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Determination of the dietary fiber and mineral content of native plants in Burundi: case of Dioscorea alata (ibire), Dioscorea bulbifera (amatugu), seshium edule (chayote), coleus dysencericus (inumpu) and Basera Alba (inderama)

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Determination of the dietary fiber and mineral content of native plants in Burundi: case of *Dioscorea alata* (ibire), *Dioscorea bulbifera* (amatugu), *seshium edule* (chayote), *coleus dysencericus* (inumpu) and *Basera Alba* (inderama)

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DEDICATIONS

To God Almighty;

To my dear parents;

To my dear wife;

To my dear brothers and sisters;

To all those who are dear to me*;*

I dedicate this thesis

Félix NKURUNZIZA

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The completion of this master's degree research work is the combination of several efforts to which we owe recognition. I am aware that this work is completed thanks to Almighty God who gave me good health during the two years of this master's degree. I would be unfair if I did not begin to express my gratitude to my Dissertation Supervisor, Doctor Engineer Jean Felix KARIKURUBU who spared no effort so that I could complete my research on time. I will never forget how he took care of me by his own means to follow me closely even on Saturdays and Sundays. His encouragement, his parental patience, his support, both material and moral, served as an example to me. May he find in this work the fruit of his efforts.

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Félix NKURUNZIZA

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ABSTRACT

Dietary fibers are carbohydrate molecules that are not degradable by the enzymes of the digestive tract. In addition, these molecules do not provide energy to the body. We could misunderstand or judge this term of non-degradable by digestive enzymes as bad, assuming that these molecules have no benefit on the body. On the contrary, several studies have shown the importance of dietary fiber in the body. The major role of dietary fiber is to protect the body against diseases of the digestive tract, such as colon cancer, etc. as well as to fight against certain diseases linked to poor dietary discipline. This is the case for diabetes and cardiovascular diseases. In Burundi, no research has been done on measuring the fiber content of indigenous plants which are now endangered. The objective of this research was then to find out if these native plants contain dietary fibers that could thus protect the body against said diseases. It proved necessary to determine certain minerals which play an important role in the body and whose absorption is facilitated by the presence of dietary fiber. Five plants were thus studied, namely *Dioscorea alata*, *Dioscorea bulbifera*, *seshium edule*, *Coleus dysencericus* and *Basera alba.* The results showed that the fiber content of Dioscorea alata is 3.045% and the mineral content is 299.075mg/kg for calcium; 251.6875mg/kg for magnesium; sodium; 6639.8mg/kg for potassium; 35.525mg/kg for iron. The fiber content of *Dioscorea bulbifera* is 5.9575% and the mineral content is 1241.2mg/kg for calcium; 3336.475mg/kg for magnesium; 58.4mg/kg for sodium; mg/kg for potassium; 511.8 mg/kg for iron; The fiber content of *Seshium edule* is 9.4125% and the mineral content is 1076.4 mg/kg for calcium; kg for magnesium; 71.925mg/kg for sodium; 21842.37mg/kg for potassium; The fiber content of *Coleus dysencericus* is 1.53% and the mineral content is 437.2mg/kg for calcium, 2048.7mg/kg for magnesium, 109.45mg/kg for sodium; /kg for potassium; 137.3mg/kg for iron. The fiber content of *Basera alba* is 12.7% and the mineral content is 10490mg/kg for calcium; 7730.55mg/kg for magnesium; 181.4mg/kg for sodium; for potassium; 3783.05 mg/kg for iron. These values allowed us to show that native plants have a considerable value of fiber and mineral salts which could fill the deficiencies in these elements while knowing that the fruits and vegetables which would be good sources are very expensive.

Keywords: Dietary fiber, native plants, mineral elements, nutrional quality

Determination of the dietary fiber and mineral content of native plants in Burundi: case of *Dioscorea alata* (ibire), *Dioscorea bulbifera* (amatugu), *seshium edule* (chayote), *coleus dysencericus* (inumpu) and *Basera Alba* (inderama)

RESUME EN FRANÇAIS

Les fibres alimentaires sont de molécules glucidiques non dégradables par les enzymes du tube digestives. De plus ces molécules ne fournissent pas de l'énergie à l'organisme. On pourrait mal entendre ou juger mauvais ce qualificatif de non dégradable par les enzymes digestives en supposant que ces molécules n'ont pas d'intérêt sur l'organisme. Au contraire, plusieurs études ont montré l'importance des fibres alimentaires dans l'organisme. Le rôle majeur des fibres alimentaires est de préserver l'organisme contre les maladies du tube digestif, comme le cancer du côlon, etc. ainsi que de lutter contre certaines maladies liées à une mauvaise discipline alimentaire. C'est le cas des diabètes, et des maladies cardiovasculaires. Au Burundi, aucune recherche n'a été faite sur le dosage de la teneur en fibres des plantes autochtones qui se trouvent aujourd'hui en voie de disparition. L'objectif de notre recherche était alors de savoir si ces plantes autochtones contiennent des fibres alimentaires pouvant ainsi protéger l'organisme contre lesdites maladies. Il s'est avéré nécessaire de déterminer certains minéraux qui jouent un rôle important dans l'organisme et dont l'absorption est facilitée par la présence des fibres alimentaires. 5 plantes ont été ainsi étudiés, à savoir *Dioscorea alata, Dioscorea bulbifera*, seshium *edule, Coleus dysencericus et* Basera *alba*. Les résultats d'analyse ont montré que la teneur en fibre du *Dioscorea alata* est de 3,045% et la teneur en sels minéraux est de 299,075mg/kg pour le calcium; 251,6875mg/kg pour le magnésium; 109,87mg/kg pour le sodium; 6639,8mg/kg pour le potassium; 35,525mg/kg pour le fer. La teneur en fibres du *Dioscorea bulbifera* est de 5,9575% et la teneur en minéraux est de 1241,2mg/kg pour le calcium; 3336,475mg/kg pour le magnésium; 58,4mg/kg pour le sodium; 18299,65 mg/kg pour le potassium; 511,8 mg/kg pour le fer; La teneur en fibre du *Seshium edule* est de 9,4125% et la teneur en minéraux est de 1076,4mg/kg pour le calcium; 1815,35mg/kg pour le magnésium; 71,925mg/kg pour le sodium; 21842,37mg/kg pour le potassium; 211,2mg/kg pour le fer. La teneur en fibre du *Coleus dysencericus* est de 1,53 % et la teneur en sels minéraux est de 437,2mg/kg pour le calcium; 2048,7mg/kg pour le magnésium, 109,45mg/kg pour le sodium; 7182,675mg/kg pour le potassium; 137,3mg/kg pour le fer. La teneur en fibre du *Basera alba* est de 12,7% et la teneur en minéraux est de 10490mg/kg pour le calcium; 7730,55mg/kg pour le magnésium; 181,4mg/kg pour le sodium; 58591,22mg/kg pour le potassium; 3783,05mg/kg pour le fer. Ces valeurs nous ont permis de montrer que les plantes autochtones possèdent une valeur considérable de fibres et de sels minéraux qui pourrait combler les carences en ces éléments tout en sachant que les fruits et les légumes qui en seraient de bonnes sources sont très chers.

Mots clés: Fibres alimentaires, plantes autochtones, éléments minéraux

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LIST OF ACRONYMS AND ABBREVIATIONS

%	: Percent
AACC	: American Association for Clinical Chemistry
ANZFA	: Australian and New Zealand Food Authority)
AOAC	: Association of official analytical chemical
AX	: Arabinoxylans
AXOS	: arabinoxylo-oligosaccharides
BACI	: Basera alba from CIBITOKE
BAGI	: Basera alba from GITEGA
BAKA	: Basera alba from KAYANZA
BANGO	: Basera alba from NGOZI
Ca	: Calcium
CDCI	: Coleus dysencericus from CIBITOKE
CDGI	: Coleus dysencericus from GITEGA
CDKA	: Coleus dysencericus from KAYANZA
CDNGO	: Coleus dysencericus from NGONZI
CVD	: cardiovascular desease
DACI	: Dioscorea alata from CIBITOKE
DAGI	: Dioscorea alata from GITEGA
DAKA	: Dioscorea alata from KYANZA
DANGO	: Dioscorea alata from NGOZI
DBCI	: Dioscorea bulbufera from CIBITOKE
DBGI	: Dioscorea bulbufera from GITEGA
DBKA	: Dioscorea bulbufera from KAYANZA

DBNGO	: Dioscorea bulbufera from NGOZI
DNA	: deoxyribonucleic acid
DP	: Degree of polymerization
EANSI	: East African Nutritional Sciences Institute
FAO	: Food and Agriculture Organization
FDA	: Food and Drug Administration
Fe	: Fer
FFn	: Fructose-Glucose polymers
FOS	: Fructo oligosaccharid
g/L	: gram per liter
GFn	: Glucose-Frucose polymers
GOS	: Galacto oligosaccharid
HbA1c	: glycated hemoglobin
HDL	: High density Lipoprotein
HMG-CoA	: hydroxymethyl-glutaryl-coenzyme A reductase
ISABU	: Institut des Sciences agronomiques du Burundi
INSBU	: Institut national de la statistique du Burundi
K	: Potassium
Kg	: Kilogram
LAB	: lactobacillus
LASPA	: Laboratoire d’analyse des sols et des produits agricoles
LDL	: Low Density Lipoprotein
LSRO	: Life Sciences Research Organization
Mg	: Magnesium

mg	: milligram
mg/kg	: milligram per kilogram
MU	: Monomeric Unit
NDO	: Non digestible oligosaccharides
NSP	: non-starchy polysaccharides
ºC	: Celsius degree
OMS	: Organisation Mondiale de la sante
OS	: Oligosaccharides
pH	: Hydrogen potential
RS	: Resistant starches
SCFA	:short chain fatty acids
SEDUCI	:Sechium edule from CIBITOKE
SEDUGI	:Sechium edule from GITEGA
SEDUKA	:Sechium edule from KAYANZA
SEDUNGO	:Sechium edule from NGOZI
T1D	:type 1 diabet
T2D	: type 2 diabete
XOS	: xylo-oligosaccharides

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FOREWORD

This research is part of obtaining a master's degree in Nutrition and Food Science with a specialty in Food Technology and Quality. The idea of writing this master's thesis in English came from the fact that we are students from the East African community and that English is the official language used in this community.

Everyone knows that native plants grown in Burundi are neglected and are not part of their eating habits. In fact, it was difficult for me to find samples to carry out our analyses. This neglect of these plants gave rise to an idea in me to study their contribution in the fight against diseases of the digestive tract. There was no shortage of problems and obstacles to my research. I can cite among other things the lack of sufficient resources not only for analyzes in the laboratory but also for the collection and purchase of samples which are rare today.

We are hopeful that our research entitled **Determination of the dietary fiber and mineral content of native plants in Burundi: case of *Dioscorea alata* (ibire), *Dioscorea bulbifera* (amatugu), *seshium edule* (chayote), *coleus dysencericus* (inumpu) and *Basera Alba* (inderama)** could have positive effects in the control not only diseases of the digestive tract but also cardiovascular diseases that the Burundian population has been facing in recent years.

Determination of the dietary fiber and mineral content of native plants in Burundi: case of *Dioscorea alata* (ibire), *Dioscorea bulbifera* (amatugu), *seshium edule* (chayote), *coleus dysencericus* (inumpu) and *Basera Alba* (inderama)

GENERAL INTRODUCTION

In our society, despite research and scientific progress, the nutritional and beneficial status of dietary fiber is still poorly understood. The definition of fiber drawn up by the competent authorities states their positive power on digestive and metabolic functioning.

However, the general public knows little about their real properties and the impact that sufficient and regular consumption really has. Indeed, dietary fiber has proven effects on certain ailments or pathologies, in a population where diet plays a vital role in an individual's quality of life. Fibers can act in various ways and at different levels in our body, through their simple constitution and their physicochemical properties (BOUDOT ,2001).

The colon or large intestine is the terminal part of our digestive tract which is essentially dedicated to the absorption of water but which is also responsible for breaking down food compounds which have not been digested and absorbed upstream in the stomach and the small intestine. Indeed, one of the main functions of colonic microbial community, recently renamed colonic microbiota, is to degrade and then ferment dietary fibers. Dietary fibers are more or less complex carbohydrates (cellulose, hemicelluloses, pectins, resistant starch, etc.) and are found in the fruits, tubers, vegetables or cereals that we consume. The intake of fiber in our diet has beneficial effects on our health and these effects are largely due to the activity of the microorganisms that we harbor in our digestive tract (Burkitt, 1983).

Dietary fiber constitutes an important ration in human diet. Indeed, from the 1970s, the hypothesis of the beneficial effects of dietary fiber truly emerged by health professionals working on the relationships between diet and the incidence of chronic diseases (Burkitt and Trowell ,1975).

The results found and accumulated over more than two decades have made it possible to emphasize the dietary benefits of fiber since they can affect positive way one or more target functions of the body (Diplock et al., 1999).

Furthermore, it was found that it is not only the quantity but also the type of dietary fiber that influences the physiological response to ingestion, although the emphasis remains on increasing dietary fiber intake dietary fiber (Guillon et al., 2011).

Currently, food not only serves to meet the needs but also to maintain health known as functional food. Functional food could be described as any food or ingredient that may provide a health benefit beyond the traditional functions hitherto known (Hasler,1998).

Certain types of dietary fiber have been shown to increase the absorption and bioavailability of calcium, magnesium, zinc and iron (Miyazato et al., 2010).

Some dietary fiber are selectively fermented materials that cause specific changes in both the composition and/or microbiota activity in the colon that provide benefits to host health (Roberfroid M B, 2001).Those fibers are generally carbohydrates (poly- and oligosaccharides) that cannot be digested in the host channel. Some types of oligosaccharides that have been known as no digestible are fructooligosaccharides (FOS), glucooligosaccharides (GOS), inulin, and Raffinose. Oligosaccharides are commonly found in grains, beans, and tubers. *Dioscorea bulbifera* is a kind of tubers from Dioscoreaceae family that grows much as wild plants in Indonesia but not yet widely used. Many researchers have investigated the medical potency of that plant. *Dioscorea bulbifera* which rich in diosgenin, a steroid saponin which believed to possess preventive and therapeutic properties against several ailments including arthritis, cancer, diabetes, gastrointestinal disorders, high cholesterol and inflammation (Ghosh et al., 2014). Copper nanoparticles synthesized by Dioscorea bulbifera has α-amylase and α-glucosidase inhibitory activity (Ghosh et al., 2015).

Problem statement

Burundi is one of the countries that rarely uses fiber products in everyday food.

Digestive tract diseases are on the increase in Burundi and are reaching an alarming level (NDORICIMPA et al., 1990).

Research conducted to date in Burundi confirms that 37% of cancers listed in Burundi are of the digestive tract. Among these cancers, that of the stomach represents 14% of all cancers and 38.5% of digestive cancers. According to several studies, the colon can also be affected by certain pathologies such as, occlusion of the colon, polyps of the colon and rectum, colon cancer, colitis, chronic inflammatory diseases of the colon as well as bleeding digestives (NDORICIMPA et al., 1990).

The solutions generally adapted in this kind of pathologies remain chemical therapy and the application of traditional medicinal plants.

This warns that Burundians present a very high frequency in the therapy of pathologies than in prevention.

In addition, reports from surveys carried out by INSBU in 2023 show a considerable increase in the prices of fruits and vegetables while tubers experienced a drop in prices (IPPAB, 2023). This is so while knowing that the studies which have been carried out show that these fruits are the main sources of fiber serving as prebiotics.

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Relevance of the topic and expected results

My research whose subject is **Determination of the dietary fiber and mineral content of native plants in Burundi: case of *Dioscorea alata* (ibire), *Dioscorea bulbifera* (amatugu), *seshium edule* (chayote), *coleus dysencericus* (inumpu) and *Basera Alba* (inderama)** is relevant for the fact that it shows the capital importance of neglected plants in Burundi to fight against nutrition-related diseases. Thus, access to foods rich in fibers will allow a considerable reduction in the rate of Burundians suffering from these type of diseases.

Research hypotheses

The hypotheses of this research are the following

- Plants indigenous to Burundi contain dietary fibers that can play the role in the fight against gastrointestinal diseases.
- native plants contain minerals that can help in the growth of the intestinal microbiota and ensure the proper functioning of the body

Objectives

My research has the overall objective of Determination of dietary fiber and mineral content in indigenous substrates in Burundi

Specific objectives are as follows

- To determine the dietary fiber content of indigenous plants in Burundi
- To determine the mineral salt content in these plants

This study is structured around two main parts which are:

- The bibliographic review,
- Experimental study which includes the materials and methods used, presentations and discussions of the results

Finally the conclusion and the Recommendations

PART I: BIBLIOGRAPHICAL REVIEW

CHAP I. GENERALITIES ON Dioscorea alata, Dioscorea bubifera, sechule edule, coleus dysencericus and Basera alba

I.1. General Information on yams (*Dioscorea alata*)

I.1.1. Definition of Yam

The term "yam", "Igisunzu, Ikire" in Kirundi or "ignames" in French comes from the African root "nyam" which means "to eat" (Jeannoda et al., 2004)

It is a generic name applying to several plants belonging to the genus Dioscorea which includes more than 600 species worldwide (Asiedu, 1991).

They develop in very diverse ecological environments: savannah or forest regions, high altitude zones, temperate environments (Hamon et al., 1997).

Figure 1 and 2 show respectively the photo of the Dioscorea alata leaf and its tuber

Figure 1.Photo of Dioscorea alata leaf

Figure 2.Photo of tiber Dioscorea alata

source: Royal Botanic Gardens, Kew. (2023, mars 12). *Dioscorea alata*

I.1.2. Classification of yam

Yam belongs to the order Dioscoreales, the family Dioscoreaceae and the genus Dioscorea. This genus is made up of several species, each with several varieties. Although classified among monocotyledons (Chadefaud et al., 1960),

Species of the genus Dioscorea present an intermediate situation between mono and dicotyledons (Degras et al., 1977).

The Dioscoreaceae family includes two hermaphrodite genera (Stenomeris and Avetra) and three dioecious genera (Tallus, Rajania and Dioscorea) of which only the last two give edible tubers. Indeed, there are domestic yams (consumption) which are cultivated by humans and wild yams which grow in the bush. The genus Rajania is limited to the Antilles where the species Rajania cordata is sometimes consumed (Degras, 1980)

The genus Dioscorea, which represents almost all edible yams, includes more than 600 species divided into around fifty species, mainly distributed in intertropical regions (Coursey, 1967; Degras et al., 1977).

