapa procera (Nkazu-kumbi in Mayombe, DRC). It belongs to the family of Meliaceae (Kabele, 1975). It is a short height plant whose fruits are very big capsule attaining 10 cm, about spheric, woody and dehiscent. Fruit is divided in five lodges containing 2 - 8 angular grains, with rounded angle, a black integument and woody.

Monodora myristica (Peyi In DRC) belongs to the family of Annonaceae (Kabele, 1975). It is a tropical tree with characteristic flowers, hollow and scented, seeming to the orchid. His superb abundant flowering attracts the bees, butterflies and birds. Flowers are yellow and red and have 4 petals of 10 cm long. They hang from 20 cm peduncles. Germination in nature is best when the seed passes through the chimpanzee's digestive system or the fruit is buried by dung beetles. Grains are very hard, it must be soaked during one day to soften.

Coula edulis (Nkumunu in Mayombe, DRC); noisetier (French). It is a medium-sized tree in the lower forest floor up to 30 m tall, often branching from 3 to 4 m above the ground. The bark is gray, 1 cm thick in thick plates often rectangular, the edge is fibrous, brittle, yellow brown ((Louis, 1948). *Coula edulis* is a species whose trees develop according to the architectural model of roux; the branches, horizontal branches, appear continuously at each node of the trunk (Adrieans, 1951). The leaves are evergreen, alternate, simple with a shiny green blade and red hair, with midribs and secondary from 10 to 13 pairs. The petiole is 1 to 3cm long (Aubreville, 1959). Flowers, 4 to 6, are hermaphrodite, white -

yellowish or slightly reddish 2 to 5 mm; the fruits are globular and ellipsoid 3.5 to 5 cm in diameter, yellowish green at maturity, weighing on average 35g. The nucleus of rounded shape and made of hard, brown and thick endocarp covered with small protrusions, in three directions, from the top, it presents a strong thickening. The almond is unique, spherical from 1.5 to 2.5 cm in diameter, oily, white and weighs 10 to 15 g (Villiers, 1973).

Hura crepitans is a tree in the Euphorbiaceae family. Like many other Euphorbiaceae, it has in its tissues a milky substance characteristic of the family (Rohwer and Novy, 2008; cite par Mutinsumu *et al*., 2015). *Hura crepitans* is majestic tree with a straight trunk, of variable size; it can measure 30 m and even 45 m in height. Its trunk can have a diameter of 80cm to 1.50 m. Its wood, beige or light olive gray is known as Acacu. The leaves are persistent, simple, alternate, toothed. They are a beautiful green with petioles as large as the leaves. They are oval, indented in the heart at their base and accumulated. It has 10 to 16 pairs of protruding secondary ribs. The first pair of ribs is reversed. The petiole has 2 glands placed under the leaf blade. *Hura crepitans* is a monoecious plant with red flowers. Male flowers are nested on a kitten that hangs from the end of a long terminal peduncle. They are cup-shaped and measure 2 to 5mm and are grouped in a conical spike measuring up to 20cm. Female flowers are solitary, they are born at the end of the branches. Its cup-shaped chalice is connected to a column ending in a disc. The female flowers measure 6cm and are formed almost exclusively of an ovary around the central axis, there are 12 carpels arranged radially. Fruits are green at the start, turn brown when ripe. They are globular and flattened, formed from 14 to 20 slices which open explosively. They look like a small pumpkin (Rohwer and Novy, 2008; cité par Mutinsumu *et al*., 2015). Seed measures 2 cm, it is disc-shaped and is enclosed between two small woody curved valves. It will survive until the onset of the rains and once in contact with water, it literally shatter. This phenomenon is accompanied by a very particular noise from where the objective of *Hura crepitans* defining the species. This is how seeds are spread over long distances.

