RESEARCH ARTICLE OPEN ACCESS

Valorization of Crops in Madagascar: Use of Cassava Flour in Baking

Razafimahefa(1)(2), Randrianantenaina Antoni(3*), Vololonirina Rangita Florida(1), Tsialy Jean Louis(1), Fanambinantsoa Fara Razafimandimby(1), Ratolonanahary Hajaniaina Fidelic(1), Rabemiarina Flavien(1), et Rabenandrasana Deric(1)

(1) *Biotechnology, Environment and Health Research Laboratory of the Doctoral School of Life Engineering and Modeling, University of Mahajanga, BP: 652-Mahajanga (401), Madagascar*

(2) *Faculty of Science, Technology and Environment, University of Mahajanga, BP: 652-Mahajanga (401), Madagascar*

(3) *Food Biochemistry and Valorization of Natural Resources, Faculty of Science, University of Antsiranana, BP: 0-Antsiranana (201), Madagascar*

(*) Corresponding author: Randrianantenaina Antoni: antoni73randria@gmail.com

--************************----------------------------------

Abstract:

Wheat flour is one of the ingredients used in baking. However, for climatic reasons, most bread producing countries are unable to grow wheat. Also, they depend on expensive imports of wheat flour at the expense of their scarce foreign exchange resources. In these countries, the price of wheat flour is automatically increased with the monetary exchange rate, thus causing a direct or indirect increase in the price of bread. It would therefore be useful to look for rustic plants that can be transformed into flour that can be used in bread-making. This study was carried out to transform the roots of Malagasy cultivars of cassava into flours and to use the flours produced to make composite breads. The flours produced were characterized by determining physical, physico-chemical and biochemical parameters. The quality of the breads made was assessed by determining their heights, volumes and specific volumes. The results obtained have shown that the characteristics of the flours produced are variable. The heights, volumes and specific volumes of the breads made decrease as the incorporation rate of the new flours produced increases. Up to 30% incorporation of these new flours, the breads made are comparable to breads containing 100% wheat flour. Thus, the prospect of using cassava flour in the bakery seems interesting; it can be integrated into the crop promotion policy in Madagascar in order to produce breads at a lower cost. It is therefore one of the strategies that could be adopted in the face of climate change and it could reduce the poverty of the Malagasy with the direct connection of producers to industries.

Keywords **- Wheat, cassava, rustic plant, bread-making, composite bread.**

--************************----------------------------------

I. INTRODUCTION

The volatility of the price of wheat in world agricultural markets is a problem for many countries around the world, especially wheat-importing countries [1]. This situation leads to instability and generally to the increase in the price of breads in these wheat-importing countries [2]. It should be noted that bread is a traditional food [3], [4]. It is usually obtained by cooking in the oven of a dough kneaded, put in shape and fermented, essentially composed of wheat flour, water, salt and a fermentation agent (yeast or leaven) [5].

It is known that in recent years, bread consumption has increased dramatically in several developing countries due to rising demographics, urbanization and changes in eating habits [6],[7]. The latter phenomenon may also be due to climate change. However, for climatic reasons, most of these countries are unable to grow wheat for bread making [6], [7] and [8]. Also, they depend on expensive imports to the detriment of their scarce foreign currency resources. In these countries, the price of wheat flour is automatically increased with the monetary exchange rate, thus leading to a direct or indirect rise in the price of breads [9], [2]. In fact, the price of wheat has become particularly volatile in recent years, although it should be noted that price instability is intrinsic to agricultural markets [1]. In addition, according to Enguehard *et al*. [10], with changing lifestyles, eating behaviors and consumer expectations have changed considerably in recent years, leading to a change in the bakery sector, forced to adapt to new market demands. The requirement to meet increased demand for wheat and bread is therefore a growing problem in wheat-importing countries.

It should also be noted that, like all commodities, the world price of wheat respects the law of supply and demand; that is, the price of wheat normally rises when the demand for that product increases. According to Laura [1], demand for wheat is dispersed both economically and geographically; while the supply of wheat is concentrated in the United States, Canada, Argentina and the European Union, which alone account for 90% of world exports. However, one attends a fast increase of the wheat consumption on a world scale since the end of the years 1990 in a context of westernization of the food habits and strong demographic growth [1]. In this context, the price of wheat and, consequently, that of bread therefore automatically increases.

In Madagascar, bread was previously consumed by a small proportion of the population of a certain social class [11]. Currently, it is adopted by the majority of the Malagasy people and it constitutes the 2nd consumer product of the Malagasy [12]. In Antananarivo, for example, about, 500 000 sticks of breads per day are consumed [12]. Because of this quantitative evolution of the bread consumption in Madagascar, and because of the insufficient national production of wheat flour, economic operators in Madagascar are forced to import wheat flour [9], [2]. However, at present, the Malagasy currency is strongly devalued against foreign currencies, in particular against the British Pound, Euro and US Dollar. The price of wheat flour then became very expensive, leading to a direct or indirect rise in the price of breads. It would therefore be useful to seek strategies necessary to resolve these problems.

One of the measures that could be taken to save foreign currency and stabilize the price of bread in Madagascar is the partial replacement of wheat flour with that of local crops [9]. This can, moreover, constitute an interesting alternative in terms of cost-benefit. To this consideration, it is right to use the plants presenting big faculties of adaptation to varied ecological situations, easy to reproduce and to cultivate, available all year and capable to be transformed into flour for use in baking. In this case, cassava can be used, which is the second most important source of calories for Malagasy people after rice [13], [14].

The general objective of this research work is therefore to contribute to the enhancement of crops in Madagascar. Its specific objectives are to transform cassava roots into flours, characterize the flours produced, make cassava-wheat composite breads with variable cassava flour incorporation rates and characterize the composite breads made to know the power of bread making for the cassava flours produced.

II. MATERIALS AND METHODS

1. Raw materials

Roots of malagasy cassava cultivars were used as raw materials. Wheat flour, type 55, without additives, purchased at the large SCORE market, was also used during this study to produce compound flours.

2. Magimix

The "Magimix" is a bread improver. It contains wheat flour, emulsifiers (diacetyl tartaric esters of mono and diglycerides of fatty acids), flour treatment agent (ascorbic acid) and processing aids (enzymes).

3. Baking ingredients

The bread ingredients used during the performance of this research work are: flour, yeast, salt, Magimix, water, sugar and butter.

4. Chemical products

All chemicals used during this study are of high quality and for chemical and biochemical analysis.

5. Choice of malagasy cassava cultivars

The most cultivated, most consumed, most abundant and widely available malagasy cassava cultivars in the DIANA (Diego-Suerez, Ambilobe, Nosy Be and Ambanja) and Boeny regions were chosen during this study. These malagasy cassava cultivars are: Menarevaka, Mena and Fotsy (in the Region of DIANA, Province of Antsiranana), Telovolana, Megaline and M32 (in the Region of Boeny, Province of Mahajanga).