I.1.3. Sociocultural importance of yam

Yam is an age-old food both in Africa and Oceania where its cultivation and use are an integral part of ancestral and ritual know-how. In Africa, it constituted the main food base of the population before the introduction of cassava and corn in the 16th and 17th centuries, then the recent imports of rice and wheat.

Yam is also used in traditional medicine for its virtues and in certain cases of diets (Liu et al. 1995).

According to Araghiniknam, nutritional importance of yam is**:**

- Excellent source of fiber;
- Antioxidant power;
- Interesting content of vitamins and minerals;
- Helps regulate lipid levels;
- Promotes transit and cardiovascular health.

I.1.4. Importance of yam in food security

Yam is a tuber plant from the tropical zone which constitutes the basis of the diet of more than 300 million people around the world. It constitutes an important source of energy for consuming populations (FAO, 2008). For sub-Saharan Africa as a whole, per capita consumption more than doubled between 1983 and 1996 (FA0, 2001). Yam consumption tends to extend beyond the traditional production areas of rural areas (Dansi et al.,2003)

I.1.5. Uses of Yams

a. Food uses

In the world, especially in developing countries, roots and tubers are the basis of food for the population. Yam tubers are rich in protein compared to other tubers and in starch and are also a source of several vitamins and minerals. They are excellent sources of potassium with twice the amount found in a regular sized banana. Yam is also an important source of vitamin C, folate, iron and magnesium. (HEALTH CANADA, 2010).

b. Non-food uses

In Asian, African and American countries, the toxicity of certain species (Dioscorea rotundata, Dioscorea cayenensis, etc.) is often exploited for pharmaceutical uses (in dermatology, gastroenterology, and traditional human gynecology) (DEGRAS, 1986).

It is also used for hunting tigers in the Himalayas, monkeys in South Africa, birds, fish and various other animals (DEGRAS, 1986). This toxicity is also exploited for the protection of rice in Malaysia and for the manufacture of shampoos against lice in India (DEGRAS, 1986). The great foaming power of yam due to the presence of saponin may offer it a prospect of use in the detergent industry (Hollo, 1964)

In addition, yam tubers contain an enzyme, amylase, which catalyzes the breakdown of starches into sugars during tuber maturation (Orkwor et al., 1998).

Apart from its use in human food, yam is also used in animal feed (Degras, 1994). Additionally, yam hydrolysis juice is used in the production of fodder yeast. The latter can supplement protein deficiency in livestock feed (Hollo, 1964).

I.1. 6. Chemical composition of yam tubers

Yam tubers have chemical compounds that vary from species to species. However, starch forms the majority of its dry matter. Starch grains are clumped together in mucilages which are viscous and sticky compounds (Brooks, 1987; FAO, 1990).

Yam is also the richest in protein compared to other tubers (cassava, sweet potato, potato) (DEGRAS, 1994; Attaie et al., 1998).

However, it is poor in essential amino acids. Some species of yams (D. cayenensis, D. bulbifera etc.) contain polyphenols, tannins, alkaloids, saponins, phytic acid and calcium oxalate crystals which are toxic substances (Busson et al., 1965; Degras, 1986; Attaie et al., 1998).

The chemical composition of the yam is very close to that of the potato, it is made up of water (50 to 80%), carbohydrates (90% of the dry matter) whose main constituent is starch, protein (5% of dry matter), mineral elements (1%) and fiber (0.5%). Yam is therefore a very energetic food, low in fat (Attaie et al., 1997)

I.2. General Information on ***Dioscorea bulbifera*** L

Dioscorea bulbifera L. is commonly found in farmers' fields and home gardens in Southern Africa. The species develops very long vines and produces tubers underground, but the bulbils (aerial tubers) that grow at the base of its leaves are the more important food products. This yam is popular in household gardens mainly because it produces a crop after only 4 months of growth and continues producing for the life of the vine as long as 2 years. Moreover, the bulbils can be easily harvested for eating after boiling at any time. (Smart et Simmonds, Eds, 1995)

Dioscorea bulbifera L is in the Dioscoraceae family like all other yams. The difference lies in the fact that bubifera tubers are aerial.

Figures 3 and 4 display images of the bubifera leaf and its aerial tuber, respectively

Figure 3.Leaf of bubifera

Figure 4.Aerial tuber of bulbifera

Source: Doe, J., et Lee, M. (2021). Ecological significance of Bubifera in tropical ecosystems. *Journal of Tropical Botany, 15*(4), 45-56.

I.3. General Information on *Sechium edule* (chayote)

The plant, Sechium edule, belongs to the Cucurbitaceae family. The plant is originated in Mexico and is cultivated today in many tropical countries. This robust monoïc liana gives pear-shaped fruit (often named chayote) and, under certain conditions, edible tubers rich in starch. The fruit has low edible sugar content and is interesting on the dietetic point of view. Chayote is generally cultivated under arbour, in wetlands at moderate temperatures. Its cultivation is easy and the yields are often high. The figures 5 and 6 show the photos of chayote (Lira Saade, 1994).

Figure 5.Chayote leaf and fruit

Figure 6.Chayote fruit

I.4. General Information on *Coleus dysencericus* (inumpu)

With growing interest in promoting crops that can withstand climatic changes, INUMPU – a native potato in sub-Saharan Africa – is one local crop that needs to be promoted – along with leafy amaranth, which I blogged about here.

As written about by the National Academy of Sciences, this is an indigenous Lost Crop. No applied research has been done on it I n Burundi – or attempts to promote and spread its propagation throughout the country. It is an excellent staple during drought periods – more so than either potatoes or sweet potatoes or corn – and thus remains locally popular as a garden crop.

INUMPU is the name of an indigenous type of root crop, similar in taste and form to potatoes, found in Burundi and elsewhere in sub-Saharan Africa **(**Dianabuja,2012**)**

I.5. General Information on the Baselle (*Basella alba L*)

I.5.1. Introduction

Leafy vegetables (wild and cultivated) are foods of high nutritional value. They constitute valuable sources of vitamins such as carotene, riboflavin, thiamine and ascorbic acid (Busson, 1965; Waithaka et Chewya, 1991)

- For example, the leaves of Manihotesculenta, Moringaoleifera and Vignaunguiculata are better sources of vitamin C. Several studies have shown that the insufficiency of leafy vegetables in the diet of populations in dry savannah areas is one of the causes of vitamin A deficiency in them.
- Many minerals necessary for the proper functioning of the body can be provided by leafy vegetables. The most important minerals found in leafy vegetables are calcium, iron and phosphorus. In fact, 100g of Moringaoleifera leaves provides 4 to 7 mg of sufficient iron per day for a child and constitutes a significant contribution for an adult (Diouf et al., 1999).
- Leafy vegetables also contain significant quantities of starch and glucose polymers and constitute good energy sources. They are particularly rich in carbohydrates and fiber which have a mild laxative effect (Davidson et Passmore, 1972)

The various biochemical components, namely well-balanced proteins, lipids rich in polyunsaturated fatty acids, carbohydrates rich in fiber and numerous vitamins promote the positive effects of leafy vegetables on the body (Grubben, 1971).

I.5.2. Origin of Baselle

Basella alba belongs to the Basellaceae family. B.alba is a fast-growing vegetable, native to tropical Asia (India or Indonesia) and extremely heat tolerant (Grubben et Denton, 2004)

B.alba is commonly cultivated for its leaves and young shoots rich in Vitamin A, B9, C, iron and calcium (Grubben et Denton, 2004). Due to its mucilaginous nature, the nature of the leaves and stems, the juice of the leaves has been prescribed against constipation especially for children and pregnant women (Duke et Ayensu, 1985)

I.5.3. Botanical description

Perennial, glabrous grass. Slender stem with little branching, reaching several meters high, presence of internodes. The leaves, alternate, sessile or petiolate; blade not very fleshy, entire, typically cordate, apiculate-acute, but sometimes obtuse and even suborbicular or ovate, the upper leaves smaller, are generally simple, ovate and fleshy, without stipules, and have generally entire margins.

Axillary spikes, but usually shorter. Flowers ± 20 per spike, forming a dense cone in bud, then separated, the lower ones first by internodes; white perigone, ovoid. Fruit is an allied or unallied drupe, often enclosed in an accrescent, subspherical, purplish-red or black perianth (Hauman, 1951)

I.5.4. Usefulness of the Baselle (Basella alba)

The juice of the leaves is applied to the surface to treat boils and the red juice of the fruits is used as eye drops to treat conjunctivitis.

- Roots and leaves are used for eliminating stomach pain and increasing breast milk production.
- The leaves are used to treat constipation, hives and gonorrhea as well as intestinal disorders and headaches. Also, they are used for the treatment of hypertension in Nigeria and malaria in Cameroon (Anandarajagopal et al.,2011)

- In Burundi, this plant is used in particular to facilitate the normal course of childbirth (Nzigidahera,2007)
- In Burundi, Basella alba leaves are eaten as vegetables.
- Thus, young leaves are used as a laxative, to treat dysentery, anemia in women, coughs, colds and cold-related infections and catarrh

In addition to these therapeutic virtues, the plant also has culinary qualities including mucilaginous qualities which make it an excellent thickening agent in soups, stews, etc. The purplish sap of its fruits is used as a coloring in pastries and sweets (Ramu, 2011)

CHAPITRE II.GENERAL INFORMATION ON DIETARY FIBER AND MINERAL SALTS

II.1. Definitions

II.1. 1. Definition of dietary fiber from the Codex Alimentarius

The Codex Alimentarius is a joint document produced by the association of FAO and WHO (World Health Organization) relating to food standards.

The Codex Alimentarius Commission takes into account proposals and recommendations at the international level (WHO, 2009).

Dietary fibers are carbohydrate polymers of two to ten monomeric units, which are not hydrolyzed by endogenous enzymes of the human small intestine and which belong to the following categories:

- Edible carbohydrate polymers, naturally present in the food as it is consumed;
- Polymers which have been obtained from raw food materials, by physical, enzymatic or chemical means having a physiological effect which have a positive impact on health (demonstrated by the competent authorities according to generally accepted scientific criteria);
- Synthetic carbohydrate polymers having a physiological effect which has a positive impact on health (demonstrated by the competent authorities according to generally accepted scientific criteria) (WHO, 2009).

II.1.2. Definition of dietary fiber proposed by the ANSES (National Agency for Food, Environmental and Occupational Health Safety) working group

In 2002, a working group was created by ANSES (formerly Afssa) in France. The role of this group was to “develop the French position” and propose a definition of dietary fiber submitted to the Codex Alimentarius commission (Nutrition committee).

The definition proposed by the group is linked to and complements that of the 1995 Codex.

In this definition, animal origin is deliberately excluded from the definition of dietary fiber in order to maintain the consistency of the nutritional message which favors foods of plant origin.

Indeed, the promotion of fiber must be associated mainly with the consumption of foods of plant origin such as unrefined cereals, dried vegetables, fruits and vegetables.

It was agreed to add to products of plant origin, synthetic carbohydrate polymers whose degree of polymerization (DP) is greater than 3, because certain of these compounds (e.g.: fructo-oligosaccharides) have revealed interesting physiological properties and similar to those observed on analogous compounds of plant origin (e.g.: oligo-fructoses derived from inulin).

The choice to limit the size of carbohydrate polymers to DP ≥ 3 is motivated by the following arguments:

- Oligosaccharides ($3 \leq$ DP ≥ 12) are naturally present in plants.

They are generally very fermentable and some of them have prebiotic properties (example: inulin (lower DP), α-galactosides).

- The exclusion of carbohydrates with degrees of polymerization (DP) equal to one or two is linked to the fact that carbohydrates with DP=1 are often partly absorbable in the small intestine.

In addition, among the indigestible carbohydrates (in the small intestine) of DP=2, there are compounds which are used as a laxative (hyperosmotic) and which we do not want to appear in foods.

Only compounds are mentioned whose beneficial properties have been widely demonstrated, at thresholds at which they are likely to be incorporated into the diet.

For a compound to meet the definition of fiber, it must exhibit at least one of the following properties:

- An increase in stool production,
- Stimulation of colonic fermentation,
- A reduction in fasting cholesterol levels,
- A reduction in postprandial blood sugar and/or insulinemia.

At these same doses, they must not cause any risk (for health) or significant digestive discomfort for the consumer.

However, there are at-risk populations likely to experience inconvenience following the consumption of dietary fiber products. They should then avoid, as much as possible, their consumption. This requires that the name of these products is mentioned on the packaging and that their composition is clearly described (GAROT, 2014).

II.2. Classification of dietary fiber

Dietary fibers can be classified according to different criteria such as structure, fermentability, etc. (Dai and Chau, 2017; Tungland and Meyer, 2002) but the best known classification is that which divides fibers into two categories according to their solubility in aqueous media. Thus, we distinguish between soluble and insoluble fiber.

II.2.1. Soluble fiber

These are fibers capable of solubilizing in water and tampons. This group includes pectic substances, gums and mucilages and soluble hemicelluloses in the form of arabinoxylans or pentosans. These are substances that are easily fermentable in the colon and can increase the viscosity of solutions, form gels or even act as emulsifiers (Elleuch et al., 2011). Due to these characteristics, the addition of soluble fiber can improve the texture, shelf life and sensory properties of starch-based foods as well as reduce the rate of aging and maintain the relative stability of rheological and tissue properties (Wan et al., 2018). In addition, soluble fiber may have health benefits such as reducing the glycemic response and the level of “bad cholesterol” LDL in plasma (Weickert and Pfeiffer, 2008).

II.2.2. Insoluble fiber

These are fibers incapable of solubilizing in water and buffers. This group includes cellulose, insoluble hemicellulose, lignin and resistant starch. These are substances that are not or poorly fermentable in the colon and are characterized by their porosity, their low density and their ability to increase the volume of fecal matter by absorbing water (Elleuch et al., 2011). In addition, insoluble fiber may have health benefits such as reducing the risk of diabetes 2 and reducing intestinal transit time following an increase in the frequency of gastric movements (Rosado, 2000; Weickert and Pfeiffer, 2008).

II.3. Characteristic of dietary fiber

Dietary fiber thus belongs to the family of complex carbohydrates comprising all carbohydrates larger than 3 monomeric units ($MU \geq 3$). They can be grouped according to their physicochemical characteristics (molecular weight, nature of carbohydrate monomers, types of bond between monomers). It is these physicochemical characteristics which will subsequently be responsible for their physicochemical behaviors in the intestine of the host (solubility, viscosity) but also for their capacity to be degraded by intestinal microorganisms (fermentability) and for their physiological effects.

They are essentially represented by oligosaccharides (OS: $3 \leq MU \leq 10$) and polysaccharides (MU > 10) including non-starchy polysaccharides (NSP) and resistant starches (RS) (Stephen AM et al., 2017)

II.4. The different types of fibers

II. 4.1. Non-starchy polysaccharides

Non-starch polysaccharides (NSP) are complex polysaccharides that contain up to several hundred thousand monosaccharide units, united by glycosidic bonds. They are composed of different types of monomers, which are linked predominantly by the β-glycosidic bond. (Flint et al., 2012)

In plants, NSP are present as structural polysaccharides in the cell walls of plants, namely fruits, vegetables or cereals.

Moreover, the cell wall and/or endosperm of plants are composed of NSP such as fibrils of cellulose, hemicellulose (xyloglucan, arabinoxylans, β-glucan) incorporated in a network of pectins (Flint et al., 2012).

These polysaccharides are associated and/or substituted by other polysaccharides, such as lignin, proteins and phenolic compounds.

NSP make up more than 90% of the cell wall of plants and conversely generally constitute less than 10% of the weight of the seed (Cummings et al., 2007).

NSP are of several types and are distinguished by the composition of their saccharide skeleton, the types of bonds, as well as the nature of their side chain. Among the best-known NSP, we find:

• Cellulose

Cellulose is a major component of plant cell walls. It represents about a quarter of the dietary fiber in cereals and fruits and a third of the fiber in vegetables and nuts. Cellulose is made up of a linear, unbranched polysaccharide skeleton of 10,000 glucose units, linked together by β-(1,4) bonds (Gidenne et al.,2015).

Cellulose molecules can be associated with other polysaccharides such as glucans or arabinoxylan in β-(1,3) bonds (Kumar,2012).

- **β-glucan**

β-glucan is a soluble fiber, present in members of the monocot family, to which cereals (wheat, rye, oats, barley) and grasses belong (Anttila H. et al., 2004). The main sources of β-glucan are barley grains (5-20%), oats (3-8%), sorghum (1.6-6.2%) and rye (1.3 -2.7%), while wheat, rice and corn have lower concentrations (0.13-1.7%) (El Khoury et al., 2012).

Unlike cellulose, ß-glucans are glucose polymers linked together by β-(1,3) and β-(1,4) bonds (Anttila et al., 2004).

β-glucan molecules in barley consist of 70% β-(1,4) linkage and 30% β-(1,3) linkage, including segments of two or three β-(1) linkages -4) are separated by a single β-(1,3) bond. The solubility of β-glucan will be influenced by its structure, and its degree of polymerization linked to the composition of its side chains and their frequency. A lesser presence of β-(1,3) bond and/or a high degree of polymerization makes β-glucan less soluble in water (Bohn et al., 1995).

- **Psyllium (arabinoxylan)**

Psyllium is a gelling mucilage isolated from the Plantago ovata plant (Indian Plantain), a plant native to Asia and the Mediterranean regions of Europe and North Africa. The husk of the psyllium seed is a rich source of soluble fiber (Theuwissen et al., 2008).

The bioactive fraction of psyllium is composed of a highly branched fiber, arabinoxylan, a hemicellulose consisting of a linear skeleton of β-(1,4)-linked Xylose units, with arabinose side chains (Qaisrani et al., 2016)

- **Pectin:**

Pectin is a polysaccharide present in the cell wall and in the intracellular tissue of many plants (35%) (Voragen AGJ et al, 2009), mainly citrus fruits (oranges, lemons, grapefruit), apples, guava and prunes (Theuwissen et al., 2008).

Pectin is used as a gelling and thickening agent in various food products such as jam, yogurt drinks, fruity milk drinks and ice cream (Ren et al., 2003).

Pectin has a linear skeleton containing 300 to 1000 units of galacturonic acid monosaccharides linked together by partially esterified (methyl or acetyl) α-(1,4) bonds(Theuwissen et al., 2008).

