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Nutritional Quality of Eleven Leafy Vegetables Consumed in the Malagasy Highlands

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Abstract:

The Malagasy population generally consumes rice with "laoka" as a side dish. A diet that has become an atypical practice, a lifestyle well structured around the very common foods for typical Malagasy dishes. A nutritional analysis enabled us to determine their nutritional composition, and thus the energy intake that these foods can contribute to the proper functioning of the human metabolism for good health. A survey to assess the weekly consumption frequency of leafy vegetables by Tananarivians was carried out in 1,280 households. The constituent elements were then determined using TXRF for each elemental constituent of the solid samples. The macronutrient contents obtained from the analyses of these samples were used to determine overall energy values. Analysis of the extracts showed that most of them contained flavonoids and phenolic compounds respectively. Based on these results, Anatsinahy (Bidens pilosa) was found to be the most lipid-rich of the other brede species. Anamamy (Solanum nigrum) (38.88%) and Anandrano (Nasturtium officinale) (34.28%) are recommended for their high protein content. The carbohydrate content, ranging from 20.85% for Bidens pilosa to 52.69% for leaves of Ypomeas Batatas, could contribute to the nutrition, food security, and health of resource-poor people. The presence of these secondary metabolites in leafy vegetables may explain the particular pharmacological virtues of some of them, such as the alterative, antifungal, anti-inflammatory, antirheumatic, and styptic properties of Bidens pilosa, and the anesthetic, diuretic, digestive, sialagogue, antiasthmatic and antiscorbutic properties of Spilanthes acmella Murr. The presence of tannins, alkaloids, saponins, and flavonoids reported in this study may induce antidiarrheal activity.

Keywords:
Leafy vegetables; mineral micronutrient; macronutrient; phytochemical; nutrition.

I. Introduction

The first shoots of herbaceous plants began just after the creation of the earth, on the 3rd day, according to Genesis 1:11. Having explored fifty-three English versions of the bible available online (https://biblehub.com/parallel/ ; https://www.biblesociety.org.uk/explore-the-bible/which-is-the-best-bible-translation/) such as : (ABPE) Aramaic Bible in Plain English, (AFV) A Faithful Version, (AKJV) American King James Version, (AMP) Amplified Bible, (ARA) Aramaic Bible Translated, (ASV) American Standard Version, (BB° Bishops' Bible of 1568, (BSB) Berean Standard Bible, (BST) Brenton Septuagint Translation, (CB) Coverdale Bible of 1535, (CEV) Contemporary English Version, (CPDV) Catholic Public Domain Version, (CSB) Christian Standard Bible , (DBT) Darby Bible Translation, (DBT) Dialectical Behavioral Therapy ou Christian Overview and Practical Taste of Dialectical Behavioral Therapy, (DRB) Douay-Rheims Bible , (ERV) English Revised Version, (ESV) English Standard Version, (GB) Geneva Bible of 1587, (GNB or TEV) Good News Bible, or Today's English Version, (GNT) Good News Bible Translation, (GWT) God's Word Translation, (HCSB) Holman Christian Standard Bible, (ISV) International Standard Version, (JB) Jerusalem Bible, (JPS) Jewish Publication Society Tanakh 1917, (KJB) King James 2000

Bible, (KJV) King James Bible, (LB) Lamsa Bible, (LSB) Legacy Standard Bible, (LSV) Literal Standard Version, (MSB) Myanmar Standard Bible, (MSG) Message, (NABRE) New American Bible Revised Edition, (NASB) New American Standard Bible, (NET) Bible (New English Translation), (NHEB) New Heart English Bible, (NIRV) New International Readers Version, (NIV) New International Version, (NJB) New Jerusalem Bible, (NKJV) New King James Version, (NLT) New Living Translation, (NRSV) New Revised Standard Version, (NRSV) New Revised Standard Version, (PHBT) Peshitta Holy Bible Translated, (REB) Revised English Bible, (RSV) Revised Standard Version, (SLT) Smith's Literal Translation, (TB) Tyndale Bible of 1525, (TLB) The Living Bible, (WBT) Webster's Bible Translation, WEB, here are the terms used: vegetable(s) ((ירקות(ים) yarkot), pulse (הדופק hadopek, pod vegetables), roots (שורשים shorashim), potage (פוטאז' photase'), seed herbs (זרעים מרפא צמחי' tsmaki marpa zeraim), herb (עשב eshev) , grains (גרגרים grains), and green plant (ירוק צמח tzmah yarok). Our study is focused on herbaceous plants, the grains were done in the article entitled "A selection of Phaseolus vulgaris bean varieties to explore their nutritional quality from the dawn of creation to the science and technology of the modern world" (Robijaona Rahelivololoniaina, 2023). Today, after traveling the earth, these seeds have found their way to America, Europe, and Asia. These vegetables have evolved over time, and are very different from their wild ancestors, which people picked in the wild. Hybridization and cross-breeding have given rise to a huge diversity of varieties. The vegetables we are familiar with today are the result of thousands of years of evolution and domestication. (Aramrueang et al., 2019)