6. Harvesting cassava roots

The roots of the malagasy cassava cultivar Mena were collected in the Rural Municipality of Anivorano North, District of Antsiranana II, Region of DIANA. Those of the malagasy cassava cultivars Fotsy and Menarevaka were harvested in the Rural Commune of Joffre Ville, District of Antsiranana II, Region of DIANA. While those of the malagasy cassava cultivars Telovolana, Megaline and M32 were harvested in Fokontany of Ambondrona, Urban Commune of Mahajanga, District of Mahajanga I, Region of Boeny.

The root harvest was carried out during the dry season (October and November). It is during this season that cassava completely loses its leaves and the stem takes on its final color. During this period, all the nutrients necessary for the development of the stems and leaves (starch, proteins, minerals and vitamins) accumulate completely in the roots. These were harvested manually at maturity; that is, after 12 months of planting. It should be noted that cassava roots are fully ripe between 10 and 13 months of cultivation [15]. This age of maturity varies depending on the nature of the planting soil, the environment and the cassava cultivar planted. Healthy stems from each cultivar were chosen. The soil above the roots has been removed to prevent the roots from cutting into the soil during pulling. The roots were pulled out by manual traction on the stem. The unearthed roots were cut carefully on the peduncle avoiding the shocks which favor the rapid deterioration of these roots before their transformations.

7. Transformation of raw materials into flour

Cassava roots were processed into unfermented flour according to the processes described by **CTA [16]**, but with some modifications. This processing method is the combination of several processes, such as peeling, peeling, washing, grating, dewatering, drying, crushing, sieving and finally storage.

8. Characterization of the flours used

To characterize the flours used during this study, 18 following parameters were determined:

- Production yield: by calculating the percentage of the mass of flour in relation to that of the raw materials used;
- Bulk density: by method described by Okaka *et al*. [17];
- Hydrogen potential (pH) and total acidity: by methods of Oywole [18] and Vasconcelos *et al*.[19];
- Dry matter and humidity rate: by drying in an oven at 105 °C for 48 h [20];
- Crude protein content: by Kjeldahl method (N x 6.25);
- Crude fat content: by gravimetry based on extraction with hexane using the properties of insolubility of lipids in water and their solubility in organic solvents [21], [22];
- Starch and simple sugars content: by polarimetric method which is based on that of Ewers[23];
- Crude ash content: by incineration in an oven at 600 °C for 6 h [21],[22];
- Total carbohydrate rate: by difference method;
- Quantity of metabolizable energies: by calculation from the levels of proteins, fats and carbohydrates and the specific calorific coefficients of Atwater used by Woot-Tsuen Wu Leung [24] for these energetic nutrients;
- Water retention capacity: by method developed by Sosulski [25];

- Oil retention capacity: by method developed by Sosulski [25];
- Hydrophilic-Lipophilic ratio: by method of Njintang *et al*. [26];
- Swelling power and solubility: by method of Leach *et al*. [27].

9. Bread-making tests

The formulation of the bakery dough used during this study is that used by most bakeries in Madagascar, but with some modifications due to the use of cassava flour. Note that the hydration rate of cassava-wheat composite flours increases with increasing incorporation rate of cassava flour **[28],** [6]. These changes then relate to the amount of water used. This quantity has been increased so as to obtain rather soft dough, which can be shaped manually. The increase in this amount of water was set at 1.20 ml or 1.50 ml/10% incorporation of the cassava flour.

In order to know the maximum incorporation rates of cassava flour in wheat flour, corresponding to a composite bread similar to a bread made from 100% wheat flour, a series of bread-making tests using the proportions (in%) cassava-wheat flours 0/100, 5/95, 10/90, 15/85, 20/80, 25/75, 30/70, 35/65 and 40/60 (w/w) were produced. Bread making processes were therefore applied to make breads made from 100% wheat flour (WF) and composite breads containing produced cassava flour (CF).

10. Characterization of made-up composite breads

To characterize the baked breads, the following three parameters were measured:

- Mass: by weighing using a laboratory balance;
- Height: by method described by Roussel [29];
- Volume: by displacement of the seeds of *Brassica campestrice*;
- Specific volume: determined by dividing its volume by its mass.

III. RESULTS

1. Characteristics of the flours used

The physical, physicochemical and nutritional characteristics as well as the functional properties of the flours used are presented in Table 1. This table indicates that the flours used have variable characteristics.

Table 1: Physical, physicochemical and nutritional characteristics and functional properties of the flours used

Parameters	WF	MerCF	MenCF	FCF	TCF	MegCF	M32CF
PY (%)	–	32,76	30,99	32,00	22,48	10,17	12,91
BD (g/cm^3)	0,72	0,60	0,72	0,63	0,58	0,59	0,57
pH	5,77	6,03	5,75	6,04	4,61	6,59	7,02
TA (%)	0,12	0,47	0,57	0,45	0,56	2,24	2,54
H (%)	11,62	10,69	11,38	11,53	7,71	7,75	8,26
DM (%)	88,38	89,31	88,62	88,47	92,29	92,25	91,74
CPr (%)	11,50	3,77	1,35	1,48	2,41	2,02	2,17
CFa (%)	1,32	2,83	3,23	2,41	2,93	0,28	0,61
Amidon (%)	60,19	73,56	88,24	82,97	68,09	77,06	71,01
SS (%)	9,89	ND	ND	ND	17,49	12,50	11,99
CA (%)	0,56	1,75	2,29	2,57	0,77	2,72	1,98
TCH (%)	75,31	80,96	81,75	82,01	85,58	87,23	86,98
ME (kcal/100 g)	367,90	360,44	360,24	354,79	379,48	359,50	361,67
WRC (%)	69,89	105,99	103,81	116,42	136,39	16,70	17,61
ORC (%)	80,17	104,97	108,61	102,58	ND	125,60	137,91
H/L Ratio	0,80	1,01	0,96	1,13	ND	0,13	0,13
SP (g/g)	11,22	12,34	14,27	13,36	9,31	8,44	9,64
Solubility (%)	9,22	10,13	11,10	11,02	2,10	5,12	4,92

WF: Wheat flour; **MerCF**: Menarevaka cassava flour; **MenCF**: Mena cassava flour; **FCF**: Fotsy cassava flour; **TCF**: Telovolana cassava flour; **MegCF**: Megaline Cassava Flour; **M32CF**: M32 cassava flour; **PY**: Production yield; **BD**: Bulk density; **pH**: Potential hydrogen; **TA**: Total acidity; **H**: humidity; **DM**: Dry matter; **CPr**: Crude protein; **CFa**: Crude fat; **SS**: Simple sugars; **CA**: Crude ash; **TCH**: Total carbohydrates; **ME**: Metabolizable energy; **WRC**: Water retention capacity; **ORC**: Oil retention capacity; **H/L ratio**: Hydrophilic-Lipophilic ratio; **SP**: Swelling power; **ND**: Not determined

2. Characteristics of wheat breads and the composite breads prepared

The mass, height, volume and specific volume of the baked breads are listed in Table 2. This table indicates that these parameters vary depending on the rate of incorporation of the cassava flour. To better understand the influence of the incorporation rate of cassava flour on these four parameters, the average of the values found for each incorporation rate of cassava flour and for each measured parameter was calculated. Then, a representative curve corresponding to the evolution of each of these parameters was established using Excel software. The results obtained are illustrated by figures 1, 2, 3 and 4.