The following figure shows the structure of the pectin molecule

- **Guar gum:**

Guar gum is extracted from the seed of the legume Cyamopsis tetragonolobus native to India and Pakistan. It is a polysaccharide composed mainly of galactomannan, a linear mannopyranose polymer composed of approximately 10,000 β-(1,4)-linked mannose monomers with branched chains of α-(1,6)-linked galactose units. (Theuwissen et al., 2008)

II. 4. 2. Oligosaccharides

Oligosaccharides (OS) are sugars made up of two to one/a few dozen simple sugar molecules.They are divided into natural oligosaccharides and functional oligosaccharides. Natural OS (sucrose, lactose, and maltose) will mainly provide energy without having any effect on bacterial growth. On the other hand, functional OS extracted from plants are used as prebiotics capable of stimulating bacterial proliferation in the colon (Zhao et al., 2017).

The functional oligosaccharides are as follows

- **Inulin**

Inulin is a fructan-type oligosaccharide made up of a polymer of 2 to 100 fructoses arranged together by β-(2,1) bonds with an α-linked terminal glucose (Apolinário et al., 2014).

They can be extracted from dicotyledonous plants such as chicory root, onion, asparagus, or artichoke (Apolinário et al., 2014)

- **Fructo-oligosaccharides and Galacto-oligosaccharides**

Fructo-oligosaccharides (FOS) are polymers of fructose and glucose in β-(2, 1) bond, while galacto-oligosaccharides (GOS) are made up of galactose in β-(1,4) bond (Crittenden et al., 1996).

They occur naturally in various plants such as blue agave, fruits (bananas, peaches), vegetables (onions, chicory roots, garlic, asparagus, and leeks) and cereals (rye, wheat, barley) (Campbell et al., 1997).

Most commercially available FOS and GOS are manufactured industrially from sucrose and are considered functional fibers due to their beneficial physiological effects in humans.

FOS and GOS can also be synthesized following the degradation of inulin or lactose by the intestinal microbiota. FOS are produced from sucrose or inulin via β-fructofuranosidase and inulinase.

On the other hand, GOS are produced from lactose via β-galactosidase. The industrial production and use of certain oligosaccharides (e.g. FOS, GOS) have increased significantly due to their beneficial health properties (Al-Sheraji et al., 2013).

- **Arabinoxylans (AX)**

Arabinoxylans (AX) are the major components of cereal dietary fiber along with cellulose, β-glucan, and lignin (31). The hydrolysis of AXs by β(1,4) xylanase gives two types of oligosaccharides, arabinoxylo-oligosaccharides (AXOS) and xylo-oligosaccharides (XOS). However, XOS and AXOS can be provided directly by food (Broekaert et al., 2011).

Xylo-oligosaccharides (XOS) are composed of xylan units, a polysaccharide found in corn cobs. On the other hand, Arabino-xylooligosaccharides (AXOS) are a substitution of the XOS backbone by arabinofuranosyl residues associated with each other by α-(1,2) or α-(1,3) glycosidic bonds (Broekaert et al., 2011).

II. 4. 3. Resistant starches (RA)

Starch is a linear polymer of D-glucose molecules linked by α(1,4) and/or α-(1,6) bonds. Food starch typically comprises a mixture of amylose, linear chains of glucose residues linked together by α-(1,4) bonds, and amylopectin, amylose chains linked by α-(1,6) side branches. It occurs in plants in granular form (Broekaert et al., 2011).

Resistant starches are starches composed of more or less branched amylose and amylopectin molecules. A high content of amylose or long branched chains of amylopectin increases the resistance of starch to intestinal hydrolysis (Tobaruela et al., 2018).

Digestion of starch begins in the mouth with salivary amylase, then in the intestine with pancreatic amylase. The starch molecules that escape this digestion are degraded by the intestinal microbiota in the colon (Asp et al., 1996).

The degree of degradation of starches in the small intestine will allow them to be classified into 3 categories: the digestible, the less digestible and the resistant (Englyst et al., 1996).

Starches can be protected from intestinal hydrolysis by α-amylases produced by the pancreas according to several physicochemical mechanisms. This allowed the classification of ARs into four types (Fuentes- Zaragoza et al., 2011).

AR 1: Physically inaccessible starch following encapsulation of the starch in cell walls (cellulose type) resistant to digestion.

AR 2: Starch naturally present in the form of starch granules, particularly in raw potatoes. However, these starches are included in a compact structure limiting access to digestive enzymes such as α-amylases.

AR 3: Starch physically modified following a destructuring reaction then a reassociation of amylose and amylopectin molecules via a heating and cooling action. A reaction randomly converting part of the α-(1,4) bonds into α- or β-(1,2), (1,3) or β-(1,4) bonds.

For example, cooking rice, pasta or potatoes followed by cooling and incorporation into a salad, sushi, etc. → AR 4: Starch chemically modified (cross-linking, esterification, trans-glycosylation) by manufacturers in order to resist digestive enzymes. They are used as food additives derived from corn, potatoes or rice.

To summarize, resistant starches occur naturally in plant products (AR1 and AR2), but can also be produced by modification of starch during food processing through cooking and cooling or extrusion of starchy foods

(AR3). It is also manufactured in industry for use as a functional fiber or texturizing element in the food industry (AR4) (Sharma et al., 2008).

Their structure in the form of granules, more or less tight, reduces their hydrolysis by digestive enzymes, compared to gelatinized starch. The lower the degree of starch gelatinization, which is found after cooking, the greater its resistance to digestion.

II.5. Molecular structure of some molecules with prebiotic characteristics

II.5.1. Fructans

Fructans are fructose oligomers or polymers built from a sucrose molecule. They contain one D-glucose residue and n D-fructose residues in furan form, their degree of polymerization (DP) is equal to n+1. The residues are linked together by O-glycosidic bonds either in β-(2→1) or in β-(2→6) which systematically engage carbon 2 of the terminal fructose carrying the reducing function. Fructans are therefore non-reducing carbohydrates. The size of fructans, which is proportional to the number of monomers that compose them, is generally expressed in degree of polymerization (DP), which can vary from 3 to 60 fructose residues.

If the DP is less than 10, these polymers are known as fructo-oligosaccharides (FOS), but if the DP is greater than 10, they are called polyfructans (Itaya et al., 1997; Corradini et al., 2004).

The best-known representative of polyfructans being inulin, discovered in the rhizomes of a dicot of the Asteraceae family Inula helenium by Rose in 1804, (Pontis et Del Campillo, 1985)

The structure of fructans in plants varies depending on the plant species but also depending on the climatic conditions of its environment (Vijn et Smeekens, 1999).

Fructans are classified into four major groups based on the glycosidic bonds connecting the fructofuranosyl residues together. Inulins are linear fructans with β(2→1) linkages between fructose units and their glucose is in the terminal position. 1-kestotriose, also called isokestose, is the smallest representative molecule of the inulin family. This type of molecule corresponds to the fructans found in dicotyledons (chicory, Jerusalem artichoke: Helianthus tuberosus, dandelion: Taraxacum officinale, artichoke: Cynara scolymus) and in some monocotyledons, belonging to the order Asterales (Koops et Jonker,1996).

II.5.2. “Levan” type fructans

Levans are also linear fructans but constituted by the chain of fructose residues linked in β(2→6) and their glucose is in the terminal position. They are mainly found in monocots and bacteria. Typically, bacteria produce levan molecules with a DP of more than 100,000 fructose units (Figure C) (Vijn et Smeekens,1999).

II.5.3. “Neoseries” type fructans

Fructans of this type are synthesized from 6G-kestotriose (or neokestose), the glucose residue is therefore found inside the molecule. When the bonds between the fructosyl residues are of the β(2→1) type, we speak of “inulin neoseries” type fructans, but if the bonds between the fructosyl residues are of the β(2→6) type, we then speak of fructans of the “neosery levan” type. The additional fructose units attach to one of the two terminal fructose residues of 6G-kestotriose by β(2→1) bonds (fructans of the inulin neoseries) or by β(2→6) bonds (fructans of the levan neoseries) (Bonnett et al., 1997).

II.5.4 "Graminan" type fructans

The fructans of this family are mixed and branched polymers whose structure is more or less complex. In general, the fructose residue of sucrose is substituted by both a chain of β(2→6)-linked fructose residues and a chain of β(2→1)-linked fructose residues.

The glucose residue can be in the terminal position but it can also be substituted by a chain of fructose residues linked in β(2→1). Finally, the fructan chains can themselves be branched if one of their fructose residues is disubstituted. We find this type of structure more specifically in grasses (wheat and barley). An example of this type of branched fructan is the bifurcose (1,6-kestotetraose) molecule (Figure D) (Bonnettetal, 1997).

Plants can accumulate fructans belonging to one or more of these four types of structures. In the Asteraceae family, Jerusalem artichoke (Helianthus tuberosus) accumulates only inulin-type fructans. On the other hand, chicory and dahlia mainly accumulate inulin-type fructans but also levan-type fructans (Carpita et al., 1989; Bonnett et al., 1994). This family also has the particularity of accumulating fructans exclusively composed of fructosyl residues (Ernst et al., 1996). These fructans are synthesized from a fructose instead of sucrose and are called inulo-*n*-ose (Van Den Ende et Van Laere ,1996).

These fructans are therefore reducing carbohydrates because the ketone function of the first fructosyl residue in the chain is free (Chatterton et al., 1990; Bancal et al. 1992).

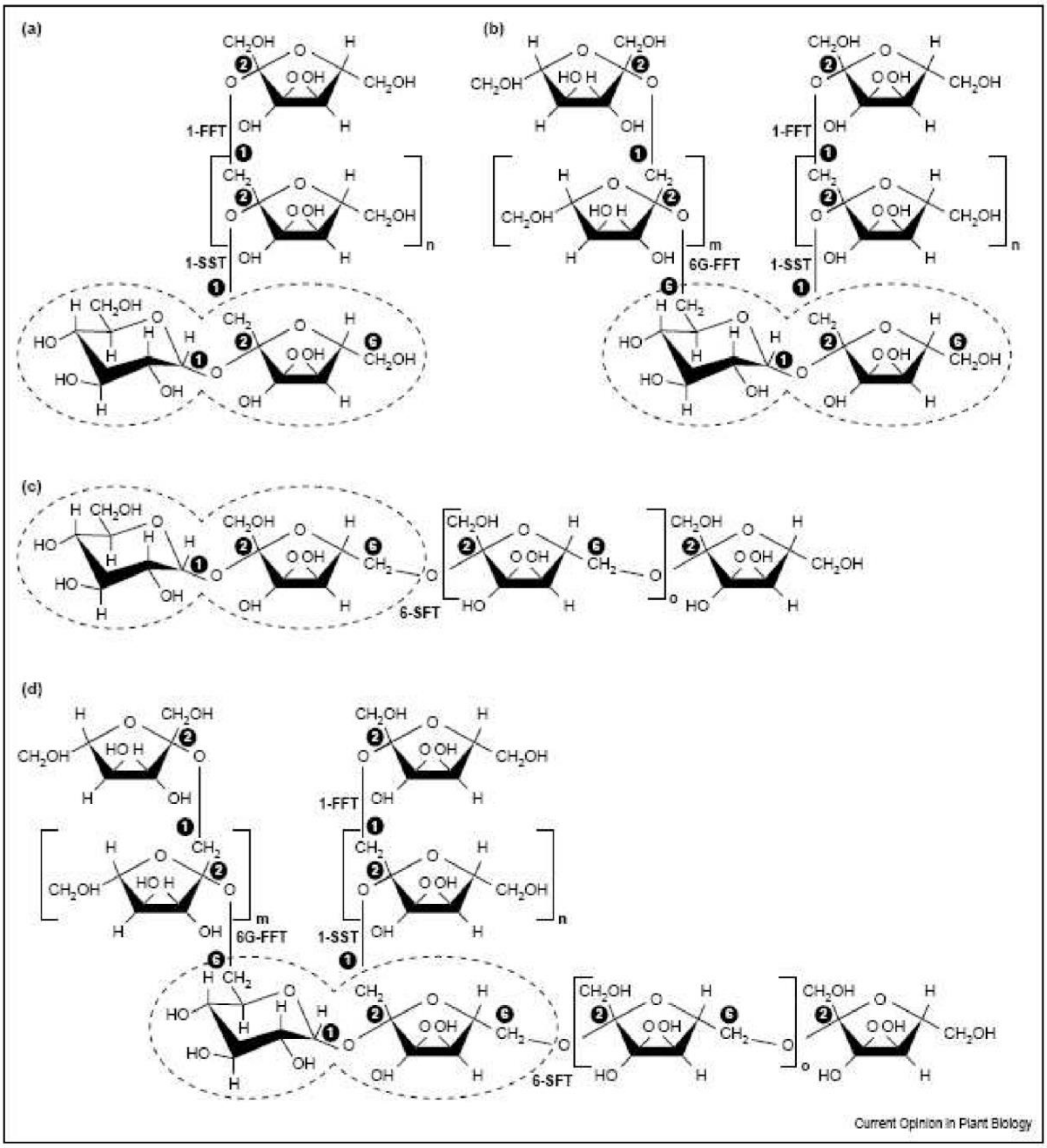

Figure 7.Structures of some polysaccharids

Structure of fructans (A) inulin type, (B) inulin neoseries type, (C) levan type and (D) graminan type. The sucrose molecule is circled in dotted lines and the numbers in a black circle correspond to the glycosidic bonds between the different monosaccha

II.6. Biochemical disparity of dietary fiber

The biochemical disparity of dietary fiber finds its origin in natural diversity, the coexistence of natural compounds and synthetic compounds, and in “post-production” technological processes. For example, the fructan family includes compounds obtained by extraction, partial enzymatic hydrolysis or enzymatic biosynthesis. It is composed of 3 subgroups ["inulin" type fructans, "levan" type fructans and branched fructans, sometimes called "graminarans" (Pavis et al., 2001).

Linear fructans are naturally present in many plants (young cereals, fruits, vegetables). Chicory and squash (Jerusalem artichoke) are the two sources exploited industrially for the production of linear fructans. Illustrating natural diversity, the average degree of polymerization of the extracted inulin differs depending on the plant source (10 to 20 for chicory, 6 for squash). Furthermore, inulin extracted from chicory is composed of both fructose-only polymers (FFn) and glucose-containing polymers (GFn) (Grizard et Barthomeuf, 1999; Flamm et al., 2001).

Fructo-oligosaccharides (FOS) are produced either by partial enzymatic hydrolysis of inulin (e.g. Raftilose) or by enzymatic biosynthesis from a mixture of sucrose, glucose and fructose (e.g. Actilight). The coexistence of these natural and synthetic compounds increases the diversity of chemical structures encountered under the same name. Indeed, the compounds resulting from each of these technological processes are not identical: the FOS obtained by hydrolysis contain a mixture of GFn and FFn structures ($2<n<7$) while only the GFn structures ($2<n<4$) are present in synthetic FOS (Frank et al., 2002).

II.7. Effect of dietary fiber on intake and eating behavior

The introduction of dietary fiber into food modifies eating behavior, with different actions on the variables describing it.

II.7.1. Effect on intestinal transit and absorption

In monogastrics, including humans, the fibers are not broken down until they arrive in the small intestine. The stomach empties more slowly and the absorption of nutrients in the small intestine is increased (effect of soluble fiber) (Harris et Ferguson, 1999).

I.7.2. Effect on gastric distension and gastric emptying

Dietary fibers in food, especially fibers with significant water retention properties, increase the volume of digestive contents in the digestive tract, and in particular in the stomach. The larger volume of stomach contents activates the mechanoreceptors more quickly and sends the satiety signal to the CNS (Lepionka et al., 1997).

II.7.3. production of short-chain fatty acids (SCFA)

In the large intestine, dietary fiber can be broken down by bacterial enzymes. The product of this degradation is then fermented to give short chain fatty acids (SCFA), mainly acetic, propionic and butyric acid, and other compounds such as water, hydrogen, carbon dioxide, methane. This process takes place to varying degrees depending on the type of fiber involved. Butyrate is the short-chain fatty acid that shows the most promising effects. Indeed, it would constitute an essential source of energy for the epithelial cells of the colon (Roediger, 1982).

On cultured tissues, studies have shown that it increases cell differentiation in particular by inhibiting the chromatin remodeling action of histone deacetylase (Davie, 2003).

Butyrate would also have an effect on the expression of cancer-related genes in cancer cells as well as on apoptosis (Lupton, 2004).

Studies have shown that butyrate can increase the concentration of Glutathione transferase π in colon cells. Glutathione transferase π is an important enzyme involved in the detoxification of electrophilic products and compounds associated with oxidative stress (Treptow-van Lishaut et al. 1999).

It is difficult to determine the exact effect of butyrate in the living organism. The physicochemical conditions in the colon (pH, arrangement of cells, etc.) are different from those that can be observed in in vitro experiments. Furthermore, it has been suggested that this effect depends on the stage of development of the disease (butyrate would be protective in early stages). The concentration of this metabolite also plays an important role: according to certain studies, cell proliferation is stimulated by low concentrations of butyrate, but inhibited by high concentrations. Finally, studies which evaluate the effect of butyrate using dietary fiber as a source of SCFA do not make it possible to dissociate the effect of butyrate from the protective effect attributed to the other properties of dietary fiber (Lupton, 2004).

II.7.4. Influence of fiber on fecal volume

Insoluble fiber has the ability to increase fecal volume and decrease gastrointestinal transit time. Additionally, corky and lignified plant walls, both insoluble fibers, have been shown to have the ability to absorb hydrophobic dietary carcinogens in vitro (Narisawa et al., 1974).

II. 7. 5. Impact of fiber and fiber-rich foods on diabetes

Type 2 diabetes results in a decreased postprandial response to glucose and an increase in glycated hemoglobin (HbA1c). A few review reviews and meta-analyses have analyzed the effect of dietary fiber (type and quantity) on glycemic control in patients with obesity, overweight and type 2 diabetes. In a longitudinal analysis of 17 prospective cohorts, an inverse relationship was observed between dietary fiber consumption (>25 g/day) and the risk of diabetes (Yao et al., 2014).

Many studies indicate improved glycemic control and hemoglobin glycation (HbA1c) in people with T1D or T2D who consumed more fiber. A meta-analysis carried out over a period of 8-16 weeks concluded that the consumption of foods rich in dietary fiber or supplemented with soluble fiber made it possible to lower the concentrations of HbA1c and fasting plasma glucose in diabetics (Silva et al., 2013).

II. 7. 6. Impact of foods rich in fiber on cardiovascular diseases

Several prospective studies in the literature have revealed that diets rich in dietary fiber could be inversely associated with the risk of cardiovascular diseases (Mente et al., 2009).

