Etude des pratiques et croyances alimentaires pour comprendre la malnutrition à Madagascar : intérêt de l"introduction de feuilles de Moringa oliefara

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« Etude des pratiques et croyances alimentaires pour comprendre la malnutrition à Madagascar. Intérêt de l'introduction de feuilles de *Moringa oleifera*»

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« Le plus difficile à voir est ce que l’on a sous les yeux. »
-Goethe

« Rien dans notre intelligence qui ne soit passé par nos sens. »
-Aristote

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Résumé

Cette thèse vise à comprendre pourquoi une grande partie de la population malgache souffre de malnutrition alors que le pays est connu pour ses richesses en ressources naturelles, comme les feuilles de *Moringa oleifera* (MO). L'hypothèse principale est que la malnutrition est liée non seulement à la pauvreté, mais aussi aux croyances et comportements alimentaires. Une démarche en trois phases a été utilisée. La caractérisation nutritionnelle et sensorielle des poudres de MO a tout d'abord montré des variations des taux en protéine, lipides, acides aminés et gras, calcium, magnésium et fer et des propriétés organoleptiques en fonction du lieu d'origine de MO. Des études de croyances et pratiques alimentaires ont ensuite été réalisées dans deux régions en zones rurales et urbaines. Elles ont montré que les aliments glucidiques dominent dans l'alimentation. En revanche, les légumes-feuilles ne sont pas considérés comme nutritives. Les attitudes et comportements alimentaires sont plus basés sur les propriétés sanitaires des aliments que sur l'équilibre en nutriments et le caractère énergétique. Les facteurs déterminants le choix alimentaire de la population ont été identifiés: disponibilité, prix, pouvoir rassasiant, habitude et préférence. Enfin, quatre formulations combinant manioc et MO ont été évaluées par des enfants : le produit avec 1,2 % de poudre de MO et sucré est le plus accepté et choisi face aux autres qui contiennent moins de MO et non sucrés. Il serait possible de contribuer dans la lutte contre la malnutrition en proposant des produits pas chers et incorporant le MO avec des programmes d'éducations adaptés à chaque zone cible.

Mots-clé :

Moringa oleifera, Madagascar, croyances alimentaires, habitude alimentaire, nutrition, sensoriel, malnutrition, manioc

Abstract

This work aims at understanding why a high proportion of Malagasy population suffer from malnutrition, while Madagascar is rich on natural resources, like *Moringa oleifera* leaves (MO). The hypothesis is that malnutrition is related not only on poverty but also on food beliefs and behaviour. The studies integrating sociopsychology, food sciences and nutrition were conducted on three phases. First, nutritional and sensory characterizations of MO powder showed variations of protein, fat, amino acids, fatty acids, calcium, magnesium and iron contents and organoleptic proprieties depending on locations. Secondly, a study of food beliefs and practices was performed in two regions in urban and rural zones. It showed that Malagasy food is mostly based on carbohydrates foods and that leafy vegetables are not considered as nutritious. Food attitudes and behaviours were mostly based on sanitary proprieties of food than on the equilibrium of nutrients and the caloric characters. The determinants factors of food choice of the Malagasy population were identified: availability, price, satiating power, habit and preference. Finally, four formulations combining cassava roots and MO were evaluated by school age children: the sweet product with 1.2% of MO was the most accepted and chosen in front of the others containing less MO and not sweet. It is possible to contribute to fight against malnutrition by proposing cheap foods containing MO and by integrating information about MO in nutrition education programs adapted to each target area.

Keywords

Moringa oleifera, Madagascar, food beliefs, food habit, nutrition, sensory, malnutrition, cassava

Communications et publications issues de ces travaux de thèse

Publications scientifiques dans des revues à comité de lecture :

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Ramaroson Rakotosamimanana, V., Valentin, D. & Arvisenet, G. *(Soumise à Appetite)* How to fight malnutrition in Madagascar? A study combining food representations and consumer tests.