It would make sense to go back to the source because Malagasy have Jewish origin (Ramilison, 1951; Raombana 1809-1855) and explore these leafy greens to deal with the collateral damage of climate change. The cumulative effects of climate change are detrimental to all dimensions of food security (availability, access, utilization and stability). Nutrition is highly sensitive to climate change, and pays a heavy price in terms of reduced nutrient quality and diversity of food produced and consumed.

Eating sufficient quantities of high-quality leafy vegetables can help to ensure good health and prevent various chronic diseases. Their richness in trace elements, vitamins and phytocompounds is a boon in developing countries such as Madagascar, where these traditional vegetables can help solve a number of public health problems.

These types of food have always been part of the Malagasy population's diet. They are frequently eaten cooked or raw, most often as an accompaniment to rice. They are of economic and social importance due to their relatively low cost, and their accessibility to the majority of households. In addition, thanks to their nutritional value in terms of minerals, vitamins, proteins and fiber, leafy vegetables are classified as foods of considerable nutritional value (Barba et al., 2014).

Some varieties of leafy vegetables have been studied for adaptation and resilience in the face of malnutrition, global warming, poverty and pandemics. Could these leafy vegetables commonly consumed by the Malagasy contribute to coping with these hazards?

Hippocrates said: your food is your medicine. Is this still true of leafy greens? Are they still medicines, nutraceuticals, nutricaments? Determining their micro-nutrients (minerals and trace elements by TXRF) and macro-nutrients (nutritional values) as well as their molecular families will determine what these leafy greens can contribute to the dilemma of poverty, global warming and pandemics.

II. Review of Literature

The Malagasy daily menu generally consists of a rice dish eaten with "Laoka", an accompaniment to the rice. Laoka" refers to a very diverse collection of edible leaves from numerous plants belonging to the leafy vegetable group, which are cooked before being eaten.

Leafy vegetables are commonly found in the diets of many populations around the world, particularly the underprivileged (De Herforth et al.,, **2020**). In developing countries, they represent an inexpensive food source of high nutritional quality, especially for the poor segment of the population affected by malnutrition.

They play an important role from a nutritional and medical standpoint, as they are generally rich in minerals and vitamins. (**Randrianatoandro et *al.*, 2010 ; Smith et *al.*, 2007 ; Kahane et *al.*, 2005 ; Tarwadi and Agte, 2003**).

A survey of 1,280 Malagasy households in the city of Antananarivo, conducted by Rafalimanana (2008), provides information on the frequency of consumption of leafy vegetables per week.

Table 1. Frequency of consumption of 10 leafy vegetables by Tananarivians (Survey of 1,280 households)

Leafy vegetables	Frequency per week	
	Number of households	Pourcentage (%)
Ravimbomanga (Leaves of *Ypomeas batata*)	613	47,89
Tissam (*Brassica chinensis*)	593	46,33
Petsay (*Brassica pekinensis*)	565	44,14
Anatsonga (*Brassica juncea*)	511	39,92
Anamamy (*Solanum nigrum*)	500	39,06
Ramirebaka (*Brassica rapa pekinensis*)	420	32,81
Anandrano (*Nasturtium officinale*)	386	30,16
Ravitoto (leaves of *Manihot esculenta*)	374	29,22
Salade de laitue (*Lactua sativa* L.)	322	25,16
Anamalaho (*Spilanthes acmella* Murr.)	308	24,06

Source : (Rafalimanana, 2008)

There are three ways to cook in Madagascar:

- **« *ro* »** (bouillon), the leafy vegetables cook and remain in a large quantity of cooking water.
- **« *ketsaketsa* »**, the leafy vegetables are cooked in water with a little oil, and the cooking water is then partially evaporated.
- **« *ritra* »**, the leafy vegetables are cooked in water with a little oil, the cooking water is then completely evaporated.