Moringa oleifera Lam (Moringa) belongs to Moringaceae family. The leaves and fruits are eaten by natives. It is a species native to India and Arabia, it is widespread in all tropical regions of Africa. In Cameroon, it is found in all types of savannahs. It is also planted in villages. It is an undemanding plant. It grows in areas with a warm climate, with fairly light, well-drained soils, of the sandy-clay type. It is a shrub or small tree up to 10 m high and 20 cm in diameter, clear treetop, spread out in parasol, low-branched; bark brownish gray or dark gray, coarsely lenticellate, thick, yellowish slice exuding a white and opaque gum which reddens on the surface. The leaves are alternate, bi- or tripinnate, 20 to 70 cm long; 5-13 opposite pinnae comprising 5-11 opposite pinnules, themselves divided into 3 or 5 leaflets; oval to elliptical leaflets, up to 2 x 1.5 cm, rounded at both ends; very short petiolule. The inflorescences in axillary panicles are 15-20 cm long. The white, fragrant flowers are hermaphrodite, irregular, pentamerous with uneven petals; 5 yellow stamens, 5 staminodes; ovary with 1 compartment. The fruits are triangular section capsules, very long, up to 50 cm in length, dehiscent 3 to 5 valves. The seeds are numerous and spherical, 7-8 mm in diameter and 0.3 g of medium weight, black, bearing, 3 membranous wings. Flowering takes place in the dry season and fruiting at the end of the dry season (Loumouamou, 2011).

Pentaclethra eetveldeana de Wild & T. Durand (Nseka, Kiseka, Nsombo, Mfusila, Nsaka en Kiyombe, DRC). It belongs to the family of Mimosaceae. It is found Cameroon, Equatorial Guinea, Gabon, Congo Brazzaville, DRC, Angola. It is present in rainforests, most often in secondary forests, where it can be dominant. It is also found in forest enclaves in the savannah zone, and in gallery forests. It is present in rainforests, most often in secondary forests, where it can be dominant. It is also found in forest enclaves in the savannah zone, and in gallery forests. It is a tree up to 30m tall; the barrel is often sinuous, up to 50 cm in diameter, with small buttresses at the base or without buttresses; the outer bark is gray, cracked and the inner bark is brown with a dome-shaped crown; the young pubescent twigs are brown. The leaves are alternate and compound bipinnate, up to 40 cm long; the stipules are linear - lanceolate, deciduous; the petiole, 4.5–7 cm long, is swollen and articulated at the base, grooved; the opposite pinnae, in 9–16 pairs, 4–12 cm long, are clearly articulated at the base, 15–30 pairs of leaflets; the leaflets are opposite, sessile, obliquely rhomboid, 8–13 mm × 2–3.5 mm, the acute apex is hairless. The inflorescence is a terminal or axillary panicle up to 30 cm long, consisting of spikes, with many flowers; peduncle 1.5–2 cm long, pubescent. The bisexual flowers are regular, 5-merous, small, very fragrant, sessile; the bell calyx, 1.5–2 mm long, with broadly triangular lobes about 0.5 mm long; the petals are oblong-lanceolate, 4mm long, swollen at the base and fused to 1–2 mm, whitish; the stamens are 5, about 5mm long, the anthers with a large gland between the theca, staminodes 5, filiform, about 9mm long; the ovary is superior, short-striped, densely hairy, style about 4mm long, stigma clubbed. The fruit is an oblique ellipsoid-oblong pod up to 20cm × 4cm, woody, reddish brown, striped longitudinally, tapering towards the base, the apex is obtuse, persistent for a long time and opening on the tree explosively before bending strongly, with 3–8 seeds. The seeds are orbicular to ovoid, flattened, 2–3 cm × 2–2.5 cm, smooth, reddish brown according to Loumouamou (2011).

2.2. Methods

Meals obtained after oil extraction were dried at room temperature and kept in appropriate vials until analysis. Each species of oilseed was ground in the following steps: Grains (Grinding), Powder (Lipid extraction by soxhlet), Lipid and Meal.

For each meal, 100 g of powder were sampled. The moisture content was determined by weight difference after oven drying; crude ash was obtained by incineration in muffle furnace as described by Ayoola (2012) at Lacoren (Laboratory of Organic and Energetic Chemistry), Faculty of Sciences, University of Kinshasa, Democratic Republic of Congo (DRC). Samples were conditioned in flasks and plunged in liquid nitrogen and sent to the Suny Oswego laboratory for mineral content. Mineral elements were determined by ICP-MS (Varian 820-MS ICP-MS system) as follows: Approximately 5mg of ash samples of each meal were weighed exactly on micro-balance; they were then dissolved in 5mL of 1 % nitric acid, transferred to Teflon vials and capped. They were digested overnight in an oven at 80°C. Then, hydrogen peroxide was added drop wise to complete digestion of the undigested material. The solvent was evaporated completely and the residues were re-dissolved in exactly weighed 1% nitric acid. Measurements were performed by ICP-MS (Varian 820-MS ICP-MS system), under OSWEGO NY/3/26, at Suny Oswego, State University of New York.