Ramaroson Rakotosamimanana, V., Arvisenet, G. & Valentin, D. (*Soumise à Journal of Sensory Studies*) Role of languages in food description: contrasting Malagasy and French descriptors of *Moringa oleifera* leaf powder

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Communications affichées lors des congrès internationaux:

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Ramaroson, V., Arvisenet, G. and Valentin, D. Bilingual panels: a tool to evaluate the role of language in descriptive tasks. 10th Pangborn Sensory Science Symposium, 11-15 August 2013, Rio de Janeiro, Brazil.

Ramaroson, V., Arvisenet, G., Razanamparany, L. and Valentin, D. Paradox between malnutrition and nutritional richness of foods in Madagascar: the example of *Moringa oleifera*. 8th International congress Taste, Nutrition, Health, 19 & 20 March 2013, Dijon, France.

Ramaroson, V., Razanamparany, L. and Valentin, D. Food choice factors in developing countries: The case of Madagascar. 5th European Conference on Sensory and Consumer Research, 9-12 September 2012, Bern, Switzerland.

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INTRODUCTION GENERALE

INTRODUCTION GENERALE

Dans le monde, plus d'un milliard de personnes vivent encore dans l'extrême pauvreté, et bien davantage souffrent de malnutrition. D'après le premier Objectif du Millénaire pour le Développement, ce chiffre doit baisser afin de réduire l'extrême pauvreté et la faim en 2015 (Banque Mondiale, 2014). D'après la même source, depuis l'an 2000, certains pays en développement ont réduit leur extrême pauvreté de moitié et sont parvenus à atteindre cet objectif plus tôt que prévu. Toutefois, cette étape n'a pas été franchie dans beaucoup de pays d'Asie du Sud et d'Afrique, tel que Madagascar. Mais tant que les facteurs responsables de la pauvreté ne sont pas éliminés ou ne sont pas diminués, il est difficile de croire à la disparition de la malnutrition.

Pour réduire la malnutrition, il est nécessaire d'identifier les facteurs responsables. Plusieurs acteurs de différents organismes internationaux issus de différents domaines, tels que la Banque Mondiale, le FMI, l'Unicef et le PAM, se sont attaqués à ce problème. La plupart de ces organismes sont arrivés à la conclusion que le facteur majeur est la pauvreté (Tanumihardjo, Anderson, Kaufer-Horwitz, et al., 2007). Bien que cette conclusion ne soit pas erronée, car le manque de moyens entraîne la faim, elle est quelque peu simpliste. En effet, d'autres facteurs que ceux liés au faible pouvoir d'achat jouent également un rôle.

Si on regarde le cas des pays développés, on peut également parler de problème de « malnutrition » quand on observe la prévalence élevée de l'obésité. De nombreuses études issues de différents domaines, telles que la psychologie ou la sociologie, cherchent à identifier les facteurs responsables du surpoids et de l'obésité. Parmi ces facteurs, le goût, l'émotion (Dressler & Smith, 2013; Stubbs, Blundell, & Caballero, 2013) et les mauvaises pratiques alimentaires (Bellisle & Dalix, 2006) semblent jouer un rôle important. Pour les pays sous développés, des facteurs tout aussi complexes peuvent être à l'origine de la malnutrition. Par exemple, selon Dettwyler (1986) au Mali, les sources de malnutrition chez les enfants sont en partie dues à des mauvaises pratiques et croyances alimentaires. D'après les croyances maliennes, si les enfants n'ont pas envie de manger, ils ne devraient pas être forcés à le faire ; s'ils ressentent le besoin de manger, ils prennent seuls la décision de manger. Dans cette thèse on s'intéressera au cas particulier de Madagascar. Comme cela a été mis en évidence au Mali, nous faisons l'hypothèse que la malnutrition n'est pas uniquement