Figure 1 shows that the mass of cassava-wheat composite breads increases linearly with increasing incorporation rate of cassava flour. The relationship between these two parameters is therefore a positive linear relationship. The correlation coefficient tween these two parameters is then positive (r = + 0.8584).

In contrast, the height, volume and specific volume of cassava-wheat composite breads decrease linearly with increasing incorporation rate of cassava flour (Figures 2, 3 and 4). Indeed, negative linear relationships are observed between these three parameters and the incorporation rate of cassava flour. The correlation coefficients (r) between the height, volume and specific volume of the composite cassava-wheat breads made and the incorporation rate of cassava flour are negative; they are respectively – 0.9939; – 0.9855 and – 0.9843.

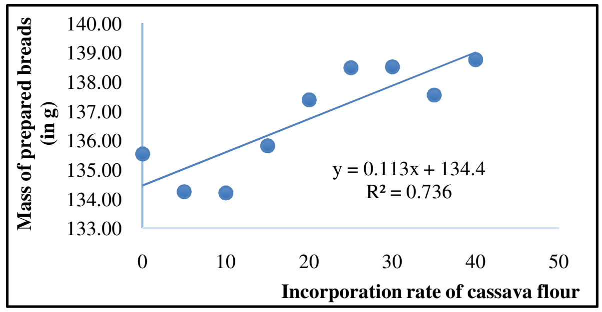

Figure 1. Evolution of the mass of composite breads made according to the incorporation rate of cassava flour

Table 2: Characteristics of wheat breads and made-up composite breads

PARAMETRES	IR (%)	MerCF	MenCF	FCF	TCF	MegCF	M32CF	Moyenne
Mass (g)	0	140,60	140,60	140,60	151,00	119,60	120,90	135,55
	5	141,90	141,50	141,70	139,00	119,30	122,15	134,26
	10	143,50	141,89	143,10	137,00	121,27	118,55	134,22
	15	144,50	143,40	143,80	142,00	122,70	118,55	135,83
	20	145,90	144,10	145,40	146,00	123,75	119,25	137,40
	25	147,70	145,30	146,60	151,00	123,35	117,00	138,49
	30	148,80	146,30	147,50	151,00	121,15	116,40	138,53
	35	149,90	147,20	148,40	145,00	121,05	113,80	137,56
	40	151,10	147,70	149,90	145,00	121,15	117,80	138,78
Height (cm)	0	7,1	7,1	7,1	7,80	7,10	7,50	7,28
	5	6,6	6,9	6,8	6,55	6,80	6,80	6,74
	10	6,5	6,8	6,7	6,30	6,60	6,00	6,48
	15	6,2	6,6	6,5	6,30	6,30	5,90	6,30
	20	6,1	6,4	6,3	6,10	5,80	5,70	6,07
	25	5,6	6,3	6,0	5,40	5,05	5,00	5,56
	30	5,3	6,1	5,8	5,40	4,85	4,50	5,33
	35	5,2	5,9	5,6	5,00	4,55	4,25	5,08
	40	5,0	5,7	5,4	4,95	4,05	3,90	4,83

Volume (cm^3)	0	340,76	340,76	340,76	575,58	455,22	454,20	417,88
	5	316,59	335,36	318,07	468,02	441,76	440,74	386,76
	10	304,83	324,69	310,47	452,03	423,53	328,16	357,29
	15	280,48	304,57	291,30	447,67	382,57	301,17	334,63
	20	278,68	299,04	288,15	434,59	327,43	294,19	320,35
	25	263,08	298,61	272,32	354,65	290,29	260,66	289,94
	30	260,11	288,43	270,29	353,20	179,50	222,13	262,28
	35	226,34	280,29	265,98	335,76	242,65	219,78	261,80
	40	206,99	269,95	260,80	334,30	213,38	214,04	249,91
SV (cm^3/g)	0	2,42	2,42	2,42	3,81	3,81	3,65	3,09
	5	2,23	2,37	2,24	3,37	3,70	3,72	2,94
	10	2,12	2,29	2,17	3,30	3,49	2,77	2,69
	15	1,94	2,12	2,03	3,15	3,12	2,55	2,49
	20	1,91	2,08	1,98	2,98	2,65	2,47	2,34
	25	1,78	2,06	1,86	2,34	2,35	2,23	2,10
	30	1,75	1,97	1,83	2,33	1,48	1,91	1,88
	35	1,51	1,90	1,79	2,32	2,00	1,93	1,91
	40	1,37	1,83	1,74	2,31	1,76	1,82	1,80

IR (%): Incorporation rate of cassava flour; **SV**: Specific volume; **MerCF**: Menarevaka cassava flour; **MenCF**: Mena cassava flour; **FCF**: Fotsy cassava flour; **TCF**: Telovolana cassava flour; **MegCF**: Megaline Cassava Flour; **M32CF**: M32 cassava flour.

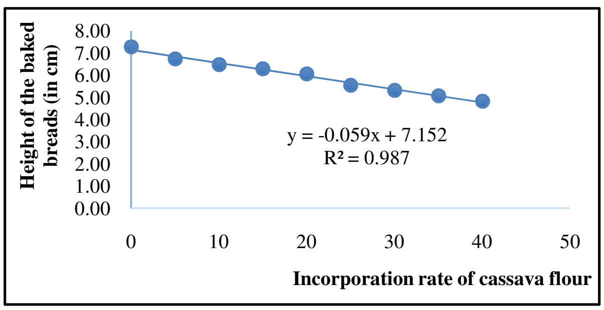

Figure 2. Evolution of the height of composite breads made according to the incorporation rate of cassava flour

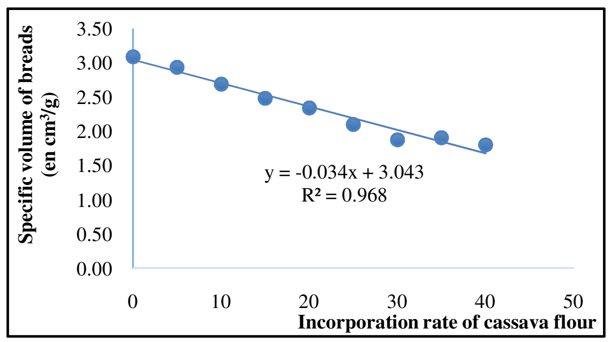

Figure 4. Evolution of the specific volume of composite breads made according to the incorporation rate of cassava flour