Most of the time, vegetable production is insufficient to cover food needs for humans. Thus, it is important to utilize other plant species present in the environment to complete food and feed, even if it is not conventionally analyzed. According to their mineral composition, meal from an oilseed species can substitute another whose mineral composition is close, as to get in human or animal ration. This is why meals from ten unconventional oleaginous have been exploiting this way, the hierarchical ascendant classification (HAC) has been applied, using XLSAT and R software to establish similarity or dissimilarity between studied unconventional oleaginous. HAC has been accompanied by the Principal Component Analysis (PCA) which establishes the correlation between oleaginous species based on their mineral composition. PCA is a multidimensional analysis method which establishes similarity and correlation between individual variables as described by Makany (2002). Hierarchical Ascendant Classification is used to predict the possibility to substitute a missing meal by the one whose mineral composition is similar.

3. RESULTS AND DISCUSSION

3.1. Determination of macro mineral elements in oilseeds meals

The results of the major mineral elements content are shown in Table 1.

Table 1. Major elements content of oilseeds meals of unconventional oleaginous seeds in 100 g of dry matter analyzed

Mineral / Plant	**Major elements (mg)**				
	Ash*	Ca	K	P	S
AA	10.07	106.62	0.00	6.56	0.00
CS	8.00	111.20	350.55	35.57	29.18
CP	5.60	254.50	925.22	29.69	185.11
CE	13.7	16.26	765.41	43.29	150.44
HC	6.45	100.61	531.10	59.75	27.07
MM	6.84	223.66	539.44	37.67	61.45
MO	10.39	10.59	528.20	57.26	102.13
OG	7.34	139.10	59.92	59.92	45.31
PE	10.35	187.68	565.80	39.60	176.52
PB	6.64	849.80	197.11	9.76	0.00

Legend: * : Ash (g) , *HC: Hura crepitans, PE: Pentaclethra eetveldeana, OG: Ongokea gore, AA: Allophylus afri-canus, CP: Carapa procera, PB: Pentadesma butyraceae, CE: Coula edulis, MO : Moringa oleifera,CS: Cannabis sativa, MM: Monodora myristica*

The total ash content decreases in the following order (for 100 g of dry matter): 13.7 g for the *CE*, 10.39 g for the *MO*, 10.35 g for the *PE* , 10.07 g for *AA* , 8.00 g for *CS* and 5.60 g for *C P*. The total ash content of all the unconventional meals examined, except for *CP*, are above those of known conventional seed oils such as coconut (7 g), cotton (6.64 g), soybean (6-6.30 g) and peanuts (5.40 g) (INRA, 1989). These meals of the unconventional oilseeds, rich in mineral salts, are an asset of value as a livestock feed, especially for cows, according to Auderset (2010).

The X-ray fluorescence spectrometry identified five major mineral elements: calcium, magnesium, potassium, phosphorus and sulfur. Calcium is the most abundant mineral in the body, the salts of which form the substance which confers hardness to bones and it intervenes in the transmission of nerve impulses, blood coagulation and in the regulation of acid-base homeostasis. *PB* meal has a high calcium content (849.80 mg), much higher than that of soybean (300mg). The calcium content of *CP* (254.50mg), *MM* (223.66mg), *PE* (187.68mg) are superior to those of peanut cake (160mg), copra (180mg g) and cotton (200mg g) (INRA, 1989). On the other hand, the calcium content of oil meals of *OG* (139.10 mg), *CS* (111.20mg), *AA* (106.62 mg), *HC* (100. 61 mg) are above 100 mg and those of *CE* (16.26 mg) and *MO* (10.59 mg) are below the average. All these cakes are important sources of calcium similarly to nuts, legumes and other oilseeds (Pamplona-Roger, 2000).