For most species, it's the young shoots and leaves that are used to prepare the dishes; the hard parts are generally discarded. Dishes based on leafy vegetables can be prepared from a single variety or a combination of several leafy varieties.

The leafy vegetables in this study are: Ravimbomanga (leaves of *Ypomeas batatas* . of the Convolvulaceae family), Tissam (*Brassica chinensis* of the Brassicaceae family*)*, Petsay (*Brassica pekinensis* of the Brassicaceae family), Anatsonga (*Brassica juncea* of the Brassicaceae family*)*, Anamamy (*Solanum nigrum*), Anandrano (*Nasturtium officinale* of the Brassicaceae family), Ravimboatavo (*Cucurbita pepo* L. leaves of the Cucurbitaceae family), Anatsinahy (*Bidens pilosa* of the Asteraceae family*)*, Chou de Chine (*Brassica rapa pekinensis* of the Brassicaceae family), Anamalaho. (*Acmella oleracea* or *Spilanthes acmella* Murr. of the Asteraceae family). Ananambo (leaves of *Moringa oleifera* of the Moringaceae family) has been added, as it has been increasingly consumed for some time.

III. Research Method

The leafy vegetables purchased at the market are stored in wicker baskets during transport. They are then washed with water, taking care not to press them too hard to avoid tearing the leaves. After this treatment, the leafy vegetables are drained, then sorted to remove unusable parts such as roots, large stems or other undesirable matter. The leaves were then cut using a stainless steel knife. Finally, the cut leaves were carefully spread out on mats for drying. Only then are the leaves finely ground into vegetable powders. These unitary operations precede the various processes for determining micronutrients, macronutrients and molecular families.

3.1 X-ray fluorescence methods for micronutrient determination

The sample to be analyzed is placed under a beam of X-rays. Under the effect of these X-rays, the atoms making up the sample change from their ground state to an excited state. The excited state is unstable, and the atoms tend to return to their ground state, releasing energy in the form of X-ray photons. Each atom, having its own electronic configuration, will emit photons of its own energy and wavelength. This is the phenomenon of X-ray fluorescence, which is a secondary emission of X-rays, characteristic of the atoms making up the sample. Analysis of this secondary X-ray radiation enables us to determine the nature of the chemical elements present in a sample, as well as their mass concentration.

3.2 Analytical methods for macronutrients and phytochemical families

Analysis of nutritional values using the Kjeldahl method (Kjeldahl, 1983) was carried out at the L.A.C.A.E. (Laboratoire d'Analyse et de Contrôle des Aliments et des Eaux) of the Centre Nationale de Recherches sur l'Environnement (CNRE) in Fiadanana.

a. Determining moisture, proteins, lipids, carbohydrates, ash, energycontent

By using the standard methods of the Association of the Analytical Chemists (AOAC), determination of moisture, ash, and crude fibers (on dry basis) was carried out (AOAC, 2000).

Water is the main constituent of living matter. Determining the moisture content of food is necessary to bring analysis results back to a fixed base, which is dry matter. This dry matter is largely made up of organic matter, which provides the energy required by the human organism (Boussama, 1999).

Moisture content affects a product's processability, shelf life, functionality and quality, so it's vital to determine this parameter accurately.

The nitrogen value was converted to protein by multiplying to a factor of 6.25. The lipid content of the samples was done using the Soxhlet type of the direct solvent extraction method. The solvent used to be petroleum ether (boiling range 40-60°C) (AOAC, 2000 ; Kjeldahl, 1983).

The energy values (kcal/100 g) were determined by multiplying the values of carbohydrates, lipids and proteins by a factor of 4.3, 9.1, and 4.3 respectively, and taking the sum, expressed in kilocalories (Merrill et al., 1973 ; Shad et al., 2013) .

The total carbohydrates were determined by the difference method [100 - (proteins + fats + moisture + ash in percentage)] (Merrill et al., 1973 ; Hussain et al., 2009)

All the proximate values were reported in percentage.

b.Phytochimical screening

Phytochemical screening to determine chemical families at the LCM (Laboratoire de Chimie et de Microbiologie) in Nanisana. (Shaikh and Patil, 2020)

1. Preparation of the various extracts

Aqueous extract: One gram of seed powder or dry evaporation residue of the extract to be tested is diluted in 20 ml of distilled water. The resulting mixture is heated to boiling, then left to cool. The decoctate is filtered, and the filtrate thus obtained constitutes the aqueous extract.