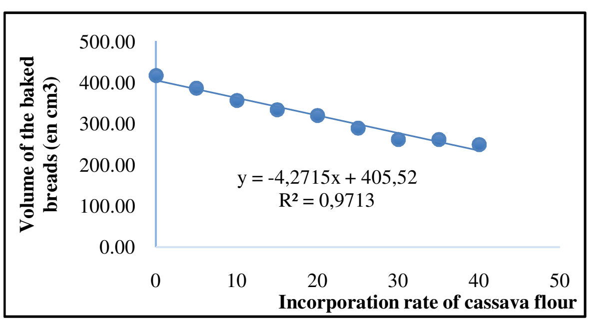

Figure 3. Evolution of the volume of composite breads made according to the incorporation rate of cassava flour

IV. DISCUSSION

The production yields of cassava root flours harvested in the DIANA region are higher than those of cassava root flours harvested in the Boeny region (Table 1). They are significantly different ($P>0.05$). These yields are lower than those obtained by Yao *et al.* (2015) on the three cassava cultivars which are respectively 42.50±1.10% (Zoglo cassava), 42.00±1.10% (Bonoua cassava) and 38.70±1.05% (Yacé cassava)). These differences can be explained by the size of the woody head, the root tail and the amount of fibrous material that is removed during processing. The differences in flour production yields observed on the six cassava cultivars studied are also probably due to the varietal difference and the unequal characteristics of the soils of the places where cassava roots are harvested. It should be noted that the soils of the rural Communes of Anivorano and Joffre Ville, District of Antsiranana II, Region of DIANA are volcanic in nature; they are therefore very fertile. While the soils of the Urban Commune of Mahajanga are limestone in nature.

The bulk densities of the cassava flours produced are similar; they are not significantly different. They are all less than 1 g/cm^3, the volumic mass of water. These flours are therefore lighter than water. However, the bulk densities are highest for wheat and manioc mena flours (0.72 g/cm^3). These flours are therefore heavier than other flours. The bulk density of flour depends on the sizes of its particles. It plays an important role in its functional properties: rehydration, water retention capacity and suitability for bread making [31]. The work carried out by Scher *et al*. [32] showed that the sizes of the granules of the flours are the main factor influencing the rheological properties of the flours. According to Tang *et al*. [33], the smaller the size of the granules, the greater the swelling. In general, the working properties (rheology, water retention capacity) of powders are highly dependent on the size, size distribution, shape of the particles and their biochemical compositions [32].

The pH of Menarevaka, Mena, Fotsy, Telovolana and Megaline cassava flours are all less than 7 (Table 1). These flours therefore have an acidic character. This acidic character is due to the presence of organic acids [34]. On the other hand, the pH of M32 cassava flour is equal to 7.02 (Table 1). This flour is slightly basic. The amount of organic acids in this flour is therefore low. The acidities of the cassava flours produced are all higher than that of the wheat flour. This indicates that cassava flours are richer in organic acids than wheat flour.

The water contents of the flours produced are low (Table 1). They are all less than 14%, a limit generally considered to be the maximum for good preservation of flour [35]. The dry matter contents of these flours are therefore all greater than 86%. The measurement of the water content of products is a capital operation which presents a quadruple interest: technological, analytical, commercial and regulatory interests [36]. Lower water content may be required for certain destinations, taking into account the climate, the duration of transport and that of storage [37]. The water contents of the products must respect the standards, because the law fixes, for reasons of good conservation and commercial honesty, the maximum water content not to be exceeded 36]. Soudy, in [38], described that a food with a water content of less than 14% can be stored without special treatment as long as it is stored under the correct conditions of humidity and temperature. Codex Standard 178-1991[37] indicated that the maximum moisture content of products is 14.50%. The low water content of the powders produced is very important to allow their long-term storage in a dry place. It would thus be difficult for microorganisms to multiply there, because they need a water activity and, consequently, water content, high enough to proliferate [39]. In addition, chemical and enzymatic spoilage reactions are greatly slowed down in foods with low water content [39], [40]. The cassava flours thus produced can therefore be stored for a long time in jars, because their water content is less than 14% (Table 1).

The cassava flours produced are not sources of protein and lipids, as the contents of these compounds are very low (Table 1). This is in agreement with the results of Razafimahefa in [9] who also found low levels of crude protein and crude fat in cassava flours ranging, respectively, between 0.63 and 1.87% and between 0.45 and 0.96%. The crude protein contents of cassava flours produced during this study are very low compared to that of wheat flour. They agree with those reported by Stupak *et al*. [41] which are between 1 and 5% (DM). By comparing with the crude protein contents of the granules of cassava cultivars Bonoua, Yacé and Zoglo from Côte d'Ivoire [30], which are respectively 3.10±0.05%, 3.20±0.05% and 2.90±0.03%, that of proteins contained in the flour of manioc cultivar Menarevaka (3.77%) is very close to these levels. The cassava cultivars Mena (1.35%) and Fotsy (1.48%) are the poorest in these compounds. These differences may be related to cultivars, agronomic conditions and age of harvest [42]. They may also be due to the difference in the cassava root processing methods used.

On the other hand, these cassava flours are sources of carbohydrates, because their total carbohydrate content is greater than 80% (Table 1). These carbohydrates are mainly made up of starch, a common characteristic of all starchy plants. The total carbohydrate levels of these flours are higher than that of wheat flour. They are very similar to those of the granules of three cassava cultivars Bonoua (84.39%), Yacé (83.50%) and Zoglo (84.20%) from Côte d'Ivoire [30]. They are lower than that of attiéké for the sweet cassava cultivar, found by Sahoré *et al*. [43], which is equal to 94.50±1.41% DM. The variability in these carbohydrate levels is due to factors. According to Balagapolan *et al*. [44], carbohydrate levels in starchy plants vary depending on environmental conditions of growing site, cultivars, harvest season and processing method.

The crude ash rates of the flour of three malagasy cassava cultivars Mena (2.29%), Fotsy (2.57%) and Megaline (2.72%) (Table 1) are comparable to those of the results of the work carried out by Koko *et al*. [45] on the three cassava cultivars Akaman, Zoklo and Yace which are respectively 2.64; 2.67 and 2.29%. They are also comparable to the results obtained by Razafimahefa [9] on unfermented cassava root flours fermented in polyethylene bags which are between 1.82 and 2.64%. They are higher than the crude ash content of wheat flour (0.56%) and that of the malagasy cassava cultivars Menarevaka (1.75%) and Telovolana (0.77%) (Table 1). These differences may be due to those of the harvest season, or to the agronomic conditions of the samples [46]. They may also be due to the inequality of the cassava cultivars studied and the cassava root processing methods used.