Potassium content of the meals decreases in the following order: *CP* (925.22 mg), *CE* (765.41 mg), *OG* (704.70 mg), *P* (531.4 mg), *MO* (528.20 mg), *CS* (350.55 mg), and *PB* (197.1 mg). Those values are relatively low compared to most conventional oilseed such as, cotton (1250 mg), soybean 44 (1700 mg) and soybean 48 (2100 mg) (INRA, 1989).

The phosphorus content is relatively low in all unconventional oilseeds meals analyzed compared to those of most conventional oil seeds, *OG* (59.92mg), *HC* (59.75 mg), *MO* (43.29 mg), *PE* (39.60 mg) Mg), *CS* (35.57 mg), groundnut cake (600 mg), coconut (600 mg), cotton (1000 mg), palm kernel (600 mg) and Soybean (620 mg) (INRA, 1989).

Sulfur content was above 100 mg per 100 g of dry matter in the following meals: *CP* (185.11 mg), *PE* (176.52mg), *CE* (150.44 mg) and *MO* (102.13 mg). The other meals' sulfur content was below 100 mg.
Qualitative and quantitative analysis of macroelements revealed a high content of calcium in the seed meal of *PB* (849.80 mg) and lowest in *MO* cakes (10.59 mg). The *CP* cake contains very high potassium content (925.22 mg), whereas this element is found at trace level in the *AA* meals. Seeds meals of *HC* (59.75 mg), *OG* (59.92 mg) and *MO* (57.26 mg) had higher levels of phosphorus than the rest of the meals. Sulfur was identified abundantly in *PE* (176.52 mg), *CP* (185.11 mg), *CE* (150.44 mg) and *MO* (102.13 mg) seed meals.

3.2 Determination of microelements

Results obtained from ICP-MS analysis of the ten unconventional oil seed meals are given in Table 2. The following 13 trace mineral elements were found in the different unconventional oilseeds: nickel, copper, zinc, arsenic, selenium, cadmium, barium, lead, vanadium, chromium, manganese, iron and cobalt. It is known that trace elements are important in human and animal body and are appreciated in terms of milligrams or micrograms. Animal nutrition requires a small amount of trace elements among which iron, zinc, copper, cobalt, iodine, molybdenum, manganese and selenium, are the main ones (Suttle, 1991; Thompson *et al.,* 1991).

Table 2. Microelement composition of oilseed meals in 100g of dry matter

Mineral / Oleaginous	Mineral content (ppm)												
	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	V	Zn
AA	0.23	33.39	1.25	2.29	15.58	378.41	1746.33	608.64	139.29	8.65	0.62	5.91	575.92
CS	0.69	9.98	0.02	0.21	12.1	179.0	2323.0	1141.0	2.32	1.64		0.11	601.0
CP	1.04	54.13	4.29	0.69	17.55	559.60	2108.55	1590.05	23.25	597.19	2.03	0.49	316.94
CE	-	21.9	0.07	0.99	3.31	237.0	3017.0	465.0	34.0	3.79	2.00	0.59	1228.0
HC	<0.06	11.46	0.42	1.42	10.1	317.56	2532.22	832.55	23.64	9.38	0.64	0.44	1733.15
MM	-	37.0	0.30	-	5.83	84.7	1123.0	631.0	36.07	4.21	-	0.34	526.0
MO	1.06	18.6	0.10	0.86	5.04	199.0	2775.0	411.0	21.4	3.84	1.87	0.54	1003.0
OG	0.38	9.85	0.06	0.33	21.04	348.19	1251.85	277.84	32.06	1.35	1.03	0.61	222.19
PE	0.94	19.51	1.63	2.12	12.81	620.38	3348.30	1020.26	73.49	13.49	1.14	1.68	1165.34
PB	<0.58	29.57	0.56	0.86	9.85	390.20	3307.02	353.43	100.71	11.71	3.88	1.89	511.22

Legend: *HC: Hura crepitans, PE: Pentaclethra eetveldeana, OG: Ongokea gore, AA: Allophylus africanus, CP: Carapa procera, PB: Pentadesma butyraceae, CE: Coula edulis, MO: Moringa oleifera, CS: Cannabis sativa, MM: Monodora myristica*
Note : Absence of value means under limit of detection

The quantities of nickel in oilseed meals decreased in the following order : *HC* (2.36mg), *PE* (7.35 mg), *OG* (3, 21 mg), *AA* (13.93 mg), *CP* (2.32 mg), *PB* (10.07 mg), *CE* (3.40 mg), *MO* (2.14 mg), *CS* (0.23 mg), *MM* (3.67 mg) per 100 g of dry meals analyzed. These meals could cover the nickel requirement at the maximum tolerable levels of 50.00 mg/kg (Gralak, 2000a).