Hydroethanol extract: The powder or dry evaporation residue of the extract, weighing 1 g, is suspended in 10 ml of 75% hydroethanol mixture. The mixture is left to macerate overnight at +4°C, then filtered. The filtrate thus obtained is the hydroethanolic extract.

Chloroform extract: One gram of powder or dry evaporation residue is diluted in 10 ml of chloroform. The mixture is left to macerate overnight, then filtered after stirring. The filtrate constitutes the chloroform solution.

Acid extract: The powder or dry evaporation residue weighing 1 g is macerated overnight in 10 ml 2N hydrochloric acid (HCl). The liquid obtained after filtration of the macerate constitutes the acid extract.

2. Characteristic reactions

Alkaloid detection: Four test tubes are required for this procedure. Each contains 0.5 ml of acid extract. The first three are used for the Mayer, Dragendorff and Wagner tests respectively, while the fourth tube serves as a control.

Mayer test: 4 and 5 drops of Mayer reagent are added to the first tube containing the acid extract. The presence of alkaloids in the extract is demonstrated by the appearance of a precipitate or flocculation after addition of the reagent.

Dragendorff test: In the second tube, 4 to 5 drops of Dragendorff reagent are added to the test extract. The presence of alkaloids in the extract is revealed by the appearance of a precipitate or flocculation.

Wagner test: The formation of a precipitate in the third tube indicates the presence of alkaloids in the extract, after addition of 4 to 5 drops of Wagner's reagent.

Confirmation test: To confirm the presence of alkaloids in the extract, a confirmation test with ethanol is necessary. Alkaloid detection reactions are said to be positive if and only if the precipitate formed in each tube is soluble in 80% ethanol, volume 0.5 ml.

Flavonoid detection: The hydroethanol extract is divided into 4 test tubes. The first serves as a control and the other 3 are used for the 3 tests (Wilstater test, modified Wilstater test, Bate-Smith test).

Wilstater test: 0.5 ml HCl 12.07 N and two or three turns of Magnesium are added to 1 ml hydroethanol extract. The change in coloration is observed: red for flavones, purple for flavonols, purplish red for flavanones and flavanols.

Modified Wilstater test: the experimental protocol is the same, but with the addition of 1 ml distilled water and 1 ml isoamyl alcohol. The color of the upper phase is noted: red for flavones, purple-red for flavonols, purplish-red for flavanones and flavanols.

Bate-Smith test: 0.5 ml of HCl 12.07 N is added to the fourth tube. The solution is heated in a water bath at 100°C for 30 min. After cooling, the appearance of a red to violet-red coloration indicates the presence of leucoanthocyanins.

Tannin detection: Aqueous extract is used for characterization tests. It is divided into 4 test tubes, the fourth of which serves as a control.

Tube n°1: 5 drops of 1% gelatin are added to 0.5 ml of aqueous extract. The appearance of white flocculation indicates the presence of tannins.

Tube n°2: 0.5 ml aqueous extract is tested with 5 drops of salted gelatin. Formation of a precipitate indicates the presence of tannins.

Tube n°3: 5 drops of a methanolic $FeCl_3$ solution are added to 0.5 ml of aqueous extract. These are the colorations:

- blue-green or green-black is due to catechol-type tannins

- bluish-black means the presence of pyrogallol-type tannins
- a negative reaction to salted gelatin accompanied by green or blue-black coloration with FeCl3 is due to the presence of other types of phenolic compounds.

Screening for triterpenes and steroids: The extract used is chloroform extract, which is divided into 4 test tubes, with the fourth tube serving as a control.

Tube n°1 for Salkowski test: the tube is tilted at 45°, then 1 to 2 ml of 4N sulfuric acid (H2SO4) is added. The change in coloration is noted immediately. The mixture is gently stirred and the gradual change in color is noted: a red color indicates the presence of unsaturated sterols.

Tube n°2 for Liebermann-Burchard test: 4 drops of acetic anhydride and 1 ml of 4N H2SO4 are added to 1 ml of chloroform extract. After 1 h, a red-purple ring appears at the interface in the presence of triterpenes, while the upper phase turns blue-green in the presence of steroids.