The metabolizable energies of the flours produced during this study are between 354.79 and 379.48 kcal/100 g of flour (Table 1). The highest are those supplied by the Telovolana cassava flour; the lowest being that provided by Fotsy cassava flour. These energies are higher than those provided by plantain flours analyzed by Dhoimir [47] and Mahatsara [48], which are respectively 314.10 kcal/100 g of flour and 314.03 kcal/100 g of flour. The energies provided by Fotsy and Megaline cassava flours are comparable to those provided by white-fleshed sweet potato flour analyzed by Soanirina [49], which provides 357.61 kcal/100 g. Those provided by the Menarevaka, Mena and M32 cassava flours are comparable to the energies provided by the yellow-fleshed sweet potato flour used by Rahajason [50], which provides 362.29 kcal/100 g of flour. These cassava flours therefore provide energy. However, these energies are mainly of carbohydrate origin, because these flours are rich in carbohydrates, but poor in proteins and lipids, which are other energy principles.

The flours produced are able to retain water, since at room temperature and in the presence of water, they absorb water. These flours are therefore hygroscopic. The water retention capacity makes it possible to estimate the degree of association of starch polymers [51], [52] and to evaluate the baking quality of flour [39]. This functional property is undoubtedly due to the presence of hygroscopic constituents which normally have hydrophilic groups. These constituents are essentially carbohydrates, because these flours (except wheat flour) don't contain any proteins practically, substances also having hydrophilic groups (=CO, –NH–). These carbohydrates can be simple sugars, starch, amylose, amylopectin, and fiber. All of these compounds have free hydroxyl groups (–OH) which are hydrophilic. They can, therefore, bind with water molecules through hydrogen bonds. The water retention capacity of these flours therefore normally depends on the level of carbohydrates. During the grinding stage of dry products, some starch grains can be physically damaged. This damage plays an important role in the water retention capacity of the flour. According to Manley [53], in excess of water, undamaged starch absorbs 33% of its weight in water, while damaged starch absorbs 100% of its weight in water. Adebowale *et al*. [54] reported that the high-water holding capacity is attributed to a loss of starch structure, while the low value indicates the compactness of the structure. According to this information, the starches contained in Megaline and M32 cassava flours are therefore less damaged than those of other flours produced, because the water retention capacities of these flours are the lowest (Table 1).

Oil retention capacity is an important property in feed formulation. It would act as a flavor retainer and mouth feel enhancer [55], [56]. It gives an indication of the retention capacity of flour flavor [55], [56]. The oil retention capacities of the cassava flours produced are higher than that of the wheat flours used. This indicates that cassava flour absorbs more oil than wheat flour. They therefore retain more flavor than that of wheat.

The oil retention capacity values of the cassava flours produced are higher than those described by Diallo *et al*. [57] for the cultivar Vigna subterranea. L (Voandzou) which is 88.83 g/100 g of dry matter. These differences could be explained by the size of the particles and the difference in the origin of the flours [58]. Indeed, the particle sizes of the flours would naturally influence their use in all food preparation processes. The literature indicates that flours with very high oil retention capacity have a flavor retention and mouth feel enhancer in food products [55], [56]. M32 cassava cultivar flour has the highest oil retention capacity. Therefore, it holds its most interesting characteristics than other cassava flours produced. The oil retention capacities of cassava flours produced during this study are all lower than that of "Kotrika" banana flour analyzed by Hachiatte [59], which is 153.78%. This difference can be explained by the varietal difference. This flour therefore retains more flavor than that of the cassava flours produced. The oil retention capacity is also interesting over a long shelf life of foods, especially in baked goods or meat products [60].

The hydrophilic-lipophilic ratio makes it possible to assess the comparative affinity of flours for water and for oil. The hydrophilic-lipophilic ratios of wheat flours and cassava roots harvested in the DIANA Region are of the order of 1 (Table 1), which indicates the affinities of these flours to water and oil are similar. While for cassava root flours harvested in the Boeny region, the values obtained are very low and less than 1 (Table 1). This means that these flours have higher affinities to oil compared to water. In contrast, flours of the cassava cultivars Menarevaka and Fotsy with a hydrophilic-lipophilic ratio greater than one (1) have a higher affinity for water compared to oil. According to Kaushal *et al*. [56] and Yadahally *et al*. [55], flour with a high affinity to oil has the indication of the ability to retain flavor and enhance mouth feel. The flours from cassava roots harvested in the Boeny region therefore retain more flavor and enhancer in the mouth than other flours.

The flours used during this study are all capable to swell. However, according to the results given in Table 1, the flours of cassava roots harvested in the DIANA region are more capable to swell than those of the roots harvested in the Boeny region. This may be due to the inequality of the cassava cultivars studied. The swelling of these flours is due to the introduction of water molecules into the starch granules contained in these flours. The swelling power provides information on the extensibility of the dough, makes it possible to assess the ability of the dough to retain carbon dioxide (CO_2) [61] and it indicates the degree of water retention of the starch granules [62]. It depends mainly on the starch granules, especially on the level of amylose and amylopectin in the starch [63]. When these starch granules are exposed to both heat and humidity (heated in excess water), there is a phenomenon of gelatinization: above the gelatinization temperature, these granules swell with water. Adsorption of water on polar hydroxyl groups [39]. The swelling of starch granules is also dependent on the structure of the water contained in the suspension [64].

The solubility of the flours used during this study is between 2.10% (for Telovolana cassava flour) and 11.10% (for Mena cassava flour) (Table 1). The variability of this solubility may be due to genetic, soil, climatic, agronomic and technological factors. This solubility is due to the presence of water-soluble substances in the flours. These water-soluble substances can be simple sugars and proteins. The solubility of flour depends on its swelling power. The search for the link between these two parameters revealed a strong positive correlation ($r = 0.9011$). This indicates that the flour having high solubility is very capable to swell. In other words, the solubility of flour increases with the increase in its swelling power.

The results obtained show that, in general, the mass of cassava-wheat composite breads increases linearly with the increase in the incorporation rate of cassava flour. The relationship observed between the mass of the composite breads and the incorporation rate of cassava flour is a positive linear relationship. This is how the correlation coefficient between these two parameters is positive ($r = +0.8584$). This phenomenon is due to the increased water retention capacity of cassava-wheat composite flours. Recall that the hydration rate of cassava-wheat composite flours increases with the increase in the incorporation rate of cassava flour [28], [6].

The data obtained concerning the height, the volume and the specific volume of the baked breads, collected in Table 2, show that the values of these three parameters decrease with the increase in the incorporation rate of the cassava flours. The relationships observed between these three parameters and the incorporation rates of cassava flour are negative linear relationships. This is why the correlation coefficients between the height ($r_1 = -0.9939$), the volume ($r_2 = -0.9855$) and the specific volume of the l breads ($r_3 = -0.9843$) and the incorporation rate of cassava flours are all negative. This situation, which confirms the absence of gluten in cassava flour, is due to the decrease in glutenin and gliadin (gluten fractions) contents in the flour medium. In composite flours, these two protein fractions, which are responsible for the elasticity and extensibility of bakery dough [39], are then found dispersed. They are therefore less likely to combine and form a viscoelastic network capable to retain the carbon dioxide released during periods of fermentation (pointing and finishing), resulting in less developed breads. The height of the breads is therefore strongly influenced by the quantity of carbon dioxide retained by the baking dough. In fact, each air cell is characterized by a critical size, beyond which the retention of carbon dioxide is uncertain, because, more often than not, it diffuses into the atmosphere [65]. Observations of the characteristics of composite breads made indicate that bakery dough incorporating up to 20% of the cassava flour used rise well during the fermentation (pointing and finishing) and baking periods; they are comparable to those obtained with 100% wheat flour. Therefore, the baked breads are of good quality like 100% wheat flour breads.