due aux problèmes de pouvoir d'achat mais aussi aux pratiques et croyances[1] alimentaires et aux représentations de l'alimentation. Cette hypothèse repose sur les observations suivantes. Le pays est connu pour sa richesse en faune et flore (Lourenço, 1996) avec, par exemple, des plantes à feuilles comestibles appelées légumes-feuilles ou *brèdes* dont la plupart ont une valeur nutritionnelle élevée (Randrianatoandro, Avallone, Picq, Ralison, & Trèche, 2010). Mais, la plupart des ressources naturelles malgaches sont mal exploitées par la population locale. Face à cette observation, nous nous sommes demandés dans cette thèse: **Pourquoi existe-t-il encore une population mal nourrie à Madagascar alors que le pays possède de nombreuses ressources naturelles ? Pourquoi certaines ressources ne sont pas assez exploitées? Autrement dit pourquoi privilégie-t-on certains aliments et ne valorise-t-on pas d'autres, alors que ces autres aliments peuvent être bons nutritionnellement et disponibles ?** Nous nous sommes particulièrement intéressés à la plante *Moringa oleifera* (MO) qui a l'avantage d'être à la fois nutritive et localement disponible. MO, connu sous le nom d' «arbre miracle » (Fuglie, 1999) fait partie des ressources alimentaires pas suffisamment valorisées à Madagascar malgré ses caractéristiques nutritionnelles intéressantes (Moyo, Masika, Hugo, & Muchenje, 2011). Dans certains autres pays, les feuilles de cette plante ont été utilisées dans des programmes de lutte contre la malnutrition, par exemple en Afrique du Sud (Fahey, 2005; Moyo, Masika, Hugo, & Muchenje, 2011; Thurber & Fahey, 2009). Ces feuilles peuvent donc jouer un rôle important dans l'apport nutritionnel chez les personnes mal nourries (Freiberger, 1998; Thurber & Fahey, 2009). Plusieurs Organisations Non Gouvernementales, en particulier Trees for Life (USA), Church World Service (USA), Educational, Concerns for Hunger Organization ou ECHO (USA), GIANT (USA), Helen Keller International (Guinée) et Santé et Nature (Congo), ont recommandé MO comme « alimentation naturelle pour les pays tropicaux ». La plante MO est présente à Madagascar notamment sur les zones côtières de l'île où la population a déjà intégré les feuilles dans son alimentation depuis des années. Par contre, elle était méconnue des habitants du haut plateau avant 2008, année à laquelle l'ONN (Office Nationale de la Nutrition) a commencé à mener un programme de sensibilisation de la population malgache sur les bénéfices nutritionnels des feuilles de MO (Randrianarivelo, 2008). Bien que cette plante commence à être plantée sur les terres du haut plateau, ses

[1] Les croyances sont définis comme une connaissance cognitive des consommateurs, associée aux attributs, avantages et produits, tandis que les attitudes correspondent à la sensation individuelle ou aux réponses affectives face aux attributs des produits (Verbeke & Viaene, 1999).

feuilles ne font pas encore partie des aliments habituellement consommés au même niveau que les autres légumes-feuilles.

Ce manuscrit s'organise en quatre grands chapitres. Les données expérimentales y sont présentées sous forme d'articles scientifiques rédigés en anglais et de posters présentés lors de congrès internationaux.

Dans le premier chapitre, une **étude bibliographique** présente dans un premier temps Madagascar avec des informations sur la population, les langues, l'état économique, l'état nutritionnel de la population et les problèmes liés à l'alimentation. Dans un second temps, les facteurs influençant les choix alimentaires notamment chez les enfants et les populations à faible pouvoir d'achat sont abordés. La dernière partie de ce chapitre s'intéresse aux changements d'habitudes alimentaires en lien avec l'introduction de nouveaux aliments.

Le deuxième chapitre présente deux études visant à **caractériser des feuilles de MO** récoltées à Madagascar. La première étude évalue la composition nutritionnelle des poudres de feuilles de MO récoltées dans cinq villes du pays. Afin de voir s'il existe des variations selon les lieux d'origine, les teneurs en protéines, matières grasses, minéraux, acides aminés et acides gras ont été mesurées (Article 1 et Poster A). La deuxième étude s'intéresse à l'aspect sensoriel des feuilles de MO. Des poudres issues des cinq mêmes villes ont été évaluées sensoriellement par quatre panels non entraînés utilisant soit la langue française soit la langue malgache lors des descriptions des produits. (Article 2 et Poster B).