Indeed, the risk of T1D is reduced, from 8% to 21%, following the consumption of fruits and vegetables, particularly citrus fruits, grapes, apples, cruciferous vegetables (broccoli, cauliflower, cabbage, watercress and turnip) and green leaves (salads, leeks, cabbage, spinach) (Afshin et al., 2014).

Hypertension is one of the major components of CVD and can be easily measured/quantified, which can be very useful in longitudinal intervention studies. Several studies carried out on healthy or unhealthy volunteers have shown a slight reduction in systolic (≈ 7 mm Hg) and diastolic (≈ 4 mm Hg) pressure following the supplementation of soluble fiber (psyllium, guar gum, β- glucan) in the diet (Cicero et al., 2010).

II. 8. Cancers and other pathologies

II. 8. 1. Impact of foods rich in fiber on cancer

Cancer is the second leading cause of death in the world with 8.8 million deaths in 2015 after cardiovascular diseases. The incidence of cancer in 2017 was estimated at 400,000 cases including 150,000 deaths. In industrialized countries, the most common cancers are prostate, colorectal, breast and lung cancer. There is a close association between consumption of obesogenic diet and cancer risk (Lauby-Secretan et al., 2016).

Conversely, several publications based on meta-analyses have shown that the consumption of fiber or foods rich in fiber (fruits, vegetables, whole grains, etc.) was associated with a reduction in the risk of cancer (Kim et al., 2016; Chen et al., 2016).

When we stratify according to the type of cancer, several studies generally demonstrate a negative association between the consumption of fiber or foods rich in fiber and cancers of the digestive tract, colorectal, breast, prostate or pancreas (Makarem et al., 2016).

II. 8. 2. Intestinal inflammatory pathologies

Aside from obesity, diabetes, cardiovascular disease or cancer, dietary fiber, particularly soluble and viscous fiber, can also play a role in intestinal inflammation, such as irritable bowel syndrome, ulcer or Crohn's disease. This intestinal inflammation leads to loss of appetite, malabsorption of nutrients, macro or micronutrient deficiency as well as weight loss (Guerreiro et al., 2007).

It was shown in an epidemiological study carried out on a cohort of more than 170,000 women over 26 years that the consumption of dietary fiber (24 g/day) was associated with a reduction in the risk of Crohn's disease (40%) and the occurrence of ulcers (18%) (Ananthakrishnan et al., 2013). In addition, interventional data highlighting an improvement in inflammatory bowel diseases following fiber consumption (Wedlake et al., 2014).

Inflammatory diseases are also reduced by the consumption of guar gum (5 g/d), psyllium (7 g/d), sprouted barley (20-30 g/d) and GOS (7 g/d) (Silk et al., 2009).

II.9. Influences of non-digestible oligosaccharides (NDOs) on the regulation of the intestinal microbiota

II. 9.1. Definition and importance of NDOs

NDOs are composed of many monosaccharides linked in different ways. They have varying chemical characteristics, but all resist digestion in the small intestine of humans and are therefore potential substrates for bacteria that colonize the large intestine. NDOs therefore have certain properties close to dietary fibers, and have been considered as such in certain publications, or have been judged as a category of carbohydrates distinct from those of dietary fibers. (Van Loo et al., 1999).

Unlike most dietary fiber polysaccharides, NDOs are soluble in an 80% ethanol solution, at Ph=2 and 0°C for 30 minutes. This allows them to be distinguished from polysaccharides. There are also methods to identify and quantify NDOs, particularly inulin-type fructans (by first separating NDOs by chromatography and then applying an acid hydrolysis technique to convert them into monosaccharides; there are quantification standards monosaccharides). This makes it possible to study their content in foods and to implement precise protocols in chemoprevention studies (Van Loo et al., 1999).

NDOs have long been present in food, but in unknown doses. They are found in more than 36,000 plant species (Carpita et al. 1989) notably wheat, banana, onion, garlic, asparagus (Verghese et al., 2002).

They are also used in the food industry, and can be produced in three different ways:

-from natural sources (For example inulin is produced by extraction from chicory roots (Cichorium Intybus).

-from natural sources but subjected to partial hydrolysis by enzymatic treatment (oligofructoses and xylo-oligosaccharides).

-synthesized by the action of transferases on disaccharides such as sucrose and lactose (e.g.,transgalacto-oligosaccharides) (Harris etFerguson, 1999).

II. 9.2. Laxative properties of NDOs

NDOs remain in solution in the chime, thereby contributing to osmotic pressure. The increase in this creates a call for water. NDOs are fermented by bacteria in the colon, which releases gases, SCFA and lactate. These gases affect intestinal motility. The fermentation of NDO also results in the production of biomass, which explains their deconstipating properties (Harris etFerguson, 1999)

II. 9.3. SCFA production by NDO fermentation

The different NDOs stimulate different bacteria in the colon ecosystem, their fermentation results in the emission of different volatile gases:

- inulin-type fructans increase the production of acetate and butyrate,
- galacto-oligosaccharides increase the production of acetate and propionate,
- xylo-oligosaccharides only that of acetate (Campbell,1997; Djouzi et Andrieux, 1997).

II. 9.4. Probiotic boost

NDOs can stimulate the growth of so-called “probiotic” bacteria. Among the NDOs likely to enable this growth, we find in particular β (2-1) fructans of the inulin type. Transgalactosylated oligosaccharides (TOS) have only shown results in certain studies (Ito et al., 1993; Bouhnik et al., 1997).

II. 9.5. Absorption of minerals

Several studies on the mouse model have confirmed that inulin-type fructans, TOS and GOS increase the absorption of minerals Ca2+, Mg2+ and Fe2+ (Coudray et al., 1997; Lemort and Roberfroid, 1997; Ohta et al 1993; 1995 et 1997); Dietary fiber, especially insoluble fiber such as cellulose and hemicellulose, can promote fermentation in the colon, leading to the production of compounds such as short-chain fatty acids (SCFA) that can improve absorption of certain minerals such as calcium and magnesium (Cummings et al., 1987) . Fermentable fibers can lower the pH, thus promoting the absorption of calcium and magnesium (Weaver et al., 2006).

Research has shown that dietary fiber slows gastric emptying while promoting increased absorption of minerals such as calcium, iron, potassium, magnesium, sodium, etc. (Slavin JL, 2005). The modulation of intestinal flora by dietary fiber strengthens the mineral absorption system in the small intestine. (Gibson et al., 1995).

The increase in absorption occurs mainly in the large intestine. This better absorption allows for an increase in bone density. Studies in humans show that inulin-type fructans allow better absorption of calcium (Van den Heuvel et al. 1999a), and therefore help the body fight against osteoporosis (Taguchi et al., 1995).

II.10. NDO and lipid metabolism

In rats, β (2-1) fructans seem to have an effect on lipid metabolism (reduction in the activity of lipogenic hepatic enzymes, postprandial triacyglycerol concentration, etc.). In humans, some information indicates that taking small doses of inulin and oligofructose could also have an effect on lipid metabolism. Further studies still need to be carried out (Van Loo et al., 1999).

Epidemiological studies have proven that a higher intake of dietary fiber is linked to a better lipid profile (Figure 8).

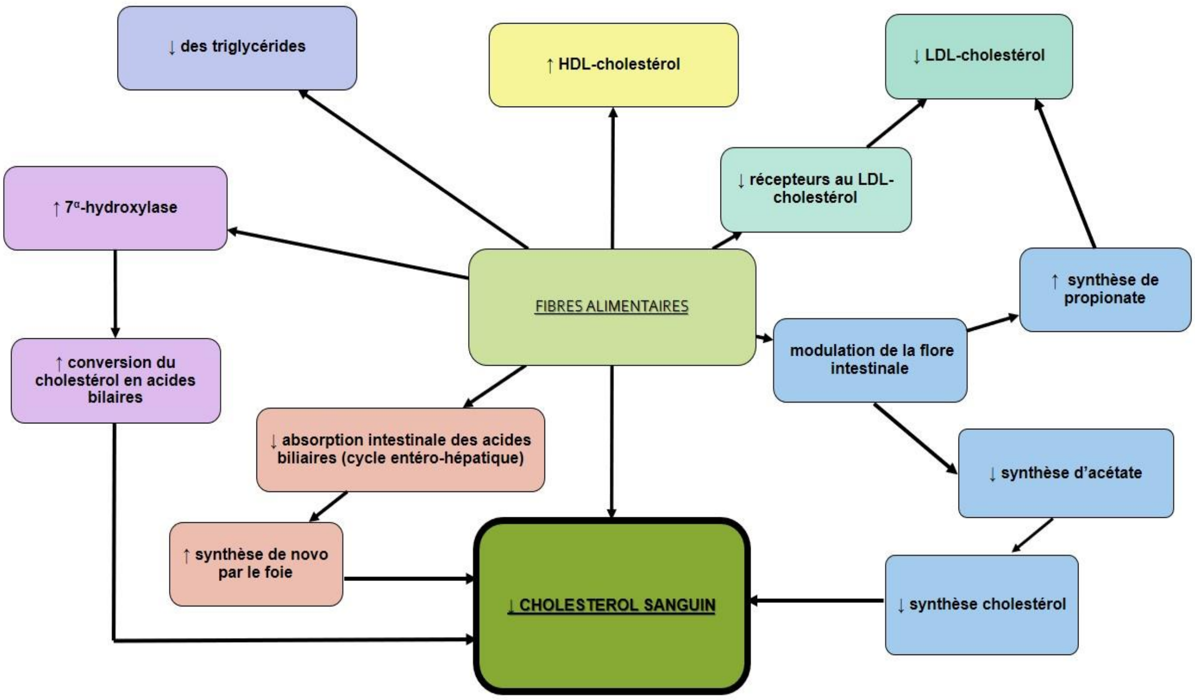

Figure 8.General diagram of the action of fiber on lipid balance (BABIO et al2010

A study carried out on a sample of 3452 adults, with a diet characterized by a high fiber consumption, highlighted a low level of triglycerides (normal value between 0.40 and 1.7 mmol/L or between 0.35 and 1.5 g/L) as well as a high level of HDL-cholesterol (normal value greater than 1 mmol/L or 0.40 g/L).A ten-year study of 2909 healthy adults aged 18 to 30 years old showed an inverse correlation between dietary fiber consumption and blood pressure, triglyceride levels of HDL-cholesterol, LDL-cholesterol (normal value less than 4.1 mmol/L or 1.6 g/L) and fibrinogen (Smith et Lee, 2020).

However, adjusting insulin significantly attenuates the results, which suggests that the action of fiber on insulin metabolism could also explain the influence of the high-fiber diet on lipid balance and cardiovascular pathologies.

A similar study carried out over seven years on 316 subjects (Japanese, Brazilian) indicated a drop of 0.125 g/L in total cholesterol levels for each ten grams increase in dietary fiber.

Concerning the clinical studies carried out, one of them highlighted, for the first time, the involvement of certain fibers in the reduction of plasma cholesterol in humans. This concerns more precisely soluble fibers (pectins, guar gum), the action of which, however, remains modest.

Finally, other studies corroborate these results. Although the action of fiber, and more particularly soluble fiber, on the respective levels of triglycerides and cholesterol is proven, it varies depending on the source (BABIO et al2010; CNCI, 2004).

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Professor Trautwein et al. suggested that due to their physicochemical properties, soluble fibers would cause a modification of the volume as well as the viscosity in the intestinal lumen, modifying the hepatic metabolism of cholesterol, the metabolism of lipoproteins and reducing their plasma level (RIDEOUT et al., 2008; TRAUTWEIN et al., 1999). Other studies suggest that dietary fiber increases the activity of the enzyme - hydroxylase, an enzyme which catalyzes the transformation of cholesterol into cholic acid and into chenodeoxycholic acid, important in the regulation of hepatic conversion of cholesterol into bile acids. This action would result in a depletion of hepatic cholesterol.

This depletion would lead to stimulation of HMG-CoA reductase (hydroxymethyl-glutaryl-coenzyme A reductase), a key enzyme in cholesterol synthesis, increasing endogenous cholesterol synthesis. However, at the same time there would be an increase in the number of LDL cholesterol receptors.

In addition, Professors Jenkins, Jones and their colleagues described a reduction in hepatic lipogenesis stimulated by insulin. (FERNANDEZ, 2001). Finally, the production of short-chain fatty acids by the colonic microflora modified by dietary fibers is also highlighted, in particular the reduction in the production of acetate and the increase in that of propionate. This results in the reduction of endogenous synthesis of cholesterol, fatty acids and low density lipoproteins(BABIO et al 2010; CNCI, 2004).

II.11. Nutritional properties and use of inulin and oligofructose in the food industry

Due to their β (2-1) glycosidic bonds resistant to intestinal degradative enzymes, inulin and oligofructose have a low caloric value. This property makes them molecules of choice to replace sucrose in industrial foods.

As no influence of these compounds on serum glucose concentration, stimulation of insulin or glucagon secretion was detected (Beringer et Wenger, 1995). Inulin and OF have long been used by diabetics. These substances also have the beneficial effects of NDOs: they stimulate transit, can relieve certain constipation, and act positively on lipid metabolism (Brighenti et al., 1995, Fiordaliso et al., 1995).

Inulin and OF are also of interest to the food industry. Due to the longer length of its chains, inulin forms crystals when mixed with water or milk. These crystals are not directly perceptible to the taste, but they give a creamy texture to the preparation. Inulin is therefore used to replace fat in many products such as baked goods, frozen desserts, etc. Oligofructose is used mainly for its sweetening properties, because it is more soluble than sucrose and has a valuable lower energy. In addition, it has no aftertaste and can mask that of other sweeteners such as aspartame or acesulfame. Since it has some of the physical properties of sugar, it is used to make low-fat pastries crunchy and it lowers the solidification point of frozen desserts. Finally, inulin and oligofructose are considered dietary fibers. They allow the development of so-called “fiber-rich” products, but with a taste of “normal” preparations, without increasing viscosity (Niness, 1999).

II.12. NDO and probiotics

II.12.1. Inulin and fructooligosaccharides.

Not being digested in the proximal part of the digestive tract, FOS and inulin are broken down into monomers by the colon microflora, which provides an excellent substrate for bifidobacteria (Hidaka et al. 1986). Indeed, studies have shown that supplementation with FOS and GOS (galactooligosaccharide, another non-digestible sugar in the small intestine) could increase bifidobacterium concentrations in the intestine (Rowland et al., 1993; Buddington et al.,1996).

All probiotics and prebiotics serving as their substrate are called “synbiotics”(Gibson et Roberfroid, 1995).

II.12.2. Protective effects of probiotics against colorectal cancer

A probiotic has been defined as a viable microbial food supplement that beneficially affects the host through its effects in the intestinal tract (Roberfroid, 2000). For example, bifidobacteria and lactobacilli are part of probiotics. Several experimental observations seem to indicate a potentially protective effect of bacteria producing lactic acid against the development of colon tumors (Wollowski et al. 2001). The ability of Lactic Acid Bacteria to prevent DNA mutations has been explored extensively. Dairy products obtained by fermentation using various strains of the genera Lactobacillus, Streptococcus, Lactococcus, and Bifidobacterium have shown variable antimutagenic properties (in vivo, on Salmonella typhimurium), in relation to the fermentation processes 38 and depending on the quantity of bacteria. . In vitro, the combination of LAB or yogurt prevents DNA damage caused by the oral administration of a carcinogen to rats (SEKINE et al., 1995).

Several mechanisms have been studied:

- The ingestion of lactic acid-producing bacteria (LAB) has an influence on the enzymatic activity of the intestinal flora associated with colon carcinogenesis, as shown in several studies in humans (Wollowski et al., 2001). LAB such as Bifidobacterium and Lactobacillus produce only a small proportion of β-glucuronidase, azoreductase, nitro- and nitrate reductases, enzymes involved in carcinogenesis, compared to other anaerobic bacteria in the human digestive system (Hughes and Rowland 2001, Saito et al., 1992).

- Furthermore, the production of lactic acid by these bacteria reduces the pH of the intestine. The resulting pH is unsuitable for harmful bacteria such as E.coli and C.clostridium, which creates a favorable microenvironment in the intestine (Reddy et al., 1997).

- In vitro and depending on the pH of the medium, LAB can bind heterocyclic amines, which are mutagenic. This ability to bind mutagens is attributed to the bacterial wall. However, the in vivo mechanism, the interest of the mutagens studied for colon carcinogenesis and the possible formation of other carcinogenic substances during the fermentation process are not yet fully known (Wollowski et al., 2001).

- It has been observed that Bifidobacterium infantis can stimulate antitumor immunity and modify the expression of cytokines (Sekine et al., 1995).

II.12.2. Dietary fiber content of some foods

The following table shows the dietary fiber content of some foods

Table 1. Dietary fiber content of some foods

Food	% in Fibers
Dioscorea alata	3.05%
Potato	1%
Dioscorea bulbufera	5.96%
Cassava	1.80%
Sechium edule	9.41%
Orange	1.60%
Coleus dysencericus	1.53%
Mango	1.60%
Basera alba	12.70%
Pineapple Ananas	1.20%
Dioscorea alata	3.05%
Green bean Haricot vert	2.85%
Dioscorea bulbufera	5.96%
Rice	1.40%

Source. Analysis results of our research and Max FEINBERG, 1993, tables de compositions des aliments, Centre informatique sur la qualité de l'aliment (CIQUAL)

II.13. Mineral salts

II.13.1. Calcium

Calcium is an essential mineral for numerous biological functions, including the formation and maintenance of bones and teeth, muscle contraction, nerve transmission, and blood clotting (Heaney, 2001). Calcium deficiency leads to a series of detrimental health effects, impacting various systems within the human body (Heaney.,2001).

- **Daily Recommended Intake of Calcium**

According to the recommendations of the World Health Organization and the Food and Agriculture Organization (FAO) of the United Nations, the daily recommended intake of calcium varies depending on age, sex, and specific physiological needs, such as pregnancy and breastfeeding. For children aged 1 to 3 years, the recommended intake is 500 mg/day, gradually increasing to 1300 mg/day for adolescents aged 10 to 18 years. Adults aged 19 to 50 years should consume 1000 mg/day, while women over 51 years of age require 1200 mg/day, and men over 51 years of age continue to require 1000 mg/day. Pregnant and lactating adolescents should receive 1300 mg/day, while pregnant and lactating adults need 1000 mg/day. These recommendations aim to ensure an adequate intake to maintain bone health and prevent calcium deficiencies (WHO, 2004; FAO, 2001).