V-CONCLUSION

The cassava flours used during this study have variable physical, physicochemical and nutritional characteristics. They have volumic mass lower than that of water. Generally, they are acidic in character. Their water contents are less than 12%. They are low in protein and fat. On the other hand, they provide energies. These energies are mainly of carbohydrate origin. The water and oil retention capacities and the swelling powers of these flours are high.

Our bread-making trials have shown that it is possible to incorporate cassava flour into wheat flour to produce composite breads similar to breads made from 100% wheat flour. During this study, up to 20% incorporation of cassava flour (gluten-free) in wheat flour (containing gluten), no major changes in the appearance of the breads made were observed. The results obtained showed that the flour from the Telovolana cassava roots is more bread-making than the other cassava flours used.

Thus, in the face of climate change, and given the climatic conditions demanded by wheat, the prospect of replacing part of the wheat flour (containing gluten) by that of cassava (gluten-free) seems interesting. This proposal can then be integrated into the policy of promoting local cultures in order to produce breads at a lower cost or at unchanging prices and to improve the food security of the population in Madagascar. This is therefore one of the strategies necessary to reduce the poverty of the Malagasy people with the direct connection of producers to industries.

This study should then be broadened and deepened. In this case, more systematic studies should be carried out on the baking value of flours produced from the roots of other cassava cultivars. These studies will therefore make it possible to identify the most bread-making cassava cultivars. The latter will then be popularized with the aim of reducing expenditure linked to imports of wheat flour and producing composite breads at a lower cost or at a fixed price and acceptable to consumers.

ACKNOWLEDGMENTS

We thank all the staff of the National Center for Environmental Research, in Tsimbazaza, Antananarivo (Madagascar) who accepted our request for analysis of our samples in their laboratory.

REFERENCES

[1]- **P. Laura**. *La volatilité du prix du blé sur les marchés agricoles mondiaux : une approche par les facteurs*. Mémoire de Master : Université lumière Lyon 2 : Institut d'Études Politiques de Lyon, 82 p, 2012.

[2]- **Razafimahefa.** *Valorisation des ressources comestibles et disponibles à Madagascar : cas des racines, des tubercules, des fruits, des graines et des légumes-feuilles.* – Mémoire en vue de l'obtention du diplôme d'Habilitation à Diriger des Recherche (HDR) en Biochimie, Microbiologie et Biotechnologie Appliquées, Spécialité Biochimie et Nutrition : Ecole Doctorale Génie du Vivant et Modélisation (EDGVM), Université de Mahajanga, Madagascar, 124 p, 2018.

[3]- **J. Trémolières, Y. Serville, et R. Jacquot.** *Manuel élémentaire d'alimentation humaine. Les aliments*, Paris XVII^{e}, Tome 2, 4ème édition. Les Editions Sociales Françaises, 519 p, 1968.

[4]- **F. Chiva, F. Hoint-Pradier, F.-M. Six, P. Verger, et E. Vergne**. *Aliments santé de A à Z : Guide pratique de la nourriture saine,* Première édition, Paris, Bruxelles, Montréal, Zurich : Edition abrégée de Aliments Santé, Aliments Danger. – (Sélection du Reader's Digest). 1999.

[5]- **P. Roussel, H. Chiron, G. Della Valle, et A. Ndiaye.** *Recueil de connaissances sur les descripteurs de qualité des pâtes et des pains ou variables d'état pour la panification française : Glossaire terminologique appliqué aux pains Français*. INRA, Polytech., Paris-UPMC, 66 p, 2010.

[6]- **G. Eggleston, E. P. Omoaka, et U. A. Arowshegbe**. Flour, Starch and Composite Breamaking Quality of Various Cassava Clones. *Journal of Science and Food Agriculture*, 62, p. 49 – 59, 1993a.

[7]- **G. Eggleston, O. P. Omoaka, et O. D. Ihedioha.** Mise au point et évaluation de produits à base de farine de manioc comme substituts du pain de blé. *La Recherche à l'IITA*, N° **7**, septembre 1993, p. 14 – 19, 1993b.

[8]- **M. Bokanga.** Cassava: Opportunities for the food, feed and other industries in Africa. In : Agbor-Egbe T., Brauman A., Griffon D. et Trèche S. (Éditeurs). *Transformation alimentaire du manioc.* – Paris : – ORSTOM Éditions, p. 557 – 569. – (Collection Colloques et Séminaires), 1995.

[9]- **Razafimahefa .** *Mise au point de production de farines de manioc panifiables et évaluation sensorielles des pains composites de manioc fabriqués.* – Thèse de Doctorat en Biochimie : Antananarivo : Faculté des Sciences, 172 p, 2005.

[10]- **E. Enguehard, L. Loriot, et J. Lanier**. Le commerce de boulangerie– pâtisserie : Evolution et repères. *Supplément technique INBP*, N° 103, 16 p, 2015.

[11]- **S. Ranomenjanahary, P. Randriambola, et L. Randriambolanoro.** La recherche sur le manioc à Madagascar : impact sur le développement intégré des zones rurales. *Roots*, Newsletter of the Southern Africa Root Crops Research Network (SARRNET) and the East Africa Root Crops Research Network (EARRNET), 2, p. 13 – 16, 1995.

[12]- **Indian Ocean Times.** Madagascar : 500 000 baguettes consommées par jour à Tananarive, Madagascar, 2016.

[13]- **V. Jeannoda, Ch. Ralison, C. Ramanitrera, C. Ramaharobandro, D. Randrianaivo, et R. A. Randrianarivony.** *La situation alimentaire et nutritionnelle à Madagascar : Stratégie nationale de sécurité alimentaire et de nutrition*. Projet Sécurité alimentaire et Nutrition Elargie (SECALINE). IDA N° 2474 MAG. Gouvernement Malgache (Madagascar), 134 p, 1997.

[14]- **B. Dostie, J. Randriamamonjy, et L. Rabenasolo**. *La filière manioc : amortisseur oublié des vulnérables*. Rapport du Projet Participation et Pauvreté, N° 623-0125-A-00-6045-00. – Cornell Food and Nutrition Policy Program (Cornell University, Ithaca, NY, 14853 USA) et Institut National de la Statistique (Antananarivo, Madagascar), novembre 1999, p. 8, 1999.

[15]- **B. N'Zué, G.P. Zohouri, et A. Sngaré A**. Performance agronomique de quelques variétés de manioc de trois zones agroclimatiques de la Côte d'Ivoire. *Agronomie Africaine.*, 16, p. 1 – 7, 2004.