Le troisième chapitre présente les **pratiques nutritionnelles et croyances alimentaires** à Madagascar. Une combinaison de groupes focus et de questionnaires a été utilisée pour étudier les attitudes et croyances alimentaires des parents d'enfants issus de quatre lieux (Article 3 et Poster C).

Le quatrième chapitre presente deux études axées sur des produits formulés incorporant les feuilles de MO. La première étude présente les **pratiques et représentations autour des feuilles de MO et des racines de manioc** par les parents malgaches. Cette étude de représentation d'aliments est associée à des tests sensoriels hédoniques sur des produits formulés à base de manioc et de MO chez des enfants dans des écoles publiques (Article 4). La deuxième étude évalue les **apports nutritionnels des produits finis** après l'ajout de MO (Poster D).

CHAPITRE 1 :
REVUE DE LA LITTERATURE

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Cette thèse s'intéresse à la population malgache, ses habitudes, attitudes et croyances alimentaires. La revue bibliographique présente dans une première partie quelques données sur Madagascar et sa population. Ensuite, la deuxième partie s'intéressera à la notion de choix alimentaire et la troisième partie aux changements d'habitude alimentaire.

A. Madagascar : son économie, sa population et sa nutrition

I. Caractéristiques de la population malgache

La population malgache a été évaluée à 22 599 098 habitants en Juillet 2013. Elle est essentiellement rurale (86 %) mais inégalement répartie sur le territoire avec une densité plus élevée sur les Hautes Terres avec 5 % de la population à Antananarivo ville, la capitale (INSTAT, 2010).

Le peuple malgache est formé de 18 ethnies qui sont caractérisées par des styles de vie, des dialectes, des traditions et des croyances différents. L'extrême variété des caractéristiques ethniques peut s'expliquer par l'histoire du peuplement de l'île à travers les vagues d'immigration successives et la cohabitation avec les premiers habitants de l'île, dont les Austro mélanésiens (Randriamandimby, 1981; Serva, 2012), puis plus tard les populations Africaines parlant la langue Bantoue (Hewitt, Krause, Goldman, Campbell, & Jenkins, 1996; Poetsch, Wiegand, et al., 2013).

D'après la dernière enquête démographique et de santé réalisée en 2008-2009, la taille moyenne des ménages est de 4,7 personnes, plus élevée en milieu rural (4,8) qu'en milieu urbain (4,4) (INSTAT, 2010). La population malgache est constituée majoritairement de jeunes avec 64 % de la population ayant moins de 25 ans et 47 % moins de 15 ans (INSTAT, 2010).

II. Caractéristiques d'Antsiranana et d'Antananarivo

Madagascar est une île localisée dans l'Océan Indien, à 400 km à l'est de la côte africaine. Ce pays est composé de 22 régions issues des découpages des six anciennes provinces. Ces dernières deviennent actuellement les ex-provinces autonomes portant les noms de leurs plus grandes villes : Antsiranana, Mahajanga, Toamasina, Antananarivo, Fianarantsoa et Toliara.

Des différences entre les régions sont dues aux variations ethniques, culturelles, économiques, climatiques, géologiques, agricoles… Par exemple, sur le haut plateau, à cause

de la haute altitude, on peut observer des différences de température entre les deux saisons, tandis que sur les zones côtières, le climat reste chaud pendant toute l'année. Ceci entraîne, par conséquent, des différences en termes de végétation entre le haut plateau et les côtes. Pour illustrer ces différences, nous allons nous focaliser sur les villes d'Antsiranana qui est une zone côtière et d'Antananarivo qui est sur le haut plateau.