II.13.2. Magnesium

Magnesium is an essential mineral that plays a significant role in many biological functions within the body. Magnesium is involved in the transmission of nerve impulses and muscle contraction. It is notably implicated in the functioning of ion channels and in the regulation of intracellular calcium concentration. It is a key component of hydroxyapatite, the primary mineral in bones. It contributes to maintaining bone mineral density and preventing osteoporosis. It participates in regulating blood pressure by influencing blood vessel function and helping maintain adequate electrolyte balance. Magnesium is necessary for energy production in cells, participating in enzymatic reactions involved in carbohydrate, lipid, and protein metabolism. It is associated with a reduced risk of cardiovascular diseases. It may help prevent cardiac arrhythmias, reduce inflammation, and improve endothelial function. Endothéliale (Volpe S, 2013 ; Gröber et al.,2015 ; Nielsen et al., 2015).

- **Daily Recommended Intake of Magnesium**

The recommendations for daily magnesium intake vary according to health authorities and specific population groups. The United States Institute of Medicine recommends a consumption ranging from 310 to 420 mg/day for adults, with variations based on age, gender, pregnancy, and lactation. Similarly, the European Food Safety Authority (EFSA) suggests a daily magnesium intake of 300 to 400 mg for adults. These guidelines are crucial for maintaining cardiovascular, muscular, neurological, and skeletal health (EFSA, 1997).

II.13.3. Sodium

Sodium plays a role in the regulation of water balance, it promotes nerve transmission and muscle contraction, regulates blood pressure, facilitates nutrient absorption, and participates in maintaining the acid-base balance (He et al., 2008; Denton et al., 1995; Humalda et al., 2011).

Sodium deficiency can have adverse effects on the body by disrupting the water, electrolyte, and acid-base balance. Sodium is an essential electrolyte needed to maintain osmotic pressure, regulate water balance, and transmit nerve and muscle signals (WHO, 1997).

- **Daily Recommended Intake of Sodium**

Specific recommendations for daily sodium intake vary depending on health authorities and organizations. Here are some general estimates based on the recommendations of the World Health Organization (WHO) and the French Agency for Food, Environmental and Occupational Health and Safety (ANSES).

The WHO recommends limiting sodium intake to less than 2 grams per day, which is approximately 5 grams of salt per day, for adults.

ANSES recommends a maximum salt intake of 5 to 6 grams per day for adults.

II.13.4. Potassium

Potassium is essential for many vital bodily functions, such as regulating water balance, nerve function, muscle contraction, maintaining blood pressure, and acid-base balance (Mount et al., 2012).

Potassium deficiency can have adverse effects on the body's physiological functions due to its crucial role in maintaining cellular fluid balance, nerve transmission, and muscle function. Symptoms of potassium deficiency, also known as hypokalemia, may include muscle weakness, cramps, irregular heartbeat (arrhythmia), (Mount et al., 2012).

- **Daily Recommended Intake of Potassium**

Potassium needs vary from person to person based on factors such as age, sex, health status, and level of physical activity. General recommendations for daily potassium intake also vary among health authorities and countries. For example, in the United States, the Institute of Medicine recommends the following potassium amounts per day: 3,400 mg for adults (aged 19 and older), 2,600 mg for pregnant women, and 2,800 mg for breastfeeding women. (Mount et al., 2012).

II.13.5. Iron

Iron is indispensable for many essential bodily functions, including oxygen transport, energy metabolism, immune function, cognitive development, and DNA synthesis. A balanced diet rich in iron sources is crucial for preventing imbalances and maintaining overall good health (Mount et al., 2012).

Iron deficiencies can have several adverse health consequences. The primary one is iron-deficiency anemia, characterized by a decrease in the number of red blood cells in the blood, leading to fatigue, weakness, and respiratory difficulties. This condition is widespread and is the main cause of anemia worldwide (McLean et al., 2009).

- **Daily Recommended Intake of Iron**

The World Health Organization (WHO) and the FAO recommend daily iron intake that varies according to age, sex, physiological status, and the bioavailability of dietary iron. For infants aged 0 to 6 months, the recommended intake is 0.27 mg per day, which is generally provided by breast milk. From 7 to 12 months, this intake should increase to 11 mg per day. Children aged 1 to 3 years need 7 mg per day; those aged 4 to 6 years need 10 mg per day; and those aged 7 to 9 years also need 10 mg per day.

For adolescents, boys aged 10 to 12 years need 12 mg per day, while girls require 15 mg per day. Boys aged 13 to 15 years should consume 19 mg per day, and girls need 21 mg per day. Boys aged 16 to 18 years need 16 mg per day, whereas girls of the same age require 26 mg per day.

For adults, men aged 19 to 50 years should consume 8 mg of iron per day, while women of the same age need 18 mg per day. After 51 years of age, both men and women require 8 mg per day. Pregnant women have increased needs, with a recommendation of 27 mg per day, and lactating women need between 9 and 10 mg per day.

The FAO and WHO also consider the bioavailability of iron in different diets. For low bioavailability (5%), men need 28 mg per day and women need 58 mg per day. With moderate bioavailability (10%), men need 14 mg per day and women require 29 mg per day. For high bioavailability (15%), the requirements are 9 mg per day for men and 19 mg per day for women. (Mount et al., 2012).

II.14. Minerals whose absorption is influenced by dietary fibers

The minerals selected for our research are chosen based on whether their absorption is influenced by dietary fibers.

II.14.1. Calcium

Certain dietary fibers, especially fermentable fibers such as inulin and fructo-oligosaccharides (FOS), can promote calcium absorption in the colon by increasing the production of short-chain fatty acids (SCFAs) during bacterial fermentation. These SCFAs lower colonic pH, thereby increasing the solubility and absorption of calcium. (Scholz-Ahrens, 2007)

II.14.2. Magnésium

Similar to calcium, magnesium absorption can be enhanced by the fermentation of fermentable fibers. The SCFAs produced by this fermentation also promote magnesium solubility. (Younes et al., 1995).

II.14.3. Iron

Fermentable fibers can also enhance the absorption of non-heme iron. The SCFAs produced can make the intestinal environment more conducive to iron solubility, although this effect is less pronounced than for calcium and magnesium (Tako et al., 2008).

II.15. Daily mineral and fiber requirements according to age groups and groups of people

II.15.1. Minerals

The table 2 shows the daily mineral requirements according to age group and population

Table 2. Daily mineral requirements according to age groups and groups of people

Age Group / Population	Iron (mg/day)	Potassium (mg/day)	Calcium (mg/day)	Magnesium (mg/day)	Sodium (mg/day)
Infants					
0-6 months	0.27	400	200	30	120
7-12 months	11	860	260	75	370
Children					
1-3 years	7	2000	700	80	1000
4-8 years	10	2300	1000	130	1200
Adolescents					
9-13 years	8	2500	1300	240	1500
Boys 14-18 years	11	3000	1300	410	1500
Girls 14-18 years	15	2300	1300	360	1500
Adults					
Men 19-50 years	8	3400	1000	400	1500
Women 19-50 years	18	2600	1000	310	1500
Men 51+ years	8	3400	1000	420	1500
Women 51+ years	8	2600	1200	320	1500
Pregnancy					
Adolescents	27	2600	1300	400	1500
Adults	27	2900	1000	350	1500
Breastfeeding					
Adolescents	10	2600	1300	360	1500
Adults	9	2900	1000	310	1500

Source. National Academies of Sciences, Engineering, and Medicine. (2019).

The table 3 shows the Average Mineral Intakes in Adult Men.

Table 3. Average Mineral Intakes in Adult Men.

Minéral	Average Intake (mg/day)
Iron	16-18
Potassium	2500-3500
Calcium	800-1000
Magnesium	300-400
Sodium	3000-4000

Sources. Centers for Disease Control and Prevention (CDC). (2020). *Sodium and Potassium*. Retrieved from https://www.cdc.gov/nutrition/data-statistics/sodium-and-potassium-intake/index.html

II.15.2. fibers

Deficiencies in dietary fiber intake can have several adverse health consequences. Here are some of the main ones:

Digestive problems:

Dietary fiber helps regulate intestinal transit by promoting the movement of food through the digestive system. A fiber deficiency can lead to constipation, bloating and abdominal pain. Increased risk of cardiovascular disease: Dietary fiber, especially soluble fiber, helps lower blood cholesterol levels by reducing the absorption of cholesterol in the intestine. Low fiber intake can therefore increase the risk of cardiovascular diseases such as heart disease and stroke.

Impact on weight control: Foods high in fiber tend to be more filling and help control appetite. A fiber deficiency can lead to overeating and excessive weight gain, increasing the risk of obesity and related metabolic disorders.

Increased risk of colon cancer: Dietary fiber has been shown to have protective effects against colon cancer by promoting regular intestinal transit and helping to eliminate toxic substances from the body. Low fiber intake may increase the risk of developing colon cancer. (Cummings et Stephen, 2007)

According to the recommendations of the World Health Organization (WHO), it is essential to integrate dietary fibers into our daily diet to promote optimal health. For adults, this typically translates to a daily intake of 25 to 30 grams of fiber. For children, the amounts vary depending on age, but generally range between 14 and 31 grams per day. During pregnancy or breastfeeding, needs may be slightly increased to meet heightened nutritional requirements. It is crucial to remember that these recommendations are general and individual needs may vary depending on various factors such as physical activity level and overall health. To achieve these fiber goals, it is recommended to consume a variety of fiber-rich foods, including fruits, vegetables, legumes, whole grains, nuts, and seeds. By following these guidelines, you can help maintain a healthy digestion and promote better overall health.

Here is the table 4 detailing the daily fiber needs for different age groups:

Table 4. Daily fiber needs according to age.

Age Group	Fiber Needs (grams/day)
Children	
1 to 3 years	Approximately 19 g
4 to 8 years	Approximately 25 g
9 to 13 years	Approximately 26 to 31 g
Adolescents	
14 to 18 years	
Boys	Approximately 38 g
Girls	Approximately 26 g
Adults	
Men	Approximately 38 g
Women	Approximately 25 g
Pregnant and Nursing Women	

Source. World Health Organization. "Carbohydrates in Human Nutrition. Report of a Joint FAO/WHO Expert Consultation." Rome: Food and Agriculture Organization of the United Nations; 1998.

PART II: EXPERIMENTAL STUDY

CHAP III: MATERIALS AND METHODS

III.1. Sampling and Study Framework

Our samples were collected in different regions of Burundi depending on their availability. They have been harvested in four provinces: NGOZI, GITEGA, KAYANZA and CIBITOKE.

All samples were collected in these four provinces that we have just cited above. The samples are the 5 plants that are the subject of our research, which are *Dioscorea alata*, *Dioscorea bulbifera*, *coleus dysencericus*, B*asera alba*, and *Sechium edule.*

All samples were conducted to the ISABU soil and agricultural products analysis laboratory located in Bujumbura.

III.2. Sample preparation

Arriving at LASPA at ISABU, the *Basera* leaves were put in an oven to be dried at a temperature of 105°C for 72 hours then reduced to powder by grinding as recommended by the international method AOAC 922.02, 21st Edition, 2019.

Following the same methods, the yam tubers were peeled, then dried in an oven set at 105°C and reduced to powder by grinding.

The pretreatment of samples of chayotes, bulbufera and the Jerusalem artichoke variety was carried out following the same principle in order to obtain a very fine powder favoring analysis.

III.3. Laboratory equipment

Table 5 below displays the laboratory equipment utilized in conducting my study :

Table 5. Laboratory Equipment

Appliances and glass	Reagents
➢ Distiller ➢ Precision balance ➢ Test tube ➢ Graduated burette ➢ Beaker ➢ Graduated cylinder ➢ Oven ➢ Bunsen burner ➢ Atomic absorption spectrometer ➢ Etc……	➢ Distilled water ➢ Sodium hydroxide ➢ Boric acid solution ➢ Sulfuric acid solution ➢ Methyl red ➢ Lanthanum solution 0.2% in distilled water ➢ Stock solution of KH2PO4 at 100γ/ml (43.9mg/100ml) ➢ Ammonium meta vanadate solution (20ml of distilled water + 20ml of concentrated HNO3 + 0.125mg of ammonium meta vanadate, reduced to 50ml with distilled water) ➢ Ammonium molybdate solution (10mg of ammonium heptamolybdate + 40ml of lukewarm water, reduced to 100ml with distilled water ➢ Hydrochloric acid at 25% (W/W) in the ED ➢ Hydrochloric acid solution at 1.128% (W/V) ➢ CARREZ I solution: 21.9g of zinc acetate Zn[CH3COOH]2.2H2O and 3g of glacial acetic acid are dissolved in the ED, reducing the volume to 100ml ➢ CARREZ II solution: 10.6g of Ferro potassium cyanate K4[Fe(CN)6], 3H2O dissolved in ED then made up to 100ml with ED. - Ethanol at 40% (V/V) ➢ ➢ Etc……

III.4. Physico-chemical analysis methods

III.4.1. Determination of moisture content

Operating mode.

According to the AOAC method (2019), the samples are weighed (PO) using a precision balance such as SARTORUIS BP310S, Gottingen, West Germany.

To carry out our analyses, 5g of each sample were exactly weighed in a porcelain crucible after tareing the empty and numbered crucible. It was placed in an oven at 105°C for 72 hours. The crucible was then taken out of the oven and brought to room temperature in a desiccator and then weighed again.

Expression of results

The dry matter (DM) expressed as a percentage (%) is given by the following relationship:

DM = (P3-P1) /(P2-P1) X100

P1: Tare weight (g)

P2: tare weight + fresh sample (g)

P3: Tare weight + dried sample (g)

The moisture content (H) expressed as a percentage (%) is given by the relationship:

H (%) = 100% - M.S (%)

III.4.2. Determination of mineral elements

While referring to the analysis method AOAC 975.03, 21st Edition, 2019, the minerals were determined by Atomic Absorption Spectrometry.

To do this, 2 g of each sample were each weighed in a porcelain crucible. The crucibles were placed in the oven at 450°C for 24 hours. These crucibles were allowed to cool to room temperature in a desiccator. Afterwards, 5 ml of HNO_3 per gram of material initially weighed was poured into the crucibles. Then 10 ml of distilled water was added.

We brought it to the oven until it boiled and then left it to digest for 30 minutes in a sand bath. It was removed and filtered on a Whatman No. 42 filter without ash in a 100 ml volumetric container.

The volume gauge was then brought to volume with distilled water. The filter and crucible were rinsed several times with distilled water.

We have a standard solution at 1000 ppm of Mg, K, Fe, Zn, Co, Cu, Zn and Ni. A 10 ppm solution was prepared by pipetting 1 ml into a 100 ml volumetric container. It was brought to volume with distilled water.

We then pipetted 5; 10 and 20 ml of the 10 ppm solution in a 100 ml volumetric flask and 10 ml of 10% $LaCl_3$ were added. It was brought to volume with distilled water. We zeroed the device and proceeded with the analysis.

The concentration for a mineral element (ppm) is given by the following relationship:

$ZYV/100 * 100/X = ZYV/X$

Where X: weight of the weighed sample (g)

V: volume after filtration (ml)

Y: Dilution

Z: Concentration of the test portion (mg/l)

III.4.3. Determination of total fiber content.

Our research is limited only to the determination of total fibers without taking into consideration the concentration of each type of fiber. The method we used for the determination of fibers is the manual Weende method described by the Livestock and Veterinary Medicine Industry of Tropical Countries, due to the fact that the automatic one is not maintained in this laboratory.

Principle of the method

The sample is subjected to two successive attacks, acidic then alkaline. The residue is then dried and then calcined. The weight loss resulting from calcination corresponds to the fibers of the test portion.

Table 6. Apparatus and reagents

Appliances and glass	**Reagents**
➢ Heating ramp ➢ 800ml beaker high form ➢ Buchner Refrigerants-Filters ➢ Filter paper ➢ etc.	➢ Sulfuric acid (H2SO4) concentrated 0.26N ➢ Sodium hydroxide 0.23 N ➢ Demineralized water

Procedure (AOAC930.10, 21st Edition)

Weigh 1 g of the sample, transfer it to an 800 ml beaker, add 100 ml of a 0.26N H2SO4 solution. Bring to the boil under refrigerant for 30 minutes, filter the contents of the beaker through hardened filter paper (Durieux 144). Rinse thoroughly with demineralized water. Return the filter containing the residue to the 800 ml beaker.

Add 100 ml of 0.23N KOH, bring to the boil for 30 minutes under refrigeration.

Remove the filter paper from the beaker, wash it thoroughly to remove all particles. Then filter through the previously tared filter paper (p) Durieux (111). Rinse with plenty of water then with acetone. Dry in the oven for 12 hours at 103oc and weigh (p1).

Place the filter containing the dry residue in a porcelain crucible, and calcine at 520°C for 4 hours. Weigh the ashes after cooling using one hand.

Expressions of the results.

W : weight of empty filter

W1 : weight of filter + dry residue + crucible

W2 : weight of ashes + crucible

W3 : crucible weight

Total fibers Fibres $= \frac{(W1-W-W3)-(W2-W3)}{sample\ weight} X100\%$

III.4.4. Analysis of the results

The laboratory analysis results allowed us to have the basis of data. The results were analyzed using three software programs EXCEL, STATA and SPSS. The various statistical tests helped us interpret the results. The Bartlett test helped us determine whether the variance between the means of the contents of the different samples is significant or not.

The anova test allowed us to see whether the averages of the contents of the parameters analyzed in the different products are significant or not.

The comparison of the values of each parameter was carried out using the Bonferroni test.

The Excel software generated a histogram which allowed us to see the extent of the contents of the different parameters studied.

CHAP IV. PRESENTATION AND DISCUSSIONS OF ANALYSIS RESULTS

IV.1. Presentation and general overview of the results obtained

The table 7 shows the values of the parameters analyzed in the different samples.

Table 7. Water content of the studied foods.

Food	**% in water**
Dioscorea alata	79.5%
Dioscorea bulbufera	68.5%
Sechium edule	94.1%
Coleus dysencericus	63%
Basera alba	91,70%

This table shows that chayote has a lower dry matter compared to other foods.