Iron plays several important roles in metabolism as part of hemoglobin, myoglobin, and in different enzymes involved in oxygen transport and cellular respiration. Iron content in the meals decrease in the following order: *PE* (334.83 mg), *PB* (330.70 mg), *CE* (301.70 mg), *MO* (277.50 mg), *CS* (277.50 mg), *HC* (253.22 mg), *CP* (210.85 mg), *AA* (174.63 mg), *OG* (121.58mg) and *MM* (112.30 mg) per 100 g of cake. These values are above those in most common cereals (30 - 60 mg/kg) and soybean meal (100 to 200 mg/kg). Animal foods, beside dairy products, contain between 400 mg/kg and 500 mg/kg. Blood meal usually contains more than 3000 mg/kg of iron. The iron content found in the seed meals of unconventional oilseeds are high and between 1000 - 3000 mg/kg of dry matter (Gralak, 2000a).

Zinc is involved in several biochemical functions. For example, it is essential in the synthesis of nucleic acids and protein and carbohydrate metabolism through its role in various metalloenzymes. The quantities of zinc per 100 g of meal is as follow: *HE* (173.31 g), *PE* (116.53 mg), *OG* (22.22 mg), *AA* (57.59 mg), *CP* (31.69 mg), *PB* (51.12 mg), *CE* (122.80 mg), *MO* (100.30 mg), *CS* (60.10 mg) and *MM* (52,60 mg). The addition of zinc to ruminant feed also remains necessary (Gralak, 2000c). These meals can be added to the animal feed to be beneficial for the immunity and good growth of the animals. Moreover, the zinc concentration of these different meals exceeds the growth requirement (30.00 mg/kg) and the maximum tolerable levels

(500.00 mg/kg) (Gralak, 2000b). These cakes range from 200 mg/kg to 1700 mg/kg.

Cobalt is required for the synthesis of vitamin B12 by rumen microorganisms in ruminants. Cobalt is supplemented in animal food via cobalt salt (Gralak, 2001). The quantities of cobalt found in different meals are: *HC* (0.14 mg), *PE* (0.21 mg), *OG* (0.03 mg), *AA* (0.23 mg), *CP* (0.07 mg), *PB* (0.08 mg), *CE* (0.09 mg), *MO* 0.08 mg), *CS (*0,02 mg). *MM* did not contain cobalt. These meals globally constitute an important cobalt supplement for ruminants.

Manganese is involved in several enzymes. A deficiency in this element delays growth and causes abnormalities in the skeletal system and reproductive system (Gralak, 2002). ICP-MS identified manganese in *HC* (83.25 mg), *PE* (102.03 mg), *OG* (27.78 mg), *AA* (60.86 mg), *CP (*159,00 mg), *MO* (41.11 mg), *CS* (114.10 mg), *MM* (63.10 mg) per 100 g of cake. The unconventional oilseeds studied are an asset to improve animal growth. However, the manganese content in all the meals exceeds the requirement and threshold maximum tolerable levels of 5.00 mg/kg (Gralak, 2000a).

Copper is involved in the synthesis of hemoglobin and in the absorption and metabolism of iron. It is usually necessary to supplement cattle feed with copper. The results of the ICP-MS analysis revealed the presence of copper in the following concentration: *HC* (31.75 mg), *PE* (62.04 mg), *OG* (34.92 mg), *CE* (23.70 mg), *MO* (19.90 mg), *AA* (37.84 mg), *CP* (55.96 mg), *CS* (17,90 mg), *MM* (8,47 mg) per 100g of meal. These meals could cover the need of copper for animal growth (10.00 mg/kg) and a tolerable maximum level is 100.00 mg/kg (Gralak, 2002).

Selenium is found in very low concentrations in forage harvested and served to animals. It must therefore be given in addition to the food. Selenium works, together with vitamin E, as an antioxidant at the cellular level. Analysis revealed the presence of selenium in seeds of *HC* (0.06 mg), *PE* (0.11 mg), *OG* (0.10 mg), *AA* (0.06), *CS* (0.20 mg), *PB* (0.39 mg), *CE* (0.20 mg), *MO* (0.18 mg) per 100 g of the oilseed meal . The cakes *of CS* and *MM* do not contain selenium.