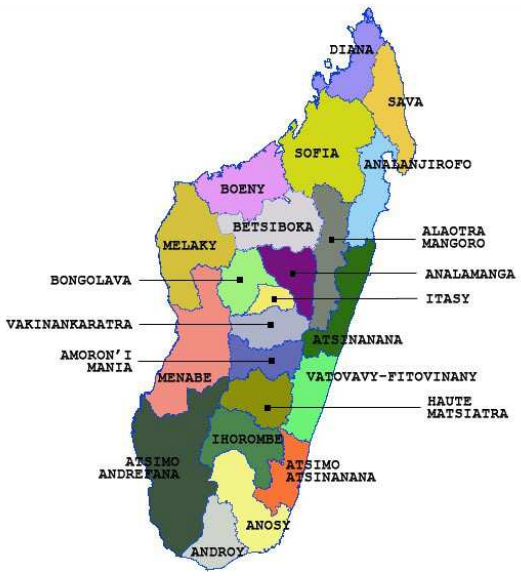

Figure 1. Carte de Madagascar montrant les 22 régions

Antsiranana

La ville d'Antsiranana, appelée aussi Diégo Suarez, fait partie de la région Diana (Figure 1). Elle est située à l'extrême nord de Madagascar à 12° 28′ 01″ S 49° 28′ 01″ E. Deux sous-préfectures constituent cette ville : Antsiranana I (Antsiranana urbain) et Antsiranana II (Antsiranana rural). Antsiranana urbain est la capitale économique de la région du nord, tandis qu'Antsiranana rural a uniquement une vocation agricole.

L'effectif de la population de la région Diana a été répertorié comme étant le plus faible par rapport à ceux des autres régions. D'après l'inventaire des districts de Madagascar en 2001, il existait 98456 et 77218 individus à Antsiranana I et II respectivement. La majorité de la population est constituée d'ethnies *Antakarana* et *Sakalava*. Les croyances et les traditions *Antakarana* sont intimement liées aux « divinités naturelles » qui peuvent être incarnées par un arbre, une plante, une montagne, une chute d'eau, un lac ou un autre élément de la nature (MAEP, 2003b).

Les écoles primaires publiques (EPP) sont au nombre de 16 à Antsiranana urbain et 111 à Antsiranana II. Il existe respectivement 2 et 7 collèges publics dans ces deux zones. Un seul lycée est repertorié à Antsiranana (MAEP, 2003b).

La région est soumise à un climat de type tropical. Il est caractérisé par une alternance d'une saison sèche de mai à novembre et d'une saison humide et chaude à partir de décembre. Les températures moyennes annuelles de la région sont relativement élevées toute l'année (entre 20 et 26°C). La ville d'Antsiranana est aussi caractérisée par la présence d'une saison du vent d'Alizé, le « Varatraza », entre Avril et Novembre (MAEP, 2003b).

Seule 8,5 % de la superficie cultivable de la région Diana est exploitée pour des cultures vivrières, de rente et industrielle. La culture vivrière occupe 67 % de la surface cultivée, dont 4/5 est occupée par le riz. Elle concerne également la culture de manioc, maïs, haricot, patate douce, pomme de terre… La culture de rente, occupant 19 % de la surface cultivée, regroupe la culture de café, cacao, poivre et vanille. La culture industrielle occupe 13 % de la surface et est focalisée sur la culture de canne à sucre, arachide et coton. La culture de fruits et légumes occupe une faible proportion de la terre cultivée. En plus de l'élevage bovin, la pêche occupe une grande partie des activités de la population : pêche maritime traditionnelle et artisanale et pêche industrielle (MAEP, 2003b).

Antananarivo

La ville d'Antananarivo est située au centre du pays et fait partie de la région Analamanga (Figure 1). Sa situation géographique est 18° 53′ S 47° 31′ E. Elle est divisée en trois sous-préfectures : Antananarivo Renivohitra (Antananarivo urbain), Antananarivo Antsimondrano et Antananarivo Avaradrano. Ces deux dernières sous-préfectures représentent Antananarivo rural. Antananarivo urbain a une superficie de 88 km² (Wikipedia, 2014).