The table 8 presents the composition of parameters in the samples analyzed

Table 8. Content of parameters in the samples studied

Description of samples	**Ca, mg/kg**	**Mg, mg/kg**	**Na, mg/kg**	**K, mg/kg**	**Fe, mg/kg**	**Fibers, %**
Diascorea alata (Yam) from NGOZI	383	456,33	111	6644	35,8	3, 05
Diascorea alata (Yam) from GITEGA	385	458,51	104	6623,7	36,3	3, 07
Diascorea alata (Igname) from KAYANZA	389,7	457,46	112,7	6645,6	34,9	3, 02
Diascorea alata (Yam) from CIBITOKE	383,6	459,45	111,8	6645,9	35,1	3, 04
Diascorea bulbifera (Amatugu) from NGOZI	1240	3332	58,5	18301	510	5,97
Diascorea bulbifera (Amatugu) from GITEGA	1238,5	3337,8	58,8	18303,2	511,3	5,98
Diascorea bulbifera (Amatugu) from KAYANZA	1239	3336,3	57	18283	511,4	5,93
Diascorea bulbifera (Amatugu) from CIBITOKE	1247,3	3339,8	59,3	18311,4	514, 5	5,95
Seshium edule (Chayote) from NGOZI	1075	1815	71,7	21841	210	9,41
Seshium edule (Chayote) from GITEGA	1075,3	1813,2	71,9	21840,4	211,7	9,45
Seshium edule (Chayote) from KAYANZA	1074	1813,5	71,7	21842,5	209,6	9,37
Seshium edule (Chayote) from CIBITOKE	1081,3	1819,7	72,4	21845,6	213,5	9,42
Coleus dysencericus (inumpu) from NGOZI	437	2048h	109	7182	137	1,53
Coleus dysencericus (inumpu) from GITEGA	436,3	2047,5	108,6	7181,7	137,2	1,54
Coleus dysencericus (inumpu) from KAYANZA	437,2	2048	108,9	7183	136,8	1,53
Coleus dysencericus (Jerusalem artichoke) from CIBITOKE	438,3	2051,3	111,3	7184	138,2	1,52
Basera alba (Inderama) from NGOZI	10490	7730	182	58591	3783	12,7
Basera alba (Inderama) from GITEGA	10487	7729	181,4	58590,3	3782,1	12,71
Basera alba (Inderama) from KAYANZA	10491	7731,2	179,9o	58591,2	3782,6	12,68
Basera alba (Inderama) from CIBITOKE	10492	7732	182,3	58592,4	3784,5	12,72

According to these results founds, the test done by SPSS shows that the difference between elements of the same group of product is no significant.

As the samples were collected in four provinces, it was convenient to determine the average value of the contents of each parameter in the 5 samples analyzed.

The table 9 shows the average concentration value of each sample.

Table 9. Average value of the contents of the samples collected in the four provinces.

Description of samples	Ca, mg/kg	Mg, mg/kg	Na, mg/kg	K, mg/kg	Iron, mg/kg	Fibers , %
Dioscorea alata	299,075±86,8	251,68±119,05	109,87±1,98	6639,8±5,38	35,52±0,32	3,04±0,010
Dioscorea bulbufera	1241,2±2,05	3336,47±1,65	58,4±0,49	18299,65±5,98	511,8±0,95	5,95±0,011
Sechium edule	1076,4±1,65	1815,35±1,50	71,925±0,16	21842,375±1,16	211,2±0,89	9,41±0,016
Coleus dysencericus	437,2±0,41	2048,7±0,87	109,45±0,62	7182,675±0,52	137,3±0,31	1,53±0,004
Basera alba	10490±1,08	7730,55±0,66	181,4±0,53	58591,22±0,43	3783,05±0,51	12,702±0,008

The anova test allowed us to conclude that the average contents of each parameter for the 5 samples are significant because P-value is less than 5%.

The figure 9 shows the magnitude of the concentrations of the parameters studied.

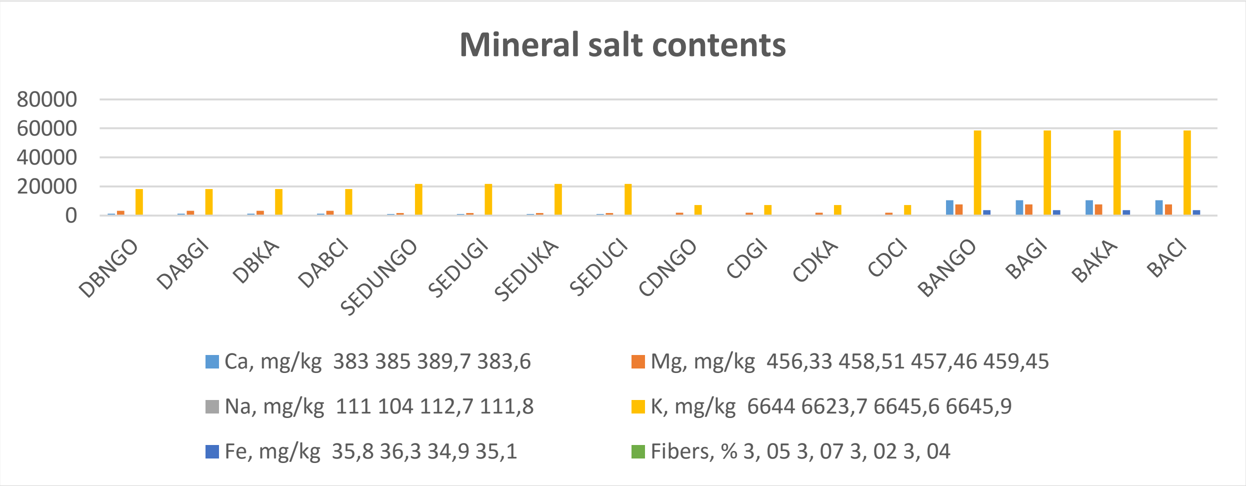

Figure 9.Mineral salt contents

IV.2. Discussions of the results

IV.2.1. Calcium

As shown in average value of the contents of the samples collected in the four provinces and on the histogram, the average calcium content is 299.075 mg/Kg for *Dioscorea alata*, 1241.2 mg/kg for *Dioscorea bulbufera,* 1076.4 mg/kg for *Sechium edule,* 437.2 mg/kg for *Coleus dysencericus* and 10490 mg/kg of *Basera alba.* It is shown that *Basera alba* is more concentrated in calcium than other plants. The calcium concentration of plants depends on the nature of the soil where they grow (Supriya A,2014).

It was found that the calcium content in yams is lower than that of other samples studied as shown in the table of averages. However, according to the World Health Organization adults aged 19 to 50, including pregnant and lactating women, need 1,000 mg of calcium per day, and people over 50 need a daily intake of 1,200 mg. The consumption of these plants will contribute to the supply of calcium in the body.

IV.2.2. Magnesium

The results of the magnesium content are summarized in the table 9. For the Magnesium content, there is a significant difference ($P < 0.05$) between the samples depending. Indeed, the magnesium content of *Dioscorea alata* is 251,68 mg/kg, 3336. 47mg/kg of *Dioscorea bulbufera,* 1815.35mg/kg of chayote, 2048.7mg/kg of *Coleus dysencericus* and 7730.55mg/kg of *Basera alba.* These results are comparable to those reported by Wu et al. (2016) who found 253mg/kg of yams, 3342.27mg/kg of *Dioscorea bulbufera,* 1813.5g/kg of chayote, 2038.9mg/kg of *Coleus dysencericus* and 7736.55mg/kg of *Basera alba.* Then, basera is a high content plant in magnesium than other plants.

IV.2.3. Sodium

The average value of sodium content is 109.875mg/kg for yams, 58.4mg/kg of Dioscorea *bulbufera*, 71.925mg/kg of *Sechium edule,* 109.45mg/kg for *Coleus dysencericus* and 181.4 mg/kg of *Basera alba* This value is close to that found by Dansi A. in 2003 who found a content of 107.4mg/kg of yams 57.3g/kg of *Dioscorea bulbufera*, 73gm/kg of *Sechium edule,* 109.45mg/kg of *Coleus dysencericus,* and 186.6 mg/kg. (Dansi A., 2003).The annova test showed a significant value of this average. Then *Basera alba* is a high content in sodium.

IV.2.4. Potassium

The average result of potassium content in yams harvested in the four provinces is 6639.8 mg/kg and are confirmed as statistically different. This is shown by a p-value less than 5% (pv≤5%). The analysis results show that yam has a high potassium content compared to other minerals analyzed.

Compared to cassava roots which contain 271 mg/kg of potassium (Salvador et al. 2014), found that fresh yam tubers contain this mineral high compared to cassava root.

We found that *Dioscorea bulbifera* is 18299.65mg/kg content in potassium, 21842.375mg/kg of *Sechium edule,* 7182.675mg/kg of *Coleus dysencericus,* 58591.22mg/kg of *Basera alba*

Basera alba is higher content in potassium than other plants.

IV.2.5. Iron

The average results obtained for iron are on average 35.525 mg/kg of *Dioscorea alata,* 511.8mg/kg of *Dioscorea bulbufera,* 211.2mg of *Sechium edule,* 137.3mg/kg of Coleus dysencericus, 3783. 05mg/kg of *Basera alba*. The means are statistically different because p-Value is less than 5%. In fact, the mineral content changes from one soil to another. These results are somewhat similar to those found by researchers such as Oko and Famurewa, 2015.

IV.2.6. Fibers

The average fiber content in yams is 3.045%, 5.95% of Dioscorea bulbifera, 9.41% of Sechium *edule*, 1.53% of *Coleus dysencericus,* 12.702% of *Basera alba* This means that in 1kg of yams, we find more than 30mg of fiber for yams, 59mg for dioscorea alata etc. According to the WHO, the recommended amount of dietary fiber is between 18 and 40 mg/day. Food based on our studied plants will contribute to providing a considerable quantity of fiber. The value that we found is almost three times lower than that found by TRECHE in 1997 which found a fiber content of 9% of yams. This difference should have been the nature of the soil where the yams grow (TRECHE, 1997)

The figure 11 below shows the Mineral content in all samples

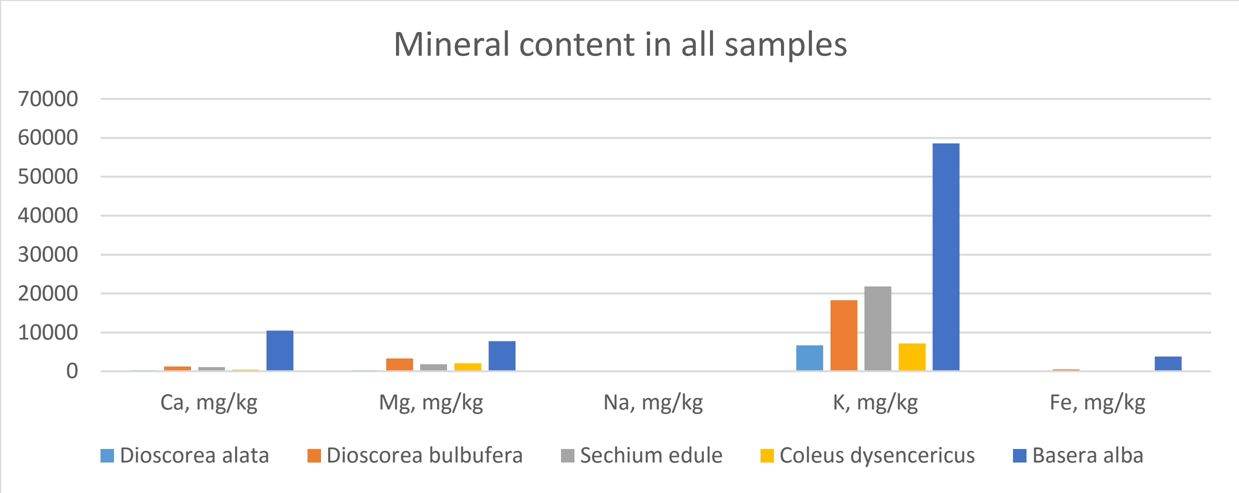

Figure 10.Cumulative of the mineral contents in all samples

The fiber content in all our samples is shown in the following table.

Table 10. Fiber content of all our samples

Description of samples	Fibers , %
Dioscorea alata	3,045
Dioscorea bulbufera	5,9575
Sechium edule	9,4125
Coleus dysencericus	1,53
Basera alba	12,7025

To properly compare the fiber analysis results, a histogram is used

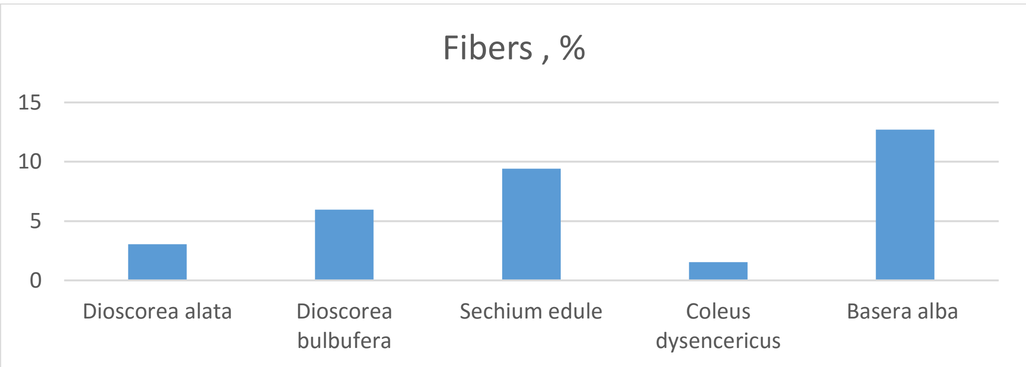

Figure 11. Fiber content of all our samples

The figure 12 shows the comparison of the fiber content of the samples studied and that of other foods

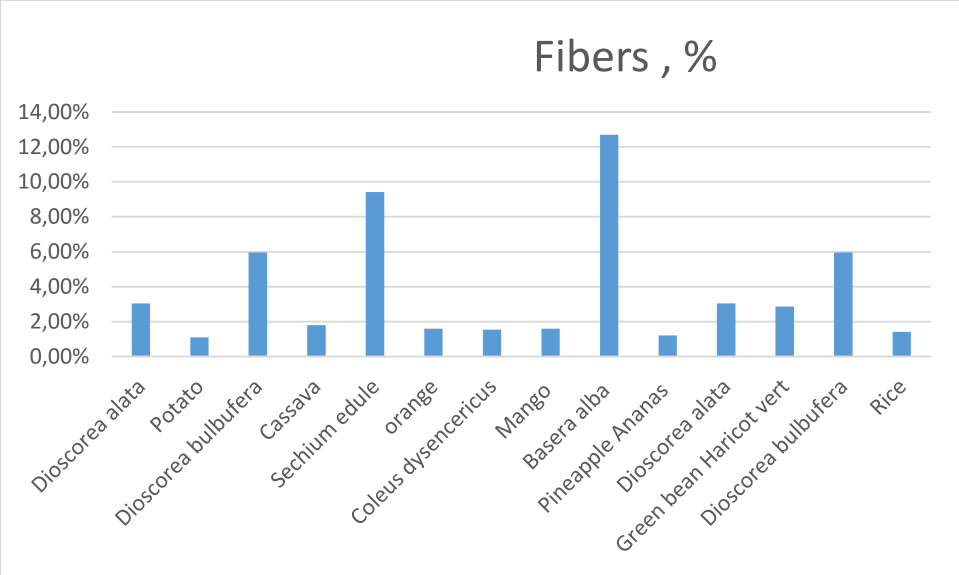

Figure 12.Comparison of the fiber content of the samples studied and that of other foods

This figure shows that the indigenous plants which were the subject of our study have a high fiber content and must be promoted to contribute to the fight against not only diseases of the digestive tract but also.

The STATA software allowed us to determine the daily quantity of each food in our study that a person should consume to meet their mineral needs.

The table 11,12,13,14,15, and 16 are the results of STATA analysing that show the quantity in kilograms of yams that a person should consume to meet the calcium demand based on different groups of people.

Table 11. Quantity in kilograms of foods that a person should consume to meet their calcium needs.

Age	Diocorea alata	Dioscorea bulbufera	Chayote	Coleus dysencericus	Basera alba
0-6 months	0,52	0,16	0,19	0,46	0,02
7-12 months	0,67	0,21	0,24	0,59	0,02
1-3 years	1,82	0,56	0,65	1,60	0,07
4-8 years	2,60	0,81	0,93	2,29	0,10
9-13 years	3,37	1,05	1,21	2,97	0,12
Boys 14-18 years	3,37	1,05	1,21	2,97	0,12
Girls 14-18 years	3,37	1,05	1,21	2,97	0,12
Men 19-50 years	2,60	0,81	0,93	2,29	0,10
Women 19-50 years	2,60	0,81	0,93	2,29	0,10
Men 51+ years	2,60	0,81	0,93	2,29	0,10
Women 51+ years	3,11	0,97	1,11	2,74	0,11
Adolescents Pregnant	3,37	1,05	1,21	2,97	0,12
Adults Pregnant	2,60	0,81	0,93	2,29	0,10
Adolescents Breastfeeding	3,37	1,05	1,21	2,97	0,12
Adults Breastfeeding	2,60	0,81	0,93	2,29	0,10

This table shows that when a breastfeeding woman consumes 100g of basera, she will have already met her daily calcium needs. In contrast, if she consumes 200g of bulbufera, she will have only met a quarter of her daily calcium needs. The table also indicates that basera is richer in calcium compared to the other foods.

The following table shows the quantities of foods to be consumed to meet magnesium needs according to age group.

Table 12. Quantities of foods in kilograms to meet magnesium needs

Age	Diocorea alata	Dioscorea bulbufera	Chayote	Coleus dysencericus	Basera alba
0-6 months	0,07	0,01	0,02	0,01	0,00388
7-12months	0,16	0,02	0,04	0,04	0,00970
1-3 years	0,17	0,02	0,04	0,04	0,01035
4-8 years	0,28	0,04	0,07	0,06	0,01682
9-13 years	0,52	0,07	0,13	0,12	0,03105
Boys 14-18 years	0,90	0,12	0,23	0,20	0,05304
Girls 14-18 years	0,79	0,11	0,20	0,18	0,04657
Men 19-50 years	0,87	0,12	0,22	0,20	0,05174
Women 19-50 years	0,68	0,09	0,17	0,15	0,04010
Men 51+ years	0,92	0,13	0,23	0,21	0,05433
Women 51+ years	0,70	0,10	0,18	0,16	0,04139
Adolescents Pregnant	0,87	0,12	0,22	0,20	0,05174
Adults Pregnant	0,76	0,10	0,19	0,17	0,04527
Adolescents Breastfeeding	0,79	0,11	0,20	0,18	0,04657
Adults Breastfeeding	0,68	0,09	0,17	0,15	0,04010

For infants and young children, meeting daily magnesium needs is crucial for their growth and development:

- **Children aged 0 to 6 months:** It is recommended that they consume at least 10 grams of bulbufera daily to meet their magnesium requirements.
- **Babies aged 7 to 12 months:** A daily intake of at least 9.7 grams of basera is advised to fulfill their magnesium needs.