Tube n°3 for Badjet-Kedde test: a few grains of picric acid are added. The appearance of an orange color is due to lactonic steroids.

Detection of deoxyoses (Keller-Killiani test): To 0.5 ml aqueous extract are successively added 0.5 ml 10% ferric chloride and 0.5 ml glacial acetic acid. The tube is tilted at 45°, then 0.5 ml of concentrated H2SO4 4N is added. The formation of a purple ring at the interface is characteristic of the presence of deoxyoses.

Detection of saponosides: Foam test: a volume of 1 ml of aqueous extract is used, and the tube containing the extract is shaken vigorously for 30s to form a foam. The tube is then placed vertically for 30 min. At the end of this period, if the foam measures 3 cm or more, the test is positive.

Irridoid detection: A few drops of HCl 12.07 N are added to 0.5 ml of aqueous extract. The mixture is placed in a boiling water bath for 30 min. The formation of a precipitate or a dark green color indicates the presence of irridoids.

Anthraquinone detection: 1 ml benzene is added to 0.5 ml aqueous extract. After stirring, the mixture is left to stand. Next, the benzene extract is transferred to a test tube and 0.5 ml ammonia (NH4OH) 25% added. The mixture is stirred. Red coloration of the alkaline phase indicates the presence of anthraquinones.

IV. Result and Discussion

4.1. Results of element determination by X-ray fluorescence

X-ray fluorescence spectrometry or XRF is a non-destructive technique used to quantify the elemental composition of solid and liquid samples.

Table 2. Mineral elements in the leafy vegetables studied

Elements (%)	Ravimbomanga (leaves of *Ypomeas batatas*)	Tissam (*Brassica pchinensis*)	Petsay Brassica rapa *pekinensis*	Anatsonga *Brassica juncea*	Anamamy *Solanum nigrum*	Anandrano *Nasturtium officinale*	Ravimboatavo *Cucurbita pepo* L. leaves	Anatsinahy *Bidens pilosa*	Chou de Chine *Brassica rapa pekinensis*	Anamalaho *Spilanthes acmella*	Ananambo leaves of *Moringa oleifera*
Mg	1,953	2,160	2,157	2,193	1,937	2,213	2,050	2,260	1,953	2,116	2,083
Al	1,380	1,270	0,317	1,047	0,487	0,427	0,377	1,310	0,227	0,361	0,860
Si	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
P	0,137	0,175	0,037	0,183	0,050	0,053	0,053	0,203	0,037	0,029	0,153
S	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,177
K	1,563	4,090	1,517	2,650	0,733	1,543	0,507	2,983	0,957	1,618	4,490
Ca	0,020	0,030	0,010	0,023	0,010	0,020	0,040	0,060	0,020	0,009	0,073

Ti	0,120	0,120	0,120	0,120	0,120	0,120	0,120	0,120	0,120	0,120	0,120
V	0,017	0,025	0,027	0,020	0,013	0,027	0,010	0,027	0,030	0,027	0,067
Cr	0,063	0,090	0,093	0,090	0,097	0,097	0,093	0,073	0,090	0,094	0,063
Mn	0,027	0,000	0,010	0,040	0,007	0,030	0,000	0,000	0,000	0,000	0,000
Fe	0,547	0,500	0,477	0,527	0,473	0,463	0,413	0,710	0,507	0,544	0,670
Co	0,000	0,000	0,000	0,003	0,000	0,000	0,000	0,000	0,000	0,001	0,010
Ni	0,043	0,055	0,047	0,047	0,040	0,043	0,040	0,047	0,050	0,045	0,063
Cu	0,010	0,020	0,020	0,017	0,013	0,013	0,010	0,020	0,020	0,019	0,037
Zn	0,010	0,020	0,020	0,010	0,010	0,013	0,010	0,020	0,017	0,011	0,023
As	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,009	0,010
Se	0,007	0,005	0,003	0,007	0,007	0,003	0,003	0,010	0,003	0,007	0,007
Sn	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sb	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Ag	0,020	0,020	0,020	0,020	0,013	0,017	0,010	0,017	0,020	0,018	0,020
Mo	0,000	0,000	0,000	0,000	0,007	0,000	0,003	0,003	0,000	0,000	0,013
Zr	0,107	0,090	0,077	0,110	0,063	0,083	0,097	0,113	0,087	0,075	0,107
Rb	0,047	0,060	0,047	0,030	0,037	0,040	0,030	0,063	0,067	0,050	0,030
Sr	0,230	0,185	0,100	0,203	0,083	0,147	0,257	0,217	0,107	0,147	0,123
Ba	0,063	0,060	0,060	0,043	0,040	0,057	0,097	0,117	0,050	0,061	0,040
W	0,047	0,050	0,050	0,050	0,050	0,050	0,050	0,050	0,050	0,050	0,063
Ta	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Au(PPM)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,000
Hg(PPM)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Pb	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Cd	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