It has been shown that selenium ingested in organic form is superior compared to inorganic selenium. Thus, the absorption and metabolism of organic selenium makes it at least twice as effective antioxidant than inorganic selenium. The selenium concentration of these different meals exceeds the needed value for growth (0.10 mg/kg) and the maximum tolerable levels (2.00 mg/kg) (Gralak, 2001; Gralak, 2002). The selenium concentration of these meals varies between 0.60 mg/kg and 4.00 mg/kg in *HC* , PE , *OG, AA* , *CP* , *PB* , *CE* , *MO* and are a good source of selenium for feeding large and small livestock.

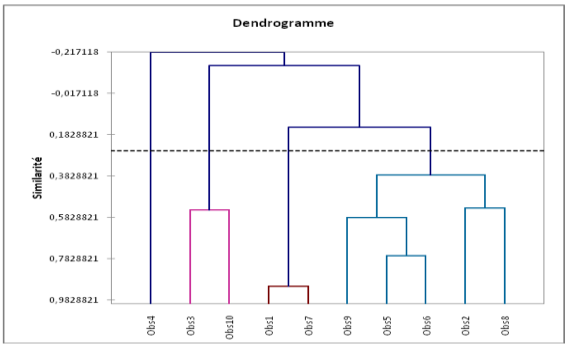
According to NRC (1996), chromium is now considered one of the nutritional requirements of cattle. In fact, results of the recent research compels to attach importance to it. In humans, however, chromium is a trace element whose essential functions have been recognized since the late 1950s. The analysis revealed the presence of chromium in seed meal of *HC* (1.00 mg), *PE* (1.28 mg), *OG* (2.10 mg), *AA* (1.56 mg), *MO* (0.50 mg), *CS* (1.21 mg), *MM* (0.98 mg), *PB* (58,00 mg) per 100 g of meal. The chromium concentration in these different meals exceeds the needs for growth (3.00 mg/kg) (Gralak, 2002). The chromium content of the various oil cakes analyzed varied between 5.00 mg/kg and 21.00 mg/kg of seed.

Vanadium is an essential element in the metabolism of some inferior plants and animals, and is possibly essential to humans. The toxic level is well beyond the level of natural diet, and the toxicity of vanadium is rare. Vanadium is also used as a hydrogenation catalyst in oils. Analysis revealed the presence of vanadium in seeds of *HC* (0.04 mg), *PE* (0.17 mg), *OG* (0.06 mg), *AA* (0.59 mg), *MO* (0.05 mg), *CS* (0.01 mg), *MM* (0.03 mg) per 100 g analyzed seeds meal.

Lead and arsenic are the two traditional metal poisons, and most countries have prescribed the legal limits of the dose of lead in food of 2μg/g. Analysis revealed the presence of lead in seed cakes of *HC* (0.94 mg), *PE* (1.35 mg), *OG* (0.13 mg), *AA* (0.86 mg), *MO* (0.38 mg), *CS* (0.16 mg), *MM* (0.42 mg) per 100g of cake analyzed. Analysis identified the presence of arsenic in seed cakes of *HC* (0.01 mg), *PE* (0.09 mg), *OG* 0.04 mg), *AA* (0.02 mg), *CP* (0.10 mg), *PB* (0.06 mg), *CE* (trace), *MO*, *CS* (0.07 mg), *M M* (trace) per 100 g of cake; but it did not reveal the presence of arsenic in the cake of *CE* and *MM* . NRC (1996) requires for the growth of the animals thresholds of 50-100 mg/kg for arsenic and 30.00 mg/kg for lead. If the levels of arsenic and lead can prove toxic to humans, this will not be the case for animals. So these meals can be used in animal husbandry. The links between the various trace elements identified and quantified have been established.

It is found that there is a strong positive correlation between the various trace elements, except for the cadmium content which is negatively correlated with the chromium content. The copper and selenium contents are correlated with those of nickel, zinc, barium, vanadium, chromium, manganese and iron. This correlation shows that the high nickel content in these meals necessarily means that there is also a high content of zinc, barium, vanadium, chromium, manganese and iron in all the cakes analyzed. The negative correlation between the content of cadmium and that of chromium means that the high content of chromium in the different cakes indicates a low cadmium content.