The following table shows the quantities of foods to be consumed to meet sodium needs according to age group.

Table 13. Quantities of foods in kilograms to meet sodium needs

Age	Diocorea alata	Dioscorea bulbufera	Chayote	Coleus dysencericus	Basera alba
0-6 months	1,09	2,05	1,67	1,10	0,66152
7-12months	3,37	6,34	5,14	3,38	2,03969
1-3 years	9,10	17,12	13,90	9,14	5,51268
4-8 years	10,92	20,55	16,68	10,96	6,61521
9-13 years	13,65	25,68	20,86	13,70	8,26902
Boys 14-18 years	13,65	25,68	20,86	13,70	8,26902
Girls 14-18 years	13,65	25,68	20,86	13,70	8,26902
Men 19-50 years	13,65	25,68	20,86	13,70	8,26902
Women 19-50 years	13,65	25,68	20,86	13,70	8,26902
Men 51+ years	13,65	25,68	20,86	13,70	8,26902
Women 51+ years	13,65	25,68	20,86	13,70	8,26902
Adolescents Pregnant	13,65	25,68	20,86	13,70	8,26902
Adults Pregnant	13,65	25,68	20,86	13,70	8,26902
Adolescents Breastfeeding	13,65	25,68	20,86	13,70	8,26902
Adults Breastfeeding	13,65	25,68	20,86	13,70	8,26902

To meet a quarter of their daily sodium needs, a child aged 0 to 6 months would need to consume at least 150 grams of basera. However, it's important to note that a balanced diet should be varied. Mineral intake should come from a variety of foods, including fruits and vegetables, to ensure a diverse and healthy nutrient intake.

The following table shows the quantities of foods to be consumed to meet potassium needs according to age group.

Table 14. Quantities of foods in kilograms to meet potassium needs

Age	Diocorea alata	Dioscorea bulbufera	Chayote	Coleus dysencericus	Basera alba
0-6 months	0,06	0,02	0,02	0,06	0,00683
7-12months	0,13	0,05	0,04	0,12	0,01468
1-3 years	0,30	0,11	0,09	0,28	0,03413
4-8 years	0,35	0,13	0,11	0,32	0,03926
9-13 years	0,38	0,14	0,11	0,35	0,04267
Boys 14-18 years	0,45	0,16	0,14	0,42	0,05120
Girls 14-18 years	0,35	0,13	0,11	0,32	0,03926
Men 19-50 years	0,51	0,19	0,16	0,47	0,05803
Women 19-50 years	0,39	0,14	0,12	0,36	0,04438
Men 51+ years	0,51	0,19	0,16	0,47	0,05803
Women 51+ years	0,39	0,14	0,12	0,36	0,04438
Adolescents Pregnant	0,39	0,14	0,12	0,36	0,04438
Adults Pregnant	0,44	0,16	0,13	0,40	0,04950
Adolescents Breastfeeding	0,39	0,14	0,12	0,36	0,04438
Adults Breastfeeding	0,44	0,16	0,13	0,40	0,04950

These findings suggest that for a child aged 1 to 3 years:

- Consuming at least 90 grams of chayote meets their daily potassium requirements.
- Alternatively, the child could consume only 30 grams of basera to satisfy the same daily potassium needs.

Both chayote and basera are essential for ensuring the health and well-being of these individuals. Chayote is valuable for providing adequate potassium levels along with being a significant source of nutrients. Similarly, basera is crucial due to its high potassium concentration, offering an effective alternative to meet the recommended daily potassium intake.

The following table shows the quantities of foods to be consumed to meet iron needs according to age group.

Table 15. Quantities of foods in kilograms to meet iron needs

Age	Diocorea alata	Dioscorea bulbufera	Chayote	Coleus dysencericus	Basera alba
0-6 months	0,01	0,00053	1,89	0,00197	0,00007
7-12months	0,31	0,02149	4,07	0,08012	0,00291
1-3 years	0,20	0,01368	9,47	0,05098	0,00185
4-8 years	0,28	0,01954	10,89	0,07283	0,00264
9-13 years	0,23	0,01563	11,84	0,05827	0,00211
Boys 14-18 years	0,31	0,02149	14,20	0,08012	0,00291
Girls 14-18 years	0,42	0,02931	10,89	0,10925	0,00397
Men 19-50 years	0,23	0,01563	16,10	0,05827	0,00211
Women 19-50 years	0,51	0,03517	12,31	0,13110	0,00476
Men 51+ years	0,23	0,01563	16,10	0,05827	0,00211
Women 51+ years	0,23	0,01563	12,31	0,05827	0,00211
Adolescents Pregnant	0,76	0,05275	12,31	0,19665	0,00714
Adults Pregnant	0,76	0,05275	13,73	0,19665	0,00714
Adolescents Breastfeeding	0,28	0,01954	12,31	0,07283	0,00264
Adults Breastfeeding	0,25	0,01758	13,73	0,06555	0,00238

For a pregnant woman, it is important to meet her daily iron requirements to support the growth and development of the fetus as well as to maintain her own health. The mentioned table shows that:

- Consuming at least 7 g of basera meets the daily iron requirements.
- Alternatively, she could consume 52 g of bulbufera to meet the same requirements.

This indicates that basera is much richer in iron than bulbufera, as a smaller amount is needed to reach the recommended intake

The following table shows the quantities of foods to be consumed to meet fibers needs according to age group.

Table 16. Quantities of foods in kilograms to meet fiber needs

Age Group / Population	Diocorea alata	Dioscorea bulbufera	Chayote	Coleus dysencericus	Basera alba
0-6 months	0,62	0,32	0,20	1,24	0,15
1 to 3 years	0,82	0,42	0,27	1,63	0,20
4 to 8 years	1,02	0,52	0,33	2,03	0,24
9 to 13 years	1,25	0,64	0,40	2,48	0,30
Boys 14 to 18 years	0,85	0,44	0,28	1,70	0,20
Girls 14 to 18 years	1,25	0,64	0,40	2,48	0,30
Men more than 18 years	0,82	0,42	0,27	1,63	0,20
Women more than 18 years	0,62	0,32	0,20	1,24	0,15

This table shows that consuming at least 150g of basera should cover the needs of Women more than 18 years in fibers. That interpretation is also applicable to others typs of food

The Student's t-test allowed us to test the richness of our foods in different elements, and thus we used hypothesis tests. The null hypothesis and the alternative hypothesis. According to a comparison test of Student's means, we found the following results for each element: The test hypotheses:

H0: This food is poorer in this element than the other

H1: This food is richer in this element than the other.

We accept H0 if the p-value is greater than 0.05

The following table shows the comparison of means in mineral elements according to the Student's

Table 17. Comparison of the richness of the studied foods in mineral elements

		Ca en mg/kg		Mg en mg/kg		Na en mg/kg		K en mg/kg		Fe en mg/kg		Fibre en %	
		Mean	**Pval**	**Mean**	**Pval**	**Mean**	**Pval**	**Mean**	**Pval**	**Mean**	**Pval**	**Mean**	**Pval**
Dioscorea alata	**Dioscorea bulbufera**	1241.2	1.000	3336.4	1.000	18299	0.000	58.4	1.000	511.8	0.000	5.9875	1.000
	Chayote	1076.4	1.000	1815.3	1.000	21842	1.000	71.925	1.000	211.2	0.000	9.4125	1.000
	Coleus dysencericus	437.2	1.000	2048.7	1.000	7182,6	1.000	109.45	0.422	137.3	0.000	1.53	0.000
	INDERAMA	10490	1.000	7730.5	1.000	58591	0.000	181.4	1.000	3783	0.000	12.7025	1.000
Chayote	**Dioscorea alata**	385.32	0.000	457.93	0.000	6639.8	0.000	109.87	1.000	35.525	1.000	3.045	0.000
	Dioscorea bulbufera	1241.2	1.000	3336.4	1.000	18299	0.000	58.4	0.000	511.8	0.000	5.9875	0.000
	Coleus dysencericus	437.2	0.000	2048.7	1.000	7182,6	0.000	109.45	1.000	137.3	1.000	1.53	0.000
	INDERAMA	10490	1.000	7730.5	1.000	58591	1.000	181.4	1.000	3783	0.000	12.7025	1.000
Dioscorea bulbufera	**Dioscorea alata**	385.32	0.000	457.93	0.000	6639.8	1.000	109.87	1.000	35.525	1.000	3.045	0.000
	CHAYOTE	1076.4	0.000	1815.3	0.000	21842	1.000	71.925	1.000	211.2	0.000	9.4125	1.000
	Coleus dysencericus	437.2	0.000	2048.7	0.000	7182,6	1.000	109.45	1.000	137.3	0.000	1.53	0.000
	INDERAMA	10490	1.000	7730.5	1.000	58591	1.000	181.4	1.000	3783	1.000	12.7025	1.000
Coleus dysencericus	**Dioscorea alata**	385.32	0.000	457.93	0.000	6639.8	0.000	109.87	0.000	35.525	1.000	3.045	1.000
	CHAYOTE	1076.4	1.000	1815.3	0.000	21842	1.000	71.925	0.000	211.2	1.000	9.4125	1.000
	Dioscorea bulbufera	1241.2	1.000	3336.4	1.000	18299	1.000	58.4	0.000	511.8	1.000	5.9875	1.000
	INDERAMA	10490	1.000	7730.5	1.000	58591	1.000	181.4	1.000	3783	0.000	12.7025	1.000
Basera alba	**Dioscorea alata**	385.32	0.000	457.93	0.000	6639.8	0.000	109.87	0.000	35.525	1.000	3.045	0.000
	CHAYOTE	1076.4	0.000	1815.3	0.000	21842	0.000	71.925	0.000	211.2	0.000	9.4125	0.000
	Dioscorea bulbufera	1241.2	0.000	3336.4	0.000	18299	0.000	58.4	1.000	511.8	0.000	5.9875	0.000
	Coleus dysencericus	437.2	0.000	2048.7	0.000	7182,6	0.000	109.45	0.000	137.3	0.000	1.53	0.000

Here we see that yam is lower in calcium compared to the other foods.

Chayotes are higher in calcium than dioscorea alata

Among the other foods, coleus is the richest in calcium.

Among the other foods, basera is the richest in magnesium.

Among the other foods, dioscorea bulbufera is the lowest in potassium.

Among the other foods, coleus is the lowest in fiber.

- **Overview of mineral and fiber intake if a person consumes 200 grams of each food**

Laboratory analysis results are expressed in mg/kg. Realistically, a person cannot consume an entire kilogram of a single food item. A balanced diet is necessary. Therefore, we considered that if a person consumes 200g of one of the foods in our research, they would meet their daily needs.

The Stata software allowed us to generate tables and graphs that show whether the consumption of 200g of one of the foods meets the needs.

Table 18. Magnesium intake from the consumption of 200g of each food.

	Magnesium				
Age	Dioscorea a.	Dioscorea.bu	Chayotte	Coleus d.	Basera a.
0-6 moths	-108,4125	467,295	163,07	1346,11	1346,11
7=12months	-168,4125	407,295	103,07	1286,11	1286,11
1-3 years	-608,4125	-32,705	-336,93	846,11	846,11
4-8 years	-908,4125	-332,705	-636,93	546,11	546,11
9-13 years	-1208,4125	-632,705	-936,93	246,11	246,11
Boys 14-18 years	-1208,4125	-632,705	-936,93	246,11	246,11
Girls 14-18 years	-1208,4125	-632,705	-936,93	246,11	246,11
Men 19-50 years	-908,4125	-332,705	-636,93	546,11	546,11
Women 19-50 years	-908,4125	-332,705	-636,93	546,11	546,11
Men 51+ years	-908,4125	-332,705	-636,93	546,11	546,11
Women 51+ years	-1108,4125	-532,705	-836,93	346,11	346,11
Adolescents Pregnant	-1208,4125	-632,705	-936,93	246,11	246,11
Adults Pregnant	-908,4125	-332,705	-636,93	546,11	546,11
Adolescents Breastfeeding	-1208,4125	-632,705	-936,93	246,11	246,11
Adults Breastfeeding	-908,4125	-332,705	-636,93	546,11	546,11

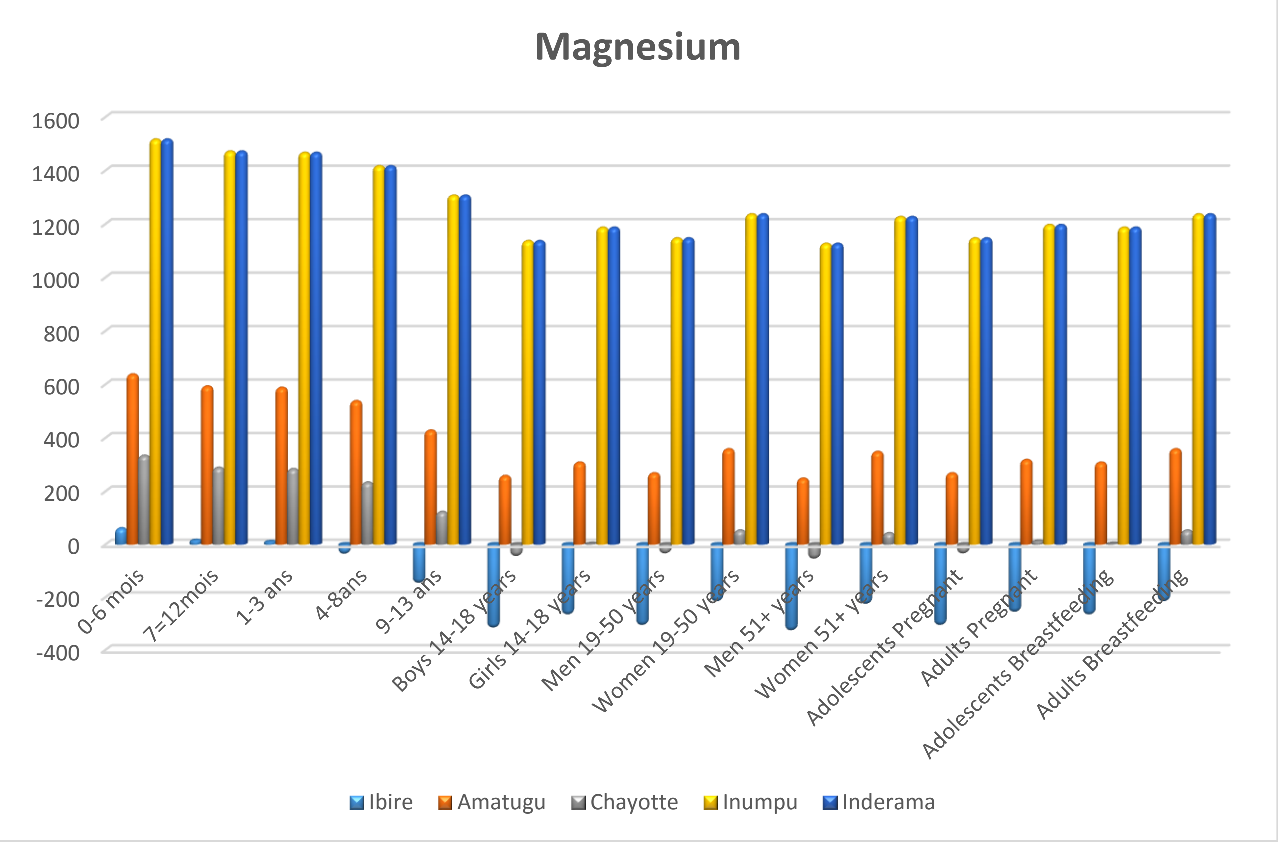

Figure 13.Magnesium intake of 200g from each food

Table 18 and Figure 13 clearly show that Dioscorea alata would provide less magnesium and That consuming 200g of this food cannot meet the calcium needs of each group of people. It is almost the same case for Dioscorea bulbifera and chayote. On the other hand, it is recommended to consume Basella alba, and coleus dysencericus which provide a large amount of potassium, to help fight osteoporosis, hypocalcemia, colon cancer, and cardiovascular diseases.

Sources: Harvard T.H. Chan School of Public Health. "Calcium." Harvard Calcium and Heart Health

Table 19. Calcium intake from the consumption of 200g of each food.