[16]- **CTA** . *Fabrication d'une farine de manioc de haute qualité*. Wageningen, Pays-Bas, 6 p. – (Collection Guides pratiques du CTA ; N° 5), 2008.

[17]- **C. J. Okaka, A. P. Okorie, and N. O. Ozo**. Quality evaluation of sun-dried yam chips. *Tropical Science*, **30**(3), p. 265 – 275, 1991.

[18]- **B.O. Oyewole.** Optimization of cassava fermentation for fufu production: effects of single starter cultures. *Journal Applied Bacteriology.*, 68, p. 49 – 54, 1990.

[19]- **T. A. Vasconcelos, R. D. Twiddy, A. Westby, and A. J. P. Reilly.** Detoxification of cassava during gari preparation. *International Journal of Food Science and Technology*, **25**, p. 198 – 203, 1990.

[20]- **AOAC**. *Official methods of analysis of Association of Official Analytical Chemists. Method 925.10 (Final Action): Food Composition, Additives, Natural Contaminants*, 15th Ed, Arlington, Virginia 22201 USA: HELRICH K. – Volume II, p.777, 1990.

[21]- **AOAC.** Official method of analysis.11th ed. *Association Official Anaytical Chemists*, Washington D.C, 1970.

[22]- **A . M. Joslyn**. Methods in Food Analysis. – 2nd ed. Academic Press. New York, 1970.

[23]- **E. Ewers**. Determination of starch by extraction and dispersion with hydrochloric acid. *International Organization of Standardization* (ISO/TC 93 WGL), 1965.

[24]- **Woot-Tsuen Wu Leung**. Table de composition des aliments à l'usage de l'Afrique. Organisation des Nation Unies pour l'Agriculture, Rome, 1970.

[25]- **W. F. Sosulski.** The centrifuge methode for determining flour absorption in hard red spring wheats. *Cereal Chem.*, 39, p. 344 – 350, 1962.

[26]- **Y. N. Njintang, F. M. C. Mbofung, and W. K. Waldron K.W**. In vitro protein digestibility and physicochemical properties of dry red bean (Phaseolus vulgaris) flour: Effect of processing and incorporation of soybean and cowpea flour. *Journal of Agriculture Food Chemistry*, 49, p. 2465 – 2471, 2001.

[27]- **W. H. Leach, D. L. Mccowen, et J.T. Thoch.** Structure of the starch granule. I. Swelling and solubility patterns of various starches. *Cereal Chemistry*, 36, p. 534 – 544, 1959.

[28]- **M. A. Almazan**. Effect of cassava flour variety and concentration on bread loaf quality. *Cereal Chemistry*, 67, p.97 – 99, 1990.

[29]- **P. Roussel.** Tests de panification. I*n* Godon B. et Loisel W. (Coordonnateurs). « *Guide pratique d'analyses dans les industries des céréales* », Paris, Technique et Documentation-Lavoisier-APRIA, p. 511– 546. – (Collection Sciences et Techniques Agro-alimentaires), 1984.

[30]- **K. A. Yao, M. D. Koffi, H. S. Blei, B. Z. Irié, et L. S. Niamke.** Nouvelle technique de transformation de la pulpe de manioc (*Manihot esculenta* Crantz) sous forme de granules conservables sur une longue période. *European Scientific Journal.*, **11**(24), p. 415 – 425, 2015.

[31]- **C. B. Ndangui**. *Production et caractérisation de farine de patate douce (Ipomoea batatas.Lam) : optimisation de la technologie de panification.* Thèse doctorat, Université de Lorraine (Marien Ngouabi). Ecole Nationale Supérieure d'Agronomie et des Industries Alimentaires. 134 p, 2015.

[32]- **J. Scher, C. M. J. Da Costa, J. Hardy.** Influence de la granulométrie sur les propriétés d'écoulement de la farine de blé. Deuxième colloque solides divisés, *Lyon*., p. 291 – 298, 1998.

[33]- **H. Tang, T. Mitsunaga, and Y. Kawamura**. Relationschip between functionnality and structure in barley starches. *Carbohydrate Polymers.,* 57, p. 145 – 152 , 2004.

[34]- **J. Trémolières, Y. Serville, R. Jacquot, et H. Dupin.** Manuel d'alimentation humaine. Les bases de l'alimentation, 10ème édition. – Les Editions Sociales Françaises, Paris. – Tome 1, p. 232 – 234, 1984.

[35]- **S. Trèche.** *Potentialités nutritionnelles des ignames (Dioscorea spp.) cultivées au Cameroun*, Vol. 1. – Edition de l'OROSTOM, Paris, 224 p. – (Collection Etudes et Thèses), 1989.

[36]- **L.-J. Multon, et G. Martin.** Mesurage de la teneur en eau. In : Godon B. et Loisel W. (Coordonnateurs). – *Guide pratique d'analyses dans les industries des céréales*. – Paris : Technique et Documentation-Lavoisier-APRIA. – p. 175 – 225, 1984. – (Collection Sciences et Techniques Agro-alimentaires).

[37]- **Codex Standard 178-1991.** *Norme codex pour la semoule et la farine de blé dur*. CODEX STAN 178-1991, 3 p, 1991.

[38]- **D. I. Soudy.** *Pratiques traditionnelles, valeur alimentaire et toxicité du Taro* (*Colocasia esculenta* L. Schott) *produit au Tchad.* Thèse de doctorat en Nutrition et Sciences des aliments : Université Blaise Pascal Clermont-Ferrand : Ecole doctorale des Sciences de la Vie et de la Santé, 153 p, 2011.

[39]- **C.-J. Cheftel, et H. Cheftel.** *Introduction à la biochimie et à la technologie des aliments*. Paris : Technique et Documentation ; Entreprise d'Edition, Vol. 1, p. 105 – 145, 1976.

[40]- **H. V. Randrianantoandro**. *Etude de la valeur nutritionnelle de quatre variétés de manioc et d'une variété de de maïs et leur utilisation dans l'alimentation infantile.* – Mémoire de fin d'études pour l'obtention du Diplôme d'Etudes Approfondies (DEA) de Biochimie Appliquée aux Sciences de l'Alimentation et à la Nutrition : Antananarivo : Faculté des Sciences, 101 p, 2004.

[41]- **M. Stupak, H. Vanderschuren, W. Gruissem, and P. Zhang.** Biotechnological approaches to cassava protein improvement. *Trends Food Science and Technology*, 17, p. 634 – 641, 2006.

[42]- **A. J. Woolfe**. The potato in the human diet. Cambridge, Royaume Uni. Cambridge Univ. Press, 1987.

[43]- **A. D. Sahoré, and J. G. Nemlin.** Effect of technological treatments on cassava (*Manihot esculenta* Crantz). *Food and Nutrition Sciences,* 1, p. 19 – 23, 2010.

[44]- **C. Balagapolan, G. Padmaja, K. S. Nanda, and N. S. Moorthy**. Cassava nutrition and toxicity. In: Hillocks R.J., Tresh J.M. & Belloti A.C. Cassava in food, feed and industry. Boca Raton, FL, USA: CRC Press., p. 13-36, 1988.