La région Analamanga se caractérise par :

- sa situation de métropole nationale : à la fois capitale de Madagascar et centre politique, administratif et économique du pays.
- sa géographie spécifique constituée de haut plateau, de collines plus ou moins escarpées et de massifs volcaniques (MAEP, 2003a).

Le nombre total de la population à Antananarivo a été estimé à 2 000 000 en 2010. L'effectif de la population est plus important en milieu rural (environ 65 %) qu'en milieu

urbain (MAEP, 2003a). Du point de vue ethnique, la majorité de la population est composée de *Merina.*

Au niveau de l'enseignement public, le nombre d'écoles primaires publiques est de 89, 129 et 53 à Antananarivo urbain, Atsimondrano et Avaradrano respectivement, d'après la direction de l'enseignement secondaire et de l'éducation de base en 2001-2002. D'après la même source, le nombre d'écoles primaires privées est plus important : 328, 169 et 128 respectivement. Le nombre de collèges et de lycées publics varie également selon les sous-préfectures. Les taux de scolarisation varient de 21,7 à 27,2 % dans les trois sous-préfectures d'Antananarivo. En ce qui concerne l'enseignement supérieur, la plus grande université publique malgache est localisée à Antananarivo.

La région Analamanga fait partie du régime climatique tropical d'altitude, supérieure à 900 mètres. Elle est caractérisée par une température moyenne annuelle inférieure ou égale à 20°C. L'année comporte deux saisons bien individualisées : une saison pluvieuse et moyennement chaude, de Novembre à Mars et une autre fraîche et relativement sèche, durant le reste de l'année. Il existe aussi de nombreux sous-climats (MAEP, 2003a).

Au niveau de l'agriculture, la culture vivrière, localisée uniquement en zone rurale d'Antananarivo, occupe plus de 95 % des superficies cultivées. Les principales cultures sont le riz, le manioc, le maïs, la patate douce, le haricot et la pomme de terre (MAEP, 2003a).

III. Langues utilisées par la population malgache et bilinguisme

Bien que le peuple malgache soit diversifié, une langue officielle est pratiquée à Madagascar : la langue Merina. Elle a plusieurs origines, dont l'influence arabe et du groupe austronésien, notamment indonésiens (Dahl, 1951; Randriamandimby, 1981; Rondreux, 1972). En plus de la langue officielle, chaque ethnie, autre que celle de la capitale, pratique un dialecte. Vingt-trois dialectes différents ont été répertoriés dans toute l'île (Dahl, 1951).

Depuis la colonisation française, qui a débuté en 1895, la langue française est devenue la deuxième langue pratiquée à Madagascar. Bien que, le français reste la langue officielle dans l'enseignement et l'administration depuis l'indépendance de Madagascar (1960), une grande proportion de la population malgache ne maîtrise pas correctement cette langue. Rondreux (1972) parle de bilinguisme imparfait ou non équilibré (ou *diglossie*) qui se définit comme étant une forme de bilinguisme dont la deuxième langue n'est pas maîtrisée avant la cinquième année de l'existence au même degré que la première langue. La diglossie stricte (les deux langues lues, parlées et écrites mais prépondérance de la première langue) par

rapport à la langue française est observée chez certaines personnes ayant atteint le niveau universitaire, celles qui ont pratiqué cette deuxième langue au cours de leur cursus scolaire. La plupart des diglottes malgaches sont soit des diglottes récepteurs (la deuxième langue comprise mais non parlée), soit des diglottes techniques (la deuxième langue comprise dans le seul domaine de la spécialité de l'usager).

IV. Etat économique du pays, pouvoir d'achat de la population

Economiquement, Madagascar fait partie des pays les moins avancés de l'Afrique subsaharienne. Plus de 92 % de la population vit avec moins de deux dollars PPA (parité de pouvoir d'achat) par jour (World Bank, 2013). Ces deux dollars (~ 4500 MGA) permettent, par exemple, d'acheter au marché seulement ¾ kg de riz (1300 MGA), trois tas de brèdes (1000 MGA), quatre cuillères à soupe d'huile (300 MGA), trois oignons (200 MGA), trois tomates (200 MGA), dix beignets traditionnels (500 MGA) et ½ kg de charbon (1000 MGA) pour nourrir une famille de cinq personnes pendant une journée. La viande ne peut pas entrer dans la liste d'achat à cause de son prix élevé : un kilogramme de viande de bœuf coûte 8000 MGA (en Janvier 2014).