Age	Calcium				
	Dioscorea a.	Dioscorea.bu	Chayotte	Coleus d.	Basera a.
0-6 moths	-122,935	48,24	15,28	-112,56	1898
7=12months	-182,935	-11,76	-44,72	-172,56	1838
1-3 years	-622,935	-451,76	-484,72	-612,56	1398
4-8 years	-922,935	-751,76	-784,72	-912,56	1098
9-13 years	-1222,935	-1051,76	-1084,72	-1212,56	798
Boys 14-18 years	-1222,935	-1051,76	-1084,72	-1212,56	798
Girls 14-18 years	-1222,935	-1051,76	-1084,72	-1212,56	798
Men 19-50 years	-922,935	-751,76	-784,72	-912,56	1098
Women 19-50 years	-922,935	-751,76	-784,72	-912,56	1098
Men 51+ years	-922,935	-751,76	-784,72	-912,56	1098
Women 51+ years	-1122,935	-951,76	-984,72	-1112,56	898
Adolescents Pregnant	-1222,935	-1051,76	-1084,72	-1212,56	798
Adults Pregnant	-922,935	-751,76	-784,72	-912,56	1098
Adolescents Breastfeeding	-1222,935	-1051,76	-1084,72	-1212,56	798
Adults Breastfeeding	-922,935	-751,76	-784,72	-912,56	1098

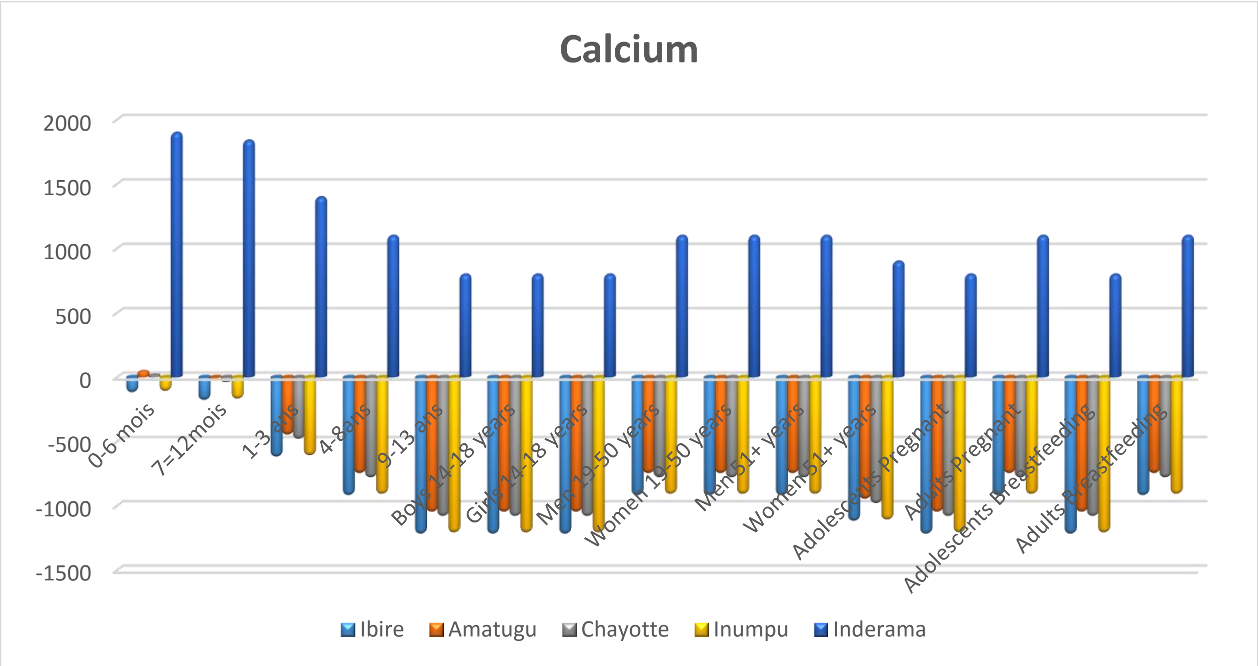

Figure 14.Calcium intake of 200g from each food

"Table 20 and Figure 14 show that only 200 grams of *Basera alba* can meet the calcium needs of populations across all age groups. This proves that *Basera* is richer in calcium than other foods and will contribute to skeletal fortification

Table 20. Potassium intake from the consumption of 200g of each food.

Age	Potassium				
	Dioscorea a.	Dioscorea.bu	Chayotte	Coleus d.	Basera a.
0-6 moths	927,96	3259,93	3968,475	11318,245	11318,245
7=12months	467,96	2799,93	3508,475	10858,245	10858,245
1-3 years	-672,04	1659,93	2368,475	9718,245	9718,245
4-8 years	-972,04	1359,93	2068,475	9418,245	9418,245
9-13 years	-1172,04	1159,93	1868,475	9218,245	9218,245
Boys 14-18 years	-1672,04	659,93	1368,475	8718,245	8718,245
Girls 14-18 years	-972,04	1359,93	2068,475	9418,245	9418,245
Men 19-50 years	-2072,04	259,93	968,475	8318,245	8318,245
Women 19-50 years	-1272,04	1059,93	1768,475	9118,245	9118,245
Men 51+ years	-2072,04	259,93	968,475	8318,245	8318,245
Women 51+ years	-1272,04	1059,93	1768,475	9118,245	9118,245
Adolescents Pregnant	-1272,04	1059,93	1768,475	9118,245	9118,245
Adults Pregnant	-1572,04	759,93	1468,475	8818,245	8818,245
Adolescents Breastfeeding	-1272,04	1059,93	1768,475	9118,245	9118,245
Adults Breastfeeding	-1572,04	759,93	1468,475	8818,245	8818,245

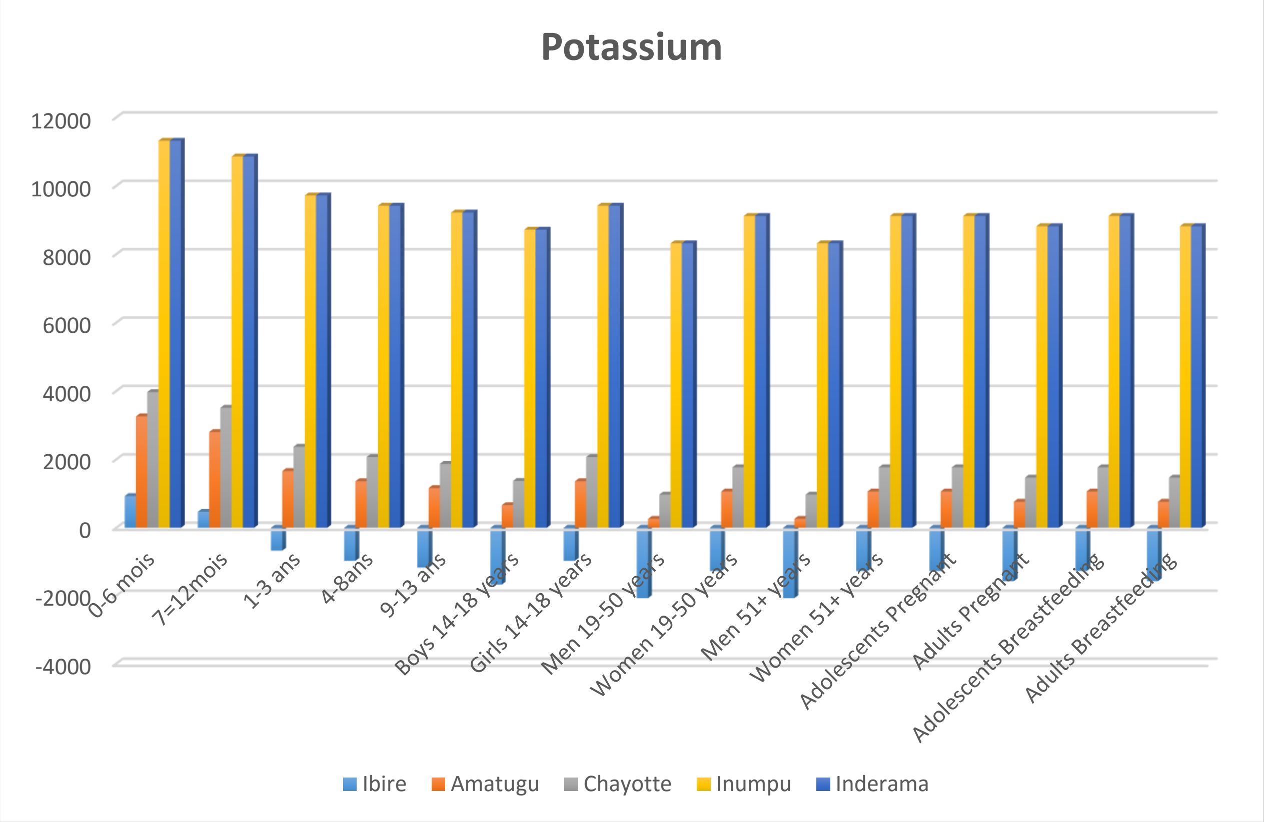

Figure 15.Calcium intake of 200g from each food

Table 20 and Figure 15 clarify that only *Dioscorea alata* does not meet the needs of each age group if 200 grams of this plant are consumed. Thus, the consumption of 200 grams of the other plants studied in our research satisfies the potassium needs of every age group

Table 21. Sodium intake from the consumption of 200g of each food

	Sodium				
	Dioscorea a.	Dioscorea.bu	Chayotte	Coleus d.	Basera a.
0-6 moths	-98,025	-108,32	-105,615	-98,11	-83,72
7=12months	-348,025	-358,32	-355,615	-348,11	-333,72
1-3 years	-978,025	-988,32	-985,615	-978,11	-963,72
4-8 years	-1178,025	-1188,32	-1185,615	-1178,11	-1163,72
9-13 years	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72
Boys 14-18 years	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72
Girls 14-18 years	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72
Men 19-50 years	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72
Women 19-50 years	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72
Men 51+ years	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72
Women 51+ years	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72
Adolescents Pregnant	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72
Adults Pregnant	-1478,025	-1488,32	-1485,615	-1478,11	-1463,72

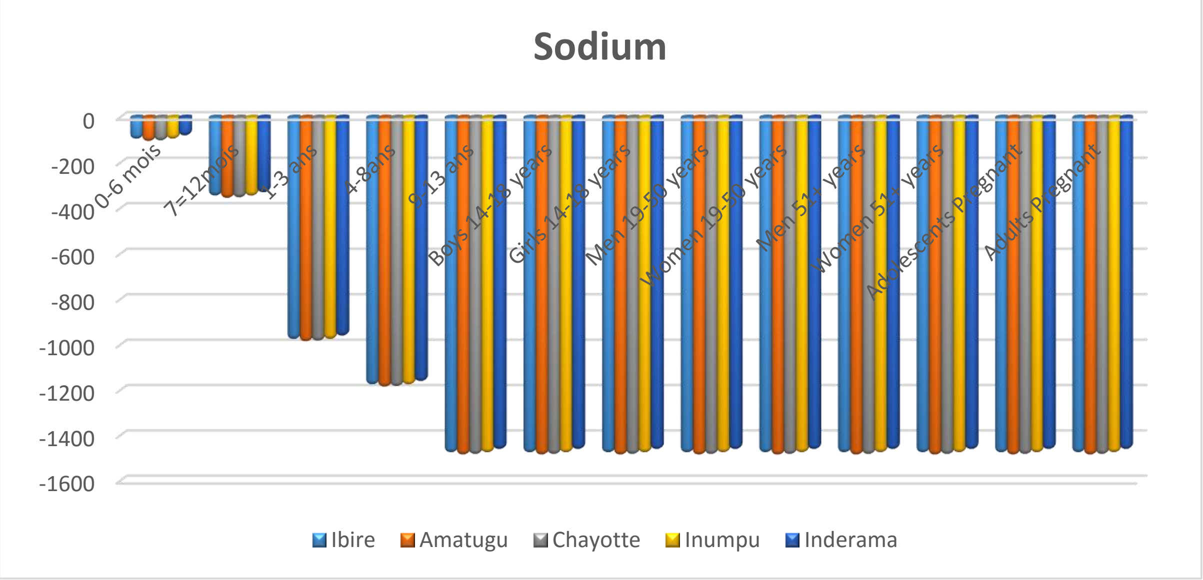

Figure 16.Sodium intake of 200g from each food

Table 21 and Figure 16 highlight the sodium deficiency in our studied indigenous plants. Indeed, if a person of any age group consumes 200 grams of any of these foods, it does not meet the sodium requirements. Therefore, maintaining a varied diet will help fill this gap, indicating that our indigenous foods are low in sodium.

Table 22. Iron intake from the consumption of 200g of each food

Age	Dioscorea a.	Dioscorea.bu	Chayotte	Coleus d.	Basera a.
0-6 moths	6,835	102,09	41,97	27,19	756,34
7=12months	-3,895	91,36	31,24	16,46	745,61
1-3 years	0,105	95,36	35,24	20,46	749,61
4-8 years	-2,895	92,36	32,24	17,46	746,61
9-13 years	-0,895	94,36	34,24	19,46	748,61
Boys 14-18 years	-3,895	91,36	31,24	16,46	745,61
Girls 14-18 years	-7,895	87,36	27,24	12,46	741,61
Men 19-50 years	-0,895	94,36	34,24	19,46	748,61
Women 19-50 years	-10,895	84,36	24,24	9,46	738,61
Men 51+ years	-0,895	94,36	34,24	19,46	748,61
Women 51+ years	-0,895	94,36	34,24	19,46	748,61
Adolescents Pregnant	-19,895	75,36	15,24	0,46	729,61
Adults Pregnant	-19,895	75,36	15,24	0,46	729,61

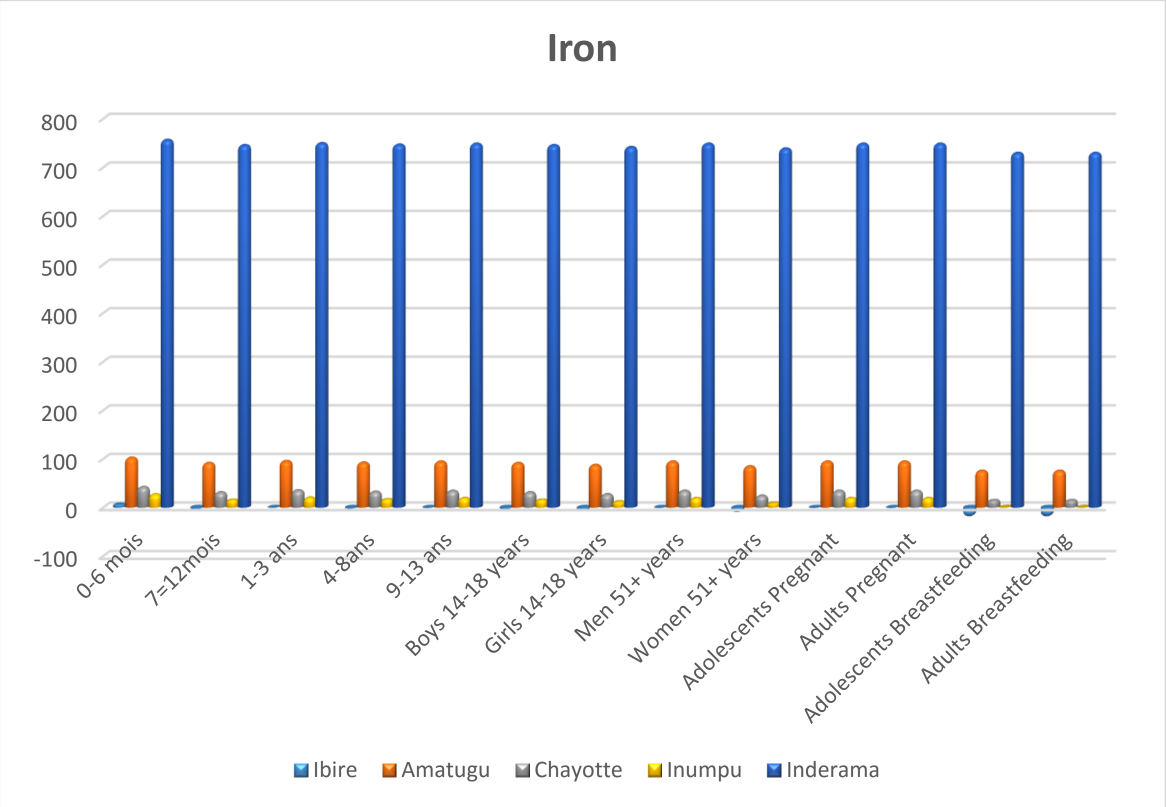

Figure 17.Iron intake of 200g from each food

Table 22 and Figure 17 clearly show that *Basera alba* is very rich in iron. Indeed, consuming 200 grams would exceed the daily iron requirements. On the other hand, only 200 grams of *Dioscorea alata* cannot meet the daily iron needs. However, varied intakes would be necessary to supplement the iron needs in case of consuming *Dioscorea alata*.

It should be noted that in our study, laboratory analysis results and analysis using Stata and SPSS software showed that *Basera alba* consistently contains high levels of all studied elements compared to other foods. Conversely, *Dioscorea alata* shows low levels of these elements.

GENERAL CONCLUSION AND RECOMMENDATIONS

General conclusion

My research showed that dietary fiber is not well known by many researchers. Being non-degradable by digestive enzymes, certain dietary fibers pass intact into the small intestine to continue to the colon in order to produce short-chain fatty acids having positive effects on health. Short-chain fibers act as prebiotics, serving to feed the beneficial bacteria in the digestive tract called probiotics. Our objective was to determine dietary fibers and mineral content in indigenous substrates in Burundi. Five plant species were analyzed, namely Dioscorea alata**,** Dioscorea bulbifera**,** Sechium edule, Coleus dysentericus, and Basella alba. The results showed that Dioscorea alata had a fiber content of 3.045% and mineral levels of 299.075 mg/kg for calcium, 251.6875 mg/kg for magnesium, 6,639.8 mg/kg for potassium, and 35.525 mg/kg for iron. Dioscorea bulbifera had a fiber content of 5.9575%**,** with mineral levels of 1,241.2 mg/kg for calcium**,** 3,336.475 mg/kg for magnesium ; 58.4 mg/kg for sodium, and 511.8 mg/kg for iron. Sechium edule contained 9.4125% fiber, with minerals measured at 1,076.4 mg/kg for calcium, 71.925 mg/kg for sodium, and 21,842.37 mg/kg for potassium**.** Coleus dysentericus had a fiber content of 1.53%**,** with mineral concentrations of 437.2 mg/kg for calcium, 2,048.7 mg/kg for magnesium, 109.45 mg/kg for sodium, and 137.3 mg/kg for iron. Finally, Basella alba had the highest fiber content at 12.7%**,** with mineral levels recorded as 10,490 mg/kg for calcium ; 7,730.55 mg/kg for magnesium, 181.4 mg/kg for sodium, and 3,783.05 mg/kg for iron. The analysis results show that indigenous plants have a significant amount of minerals and a high fiber content compared to other foods widely consumed in Burundi. Raising awareness among the population about the benefits of cultivating and consuming these indigenous plants could significantly help reduce the prevalence of digestive tract diseases such as colon cancer, gastritis, diabetes, and other conditions linked to poor digestion management. The hypotheses of our research were

- Plants indigenous to Burundi contain dietary fibers that can play the role in the fight against gastrointestinal diseases.
- native plants contain minerals that can help in the growth of the intestinal microbiota

All our hypotheses are confirmed by the analysis results and our objectives have been achieved.

Recommendations

This work is far from exhaustive, in fact, there were limitations during our research. Recommendations and suggestions are offered

- **To seek**. To follow suit to continue this subject in order to extract dietary fibers playing the role of prebiotics. This would be the case for inulin, pectins, oligosaccharides, etc., in order to quantify them and know how specific they are due to the fact that we have limited ourselves to the dosages of total fibers.
- **To food manufacturers**. To carry out studies on the formulation of functional foods containing dietary fibers as is done in other countries.
- **To decision-makers**. To take necessary measures to promote research. The lack of specialized laboratories in Burundi and the region hinders the success of sustainable development objectives. Seeing Burundi as an advanced country in 2040 and a developed country in 2060 requires the promotion of the pillars of development which are none other than research facilities.
- **To farmers**, to promote the agriculture of yams, chayote, bulbs, coleus and not to neglect them because they are more important in the organism.

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