The similarity of the various oil cakes with based on their microelements composition is shown in the dendrogram of Figure 2.



Legend: obs1: *Coula edulis*, obs2: *Pentachletra eetveldeana*, obs3: *Monodora myristica*, obs4: *Carapa procera*, obs5: *Moringa oleifera*, obs6: *Monodora myristica*, obs7: *Hura crepitans*, obs8: *Ongokea gore*, obs9: *Pentadesma butyraceae*, obs10: *Cannabis sativa.*

Figure 2: Cluster of oilseed meals of unconventional oleaginous seeds according to their similarity

The different cakes studied are grouped according to their contents of iron or zinc in Table 3.

Table 3. Class of analyzed oleaginous according to the mineral composition of their seeds

Class	Number of oleaginous per class	Plants comprised in the class
1	2	*Hura crepitans, Allophilus africanus*
2	5	*Pentadesma butyraceae, Moringa oleifera, Pentachletra eetveldeana, Coula edulis, Ongekea gore*
3	2	*Monodora myristica, Cannabis sativa*
4	1	*Carapa procera*

The Hierarchic Ascending Classification (HAC) shows that there are four classes depending on the trace element content in the different unconventional oilseeds and the class 2 collects more objects than the other three.

The homogeneous groups consist of similar species due to their trace element content. For example, class 1 contains meals with very high zinc content and is composed with *HE* (173.31 mg/100 g). Class 2 consists of meals characterized by high iron content in *PE* (334.83 mg/100 g), *C P* (210.85 mg/100 g), *PB* (330.70 mg/100 g), *MO* (277.50 mg/100 g), *OG* (121.58 mg/100 g) which are similar in their high iron content. Class 3 consists of meals characterized by low iron content: *CS* (232.30 mg/100 g), *MM* (112.3 mg/100 g). Class 4 contains a single individual, *CP* characterized by a low content of all mineral elements in general.

4. CONCLUSION

The objective of the present study was to identify and determine the mineral content and to establish the links between the levels of the trace elements and the similarity of the meals studied. Results on the total ash content show that all the unconventional oilseeds studied are rich in mineral salts. This is an asset to value them as a livestock feed, especially for cows. Identification and dosage of major elements in meals have established an important presence of calcium in the cake of the seeds of *P. butyraceae* and low in the cakes of the seeds of *M. oleifera*. The seed meal of *C. procera* contains a very high content of potassium, whereas this element is found as traces in the *A. africanus* cake. Seed cakes of *H. crepitans*, *O. gore* and *M. oleifera* have higher levels of phosphorus than the rest of the meal. Sulfur has been identified abundantly in seed meals of *P. eetveldeana*, *C. procera*, *C. edulis* and *M. oleifera*.

Micronutrient analysis by ICP-MS revealed the presence of 13 trace elements (nickel, copper, zinc, arsenic, selenium, cadmium, barium, lead, vanadium, chromium, manganese, iron and cobalt) in all the studied unconventional oilseeds. Animal nutrition requires a small amount of trace elements; the main ones are iron, zinc, copper, cobalt, iodine, molybdenum, manganese and selenium. Thus, all the oil cakes analyzed contain most of the mineral micronutrients used for human and animal consumption. The content of lead and arsenic does not prevent the use of these cakes in animal feed.

The copper and selenium contents correlated with those of nickel, zinc, barium, vanadium, chromium, manganese and iron. This correlation shows that the high nickel content in these meals necessarily means that there is also a high content of zinc, barium, vanadium, chromium, manganese and iron in all the cake analyzed. However, for cadmium and chromium, the high content of cadmium in the different cakes, indicates low chromium content.

According to their composition in trace elements, the HAC grouped the cakes in four similar groups: the *H. crepitans* and *A. africanus* cakes having a very high zinc content, the cakes of *P. eetveldeana*, *C. edulis*, *P. butyraceae*, *M. oleifera* and *O. gore* similar in their high iron content; *C. sativa* cakes, *M. myristica* characterized by their low iron content, and the *C. procera* cake characterized by a low content of all mineral elements in general.

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