The detection limit is 0.000 and the error is 0.000 (Table 2). Mineral micronutrients are nutrients that do not provide energy. However, they are essential for the body to function properly. The body needs them in small quantities. They are involved at all functional and structural levels.

The leafy vegetables studied are free from heavy metals such as mercury, lead and cadmium.

The major minerals for which the daily intake is greater than 100 mg, including calcium, magnesium, phosphorus and potassium, are present in all the leafy vegetables analyzed. These leafy greens also contain minor minerals or trace elements (found in trace amounts in the body, which makes them no less important) including Chromium, Copper, Iron, Iodine, Selenium, Zinc and Manganese.

4.2 Macronutrient analysis results for the leafy vegetables studied

Macronutrients such as fats, carbohydrates and proteins provide calories. They provide the most important energy in our diet for the brain and all physical activities.

Dry matter content is calculated from water content. Total lipid, protein, ash and carbohydrate contents are expressed (in grams) per 100 g of dry matter.

Table 3. Summary of nutritional analysis results

Leafy vegetables	Energiy (Kcal/100g)	Moisture (%)	Proteins (%)	Lipids (%)	Carbohydrates (%)	Ash (%)
Ravimbomanga (leaves of *Ypomeas batatas*)	329,69	11,11	24,49	2,33	52,69	9,38
Tissam (*Brassica pchinensis*)	296,57	12,71	33,04	2,69	35,05	16,51
Petsay Brassica rapa *pekinensis*	305,42	13,65	22,70	3,10	46,68	13,87
Anatsonga	296,95	12,49	31,17	2,23	38,05	16,06

Brassica juncea						
Anamamy *Solanum nigrum*	323,68	11,58	38,88	2,64	36,10	10,80
Anandrano *Nasturtium officinale*	304,18	14,65	34,28	2,82	35,42	12,83
Ravimboatavo *Cucurbita pepo* L. leaves	319,80	13,10	32,63	5,96	33,91	14,40
Anatsinahy *Bidens pilosa*	430,71	11,56	30,96	24,83	20,85	11,80
Chou de Chine *Brassica rapa pekinensis*	312,54	12,89	23,83	4,70	43,73	14,85
Anamalaho *Spilanthes acmella*	311,29	12,72	23,50	3,77	45,84	14,17
Ananambo leaves of *Moringa oleifera*	350,32	11,34	29,28	5,20	46,60	7,58

Ravimbomanga (leaves of *Ypomeas batatas*) and Ananambo (leaves of *Moringa oleifera*) have lower moisture contents, ranging from 11.11% to 11.34%. Anandrano (*Nasturtium officinale*) or water cress has the highest moisture content at 14.65%, followed by Petsay (*Brassica pekinensis*) (13.65%) and Ravimboatavo (*Cucurbita pepo* L. leaves) (13.10%). The Anatsinahy (*Bidens pilosa)* has fairly high values, compared with the other species, with lipid contents respectively equal to 24.83%. However, the majority is around 2% and does not exceed 5%. Anatsonga (*Brassica juncea*) has the lowest lipid content at 2.23%. Carbohydrate content ranges from 20.85% for Anatsinahy (*Bidens pilosa)* to 52.69% for Ravimbomanga (leaves of *Ypomeas batatas*).

These results show that the leafy vegetables studied are mainly protein-rich, with levels above 20%, such as Petsay (*Brassica pekinensis*), Anamalaho (*Spilanthes acmella* Murr.), Chinese cabbage (*Brassica rapa pekinensis*), Ravimbomanga (leaves of *Ypomeas batatas*), Ananambo (leaves of *Moringa oleifera*) and Anatsinahy (*Bidens pilosa)*.