[45]- **C. A. Koko, B. K. Kouame, B. Y. Anvoh, G. N. Amani, and E. N. Assidjo**. Comparative study on physicochemical caracteristics of cassava roots from three local cultivars in Côte d'Ivoire. *European Scientific Journal*., 10(33), p. 418 – 432, 2014.

[46]- **K. B. Ndabikunze, L. A. H. Talwana, J. R. Mongi, A. Issa-Zacharia, K. A. Serem, V. Palapala, and M. O. J. Nandi**. Proximate and mineral composition of cocoyam (*Colocasia esculenta* L. and *Xanthosoma sagittifolium* L.) grown along the Lake Victoria Basin in Tanzania and Uganda. *African Journal of Food Science*, 5(4), p. 248 – 254, 2011.

[47]- **Y. M. Dhoimir.** *Essai de fabrication des pains à partir d'une farine composite à base des farines de blé et des bananes*. Mémoire de fin d'études pour l'obtention du Diplôme de Master en Biochimie et Sciences de l'Environnement : Mahajanga : Faculté des Sciences, de Technologies et de l'Environnement, Madagascar, 73 p, 2017.

[48]- **H. M. Mahatsara.** *Mise au point des procédés de production de la farine infantile a base des pates du sésame, farine des bananes plantains et de la poudre des feuilles de moringa oleifera.* Mémoire de fin d'études pour l'obtention du Diplôme de Master en Biochimie et Sciences de l'Environnement : Mahajanga : Faculté des Sciences, de Technologies et de l'Environnement, Université de Mahajanga, Madagascar, 81 p, 2017.

[49]- **C. Soanirina.** *Essai de fabrication des pains composites à base des farines de blé et de patate douce à chair blanche*. – Mémoire de fin d'études pour l'obtention du diplôme de Master en Parcours de Biochimie, Microbiologie et Biotechnologie Appliquées (BMBA), Mention de Biochimie et Sciences de l'Environnement (BSE) : Mahajanga : Faculté des Sciences, de Technologies et de l'Environnement (FSTE), Université de Mahajanga, Madagascar, 64 p, 2017.

[50]- **N. A. Rahajason .** *Essai de fabrication des pains composites à base des farines de blé et de patate douce à chair jaune récoltée à Port-Bergé*. – Mémoire de fin d'études pour l'obtention du diplôme de Master en Parcours de Biochimie, Microbiologie et Biotechnologie Appliquées (BMBA), Mention de Biochimie et Sciences de l'Environnement (BSE) : Mahajanga : Faculté des Sciences, de Technologies et de l'Environnement (FSTE), Université de Mahajanga, Madagascar, 83 p, 2017.

[51]- **L. P. Soni, W. H. Sharma, P.N. Dobhal, S. S. Bisen, C. H. Srivastava, and M. M. Gharia**. The strarches of Dioscorea ballophylla and Amorphophallus companulatus. *Starch*, 37, p. 6 – 9, 1985.

[52]- **L. P. Soni, H. Sharma, C. H. Srivastava, and M. M. Gharia**. Physicochemical properties of *Canna edulis* starch – Comparison with maize starch. *Starch/Stärke*, 42, p. 460 – 464.

[53]- **J. D. Manley**. Technology of biscuits, crackers and cookies." 2nd ed. I.D. Morton ed. (Ellis Horwood series in food science and technology, Chichester, GB), 1991.

[54]- **A. A. Adebowale, O. L. Sanni, and O. S. Awonarin.** Effect of texture modifies on the physicochemical and sensory properties of dreid fufu. *Food Science Technology International*, 11, p. 373-385, 2005.

[55]- **N. Yadahally, Sreerama, B. Vadakkoot, Sashikala, M. Vishwas, Pratape, and S. Vasudeva**. Nutrients and antinutrients in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their flour functionality. *Food Chemistry,* 131, p. 462 – 468, 2012.

[56]- **P. Kaushal, V. Kumar, and K. H. Sharma**. Comparative study of physicochemical, functional, antinutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*) flour, pigeon pea

(*Cajanus cajan*) flour and their blends. *LWT - Food Science and Technology.*, 48, p. 59 – 68, 2012.

[57]- **K. S. Diallo, D. Soro, Y. K. Kone, E. N. Assidjo, K. B. Yao, et D. Gnakri.** Fortification et substitution de la farine de blé par la farine de Voandzou [*Vigna subterranea (*L) verdc. Fabaceae] dans la production des produits de boulangerie. *International Journal of Innovation and Scientific Research.* SSN 2351-8014, 18(2), p. 434 – 443, 2015b.

[58]- **K S. Diallo, K. Y. Koné, D. Soro, E. N. Assidjo, K. B. Yao, et D. Gnakri**. Caractérisation biochimique et fonctionnelle des graines de sept cultivars de voandzou [*Vigna subterranea (*L) verdc. Fabaceae] cultivés en Côte d'Ivoire. *European Scientific Journal.*, 11(27), p. 288 – 304, 2015a.

[59]- **S. Hachiatte.** *Caractéristiques physiques, physico-chimiques, fonctionnelles et nutritionnelles de la farine des bananes kotrika*. Mémoire de fin d'études pour l'obtention du Diplôme de Master en Biochimie et Sciences de l'Environnement : Mahajanga : Faculté des Sciences, de Technologies et de l'Environnement, Université de Mahajanga, Madagascar, 66 p, 2019.

[60]- **S. Soro, G. Konan, E. Elleingand, D. N'Guessan, et E. Koffi**. Formulation d'aliments infantiles à base de farines d'igname enrichies au soja. *African Journal of Food Agriculture Nutrition and Development.*, 13(5), p. 8313 – 8339, 2013.

[61]- **N. Sakr, et E. Hajj Moussa**. Comparaison de la qualité des blés libanais à celle des variétés importées de l'étranger et destinées à la préparation du pain libanais. *Lebanese Science Journal.,* 8(2), p. 87 – 103, 2007.

[62]- **M. Carcea, and R. Acquistucci.** Isolation and physicochemical characterization of Fonio (Digitaria exillis Stapf). *Starch. Starch.*, 49, p. 131-135, 1997.

[63]- **N. Singh, L. Kaur, K. Singh Sandhu, J. Kaur, and K. Nishinari.** Relationships between physicochemical, morphological, thermal, rheological properties of rice starches. *Food Hydrocolloids.*, 20, p. 532 – 542, 2006.

[64]- **H. Brun.** Composition et structure chimique de l'amidon. *Industrie Agricole et Alimentaire*, 65, Avril – Juin, p.135, 1948.

[65]- **I. Defloor, C. De Geest, M. Schellekens, A. Martens, and A. J. Delcour**. Emulsifiers and/or extruded starch for the production of breds from cassava. *Cereal Chem*istry*,* 68, p. 323 – 327, 1991.