Analyses show that Anamamy (*Solanum nigrum*), Anandrano (*Nasturtium officinale*), Tissam (*Brassica chinensis*), Ravimboatavo (*Cucurbita pepo* L. leaves) and Anatsonga (*Brassica juncea*) are the richest in protein, with values ranging from 31.17% to 38.88%.

Anatsonga (*Brassica juncea*) and Tissam (*Brassica chinensis*) have the highest ash contents of the 11 species studied, at 16.51% and 16.06% respectively. They are followed by Anamalaho (*Spilanthes acmella* Murr.) and Chinese cabbage (*Brassica rapa pekinensis*).

4.3 Results of phytochemical screening of leafy vegetables studied

The chemical reaction tests of phytochemical screening focus on the search for chemical groups in the various aqueous, alcoholic and acid extracts. These tests provide information on the plant's chemical composition.

Table 4. Summary of phytochemical screening results for the leafy vegetables studied

Chemical families	Tests	Ravimbomanga	Tissam	Petsay	Anatsonga	Anamamy	Anandrano	Ravimboatavo	Anantsinahy	Chou de Chine	Anamalaho	Ananambo
	Mayer	+	-	-	-	-	+	+	-	-	+	+
Alkaloïds	Wagner	+	-	-	-	-	+	+	-	-	+	+
	Dragendorff	+	-	-	-	-	+	+	-	-	+	+
	Wilstater	+	+	-	+	+	+	+	-	+	-	+
Flavonoids and Leucoanthocyanins	Wilstater modifié	-	-	-	-	-	-	-	-	-	-	-
	Bate Smith	-	-	-	-	-	-	-	-	-	-	-
	Gélatine 1%	-	-	-	-	-	-	-	-	-	+	-
Tannins and polyphenols	Gélatine salée	-	-	-	-	-	-	-	-	-	-	-
	$FeCl_3$(MeOH)	+	+	+	+	+	+	+	+	+	+	+
Anthraquinones	Börnstrager	-	-	+	-	+	-	-	+	-	-	-
Saponins	Foam test	-	-	-	-	-	-	-	-	-	-	-
	Salkowski	-	-	-	-	-	-	-	-	-	-	-
Steroids and Triterpenes	Libermann-Burchard	-	-	-	-	-	-	-	-	-	-	-
	Badjet-Kedde	-	-	-	-	-	-	-	-	-	-	-
Deoxyoses	Keller Killiani	-	-	+	-	-	-	-	+	-	-	-
Irridoids	HCl	+	+	-	+	+	-	+	-	+	-	+

Table 5. Grading scales used for assessments

Notations	Precipitation	Coloration	Moss index
-	Negative	None	0 à 2 cm
+	Low	Low	2 à 4 cm
++	Abundant	Frank	4 à 5 cm
+++	High	Intense	Over 5 cm

Almost all these extracts contain flavonoids and phenolic compounds respectively. Only Anamalaho (Spilanthes acmella Murr.) contains tannins, while Anamamy (Solanum nigrum), Petsay (Brassica pekinensis) and Anatsinahy (Bidens pilosa) contain anthraquinones. Ravimbomanga (leaves of Ypomeas batatas), Ananambo (leaves of Moringa oleifera), Anamalaho (Spilanthes acmella Murr.) and Anandrano (Nasturtium officinale) contain alkaloids.

4.3 Discussion

a. Mineral micronutrients in the leafy vegetables studied

Raw ash contains all the substances that are ingested in the form of minerals or trace elements, and which are decisive for numerous processes in the body.

2 Macronutrients of leafy vegetables studied

Like all plants, leafy vegetables always contain a residual water content, corresponding to bound water. High moisture content means that leafy vegetables need to be stored properly, as they are susceptible to degradation by microbial activity. (Kwenin et al., 2011)

Lipids are a source and reserve of energy for the body's proper functioning, and are also used to synthesize hormones and other necessary substances such as prostaglandins, particularly in the event of increased storage requirements prior to winter. On the basis of these results, Anatsinahy (Bidens pilosa) should be considered when buying and choosing leafy vegetables, bearing in mind that it is rich in lipids compared with other breeds.

Fats are involved in many of the body's vital processes, such as the absorption of fat-soluble vitamins. (Sarker and Oba, 2020).

To cover the body's basic requirements for the development and maintenance of its cells, it is advisable to consume Anamamy (Solanum nigrum) (38.88%) and Anandrano (Nasturtium officinale) (34.28%), given their high protein content.

Carbohydrate levels, which range from 20.85% for Anatsinahy (Bidens pilosa) to 52.69% for Ravimbomanga (leaves of Ypomeas batatas) could contribute to nutrition, food security and health for resource-poor people.

In fact, raw ash contains all the substances that are ingested in the form of minerals or trace elements, and which are decisive for numerous processes in the body. Calcium and phosphorus, for example, are essential for skeletal formation. Sodium, potassium, magnesium and chlorine are involved in metabolic processes, while iron is essential for oxygen transport in the blood.

In addition, the ash content indicates an excellent source of mineral elements in vegetables (Ntuli, 2019), because ash contains inorganic matter, including anions, cations, oxides and salts. (Datta et al., 2019).

3 Phytochemical screening of the leafy vegetables studied

The hydroethanolic and aqueous extracts of the leafy vegetables studied are rich in natural chemical substances due to their diversity.

Phytochemical screening of Ravimbomanga (leaves of Ypomeas batatas), Ananambo (leaves of Moringa oleifera), Anamalaho. (Acmella oleracea) and Anandrano (Nasturtium officinale) leaves revealed the presence of alkaloids with a range of biological activities, including antimicrobial activity.

The presence of these secondary metabolites in leafy vegetables may explain the particular pharmacological virtues of some of them, such as the alterative, antifungal, anti-inflammatory, antirheumatic and styptic properties of Anatsinahy (Bidens pilosa), and the anesthetic, diuretic, digestive, sialagogue, antiasthmatic and antiscorbutic properties of Anamalaho (Spilanthes acmella).

The presence of tannins, alkaloids, saponins and flavonoids reported in this study may induce antidiarrheal activity. The antidiarrheal activity of medicinal plants is due to tannins, alkaloids, saponins and flavonoids. (Kubacey and al., 2012)

Leafy vegetables play an economic role in people's food security strategy, as they are produced and available on the market all year round, even during difficult periods such as a pandemic. These characteristics enable consumers to keep leafy greens in their diet according to their financial situation.

Ravimbomanga (leaves of Ypomeas batatas), Ananambo (leaves of Moringa oleifera), Anamalaho (Spilanthes acmella Murr.) and Anandrano (Nasturtium officinale) contain alkaloids, and alkaloids taste bitter. Would these 4 leafy vegetables be among the bitter breeds to be eaten with unleavened bread, as stated in Exodus 12:8 and Numbers 9:11? Malagasy people are of Jewish origin. In Malagasy culture and tradition, it is highly recommended to eat bitter brèdes from time to time and to drink bitter tambavy (decocted) to diversify dishes and balance good health and well-being. The results of this study vindicate Malagasy culture and tradition.

According to this study, leafy vegetables are rich in nutritional compounds (micronutrients, minerals, macronutrients) and phytochemical families. Could these be the phytochemical treasures that vegans enjoy, just as they did in the time of Adam and Eve at the very beginning of creation, and which they can use to cope with global warming as a form of adaptation and resilience

V. Conclusion

In this study, based on the consumption of leafy vegetables, micronutrient (minerals essential to the body) and calorie-rich macronutrient intakes were determined. he dietary significance for lack of financial resources during the pandemic period and for adaptation and resilience in the face of global warming of leafy vegetable species for nutritional analysis allowed their nutritional compositions, which include proximal analyses (moisture, ash, protein, fat, fiber and carbohydrate), and mineral composition (P, K, Ca, Mg, Fe, Na, Mn, Zn and Cu), to be evaluated. Through their phytochemical composition with families of bioactive molecules, these leafy vegetables have biological properties and can therefore be considered nutricaments or nutraceuticals. The presence of these secondary metabolites in leafy vegetables may explain the particular pharmacological virtues of some of them, such as the alterative, antifungal, anti-inflammatory, antirheumatic, and styptic properties of Bidens pilosa, and the anesthetic, diuretic, digestive, sialagogue, antiasthmatic and antiscorbutic properties of Spilanthes acmella Murr. The presence of tannins, alkaloids, saponins, and flavonoids reported in this study may induce antidiarrheal activity. This contributes to the expansion of nutrient databases and benefits future research on food and human health. They can use to cope with global warming as a form of adaptation and resilience

Determining the need for each nutrient, which varies from one individual to another due to age, sex, level of physical activity or pregnancy in progress, will complete this study at a later date.

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