La croissance de Madagascar a été affectée par de nombreuses crises politiques et sociales (Ralambomahay, 2011). Suite à la quatrième crise politique entre 2009 et 2013, le pays a été classé économiquement à la 135ème place sur 169 pays en 2010.

La majorité de la population pauvre est localisée dans les zones rurales, lieux où le secteur agricole prédomine : 82 % contre 14 % en milieu urbain. 73 % de femmes et 74 % d'hommes pratiquent l'agriculture (Barrett & Minten, 2003; INSTAT, 2010). Une grande proportion de la population urbaine se classe dans les deux quintiles les plus riches (93 %). À l'opposé, en milieu rural, cette proportion n'est que de 31 %. Entre les régions, on constate également des écarts importants. En effet, dans la région d'Analamanga (au centre), 84 % de la population sont classés dans les deux quintiles les plus riches et 5 % dans les deux plus pauvres (INSTAT, 2010; Razafindravonona, Stifel, & Paternostro, 2001).

Divers facteurs limitent le développement de l'économie de l'île tels que la faiblesse des performances agricoles (Minten & Barrett, 2008), l'état du réseau routier (IMF, 2003), les catastrophes naturelles (OECD African Development Bank, 2006).

D'après l'enquête nationale sur les ménages réalisée par l'INSTAT (Institut National de la Statistique de Madagascar) en 2001, les gens les plus pauvres à Madagascar, souvent non qualifiés et apatrides, utilisent le système de culture de subsistance, qui est une

agriculture de survie avec peu ou pas de récolte à vendre, comme dans la plupart des pays d'Afrique subsaharienne (Tangtrakul, 2010). La limitation de la culture à petite échelle provient du fait que les ménages pauvres ne possèdent pas assez de terrain à exploiter. En plus des crises « interminables », le pays connaît, chaque année, une période de pauvreté saisonnière qui touche les populations les plus pauvres, notamment les populations rurales. Cette période, appelée « période de soudure », dure quatre mois et demi et s'étend de Novembre à Février (Minten & Barrett, 2008) et correspond à un épuisement précoce des récoltes jusqu'aux nouvelles récoltes. Les périodes de soudure sont marquées par l'adoption de stratégies de survie au sein des ménages, dont la réduction du nombre de repas par jour.

V. Etat nutritionnel de la population malgache : malnutrition

V.1. Situation de la malnutrition à Madagascar

Madagascar est l'un des pays les plus touchés par le problème de la malnutrition (Figure 2). Le niveau d'insécurité alimentaire, défini par rapport au pourcentage de la population n'ayant pas assez à manger de façon permanente ou temporaire, est évalué au niveau national à plus de 50 %, d'après l'enquête nationale sur les ménages en 2001 (INSTAT, 2003).

Comme dans la plupart des pays d'Afrique subsaharienne et ceux en voie de développement, la malnutrition protéino-énergétique est la plus répandue. En 2001, les disponibilités énergétiques alimentaires (DEA) ont été évaluées à 2048 kcal/per capita/jour, disponibilités insuffisantes pour couvrir les besoins énergétiques moyens de la population (2129 kcal/per capita/jour) (FAO, 2005).

D'importantes carences en micronutriments sont associées à la malnutrition. Le goitre sévit encore dans certaines régions, malgré une consommation assez répandue de sel iodé. Comme l'alimentation apporte peu de lipides et peu de produits riches en vitamine A, la carence en vitamine A est courante, en particulier chez les mères. L'anémie touche quant à elle surtout les groupes vulnérables, enfants préscolaires et femmes en âge de procréer (INSTAT, 2010).

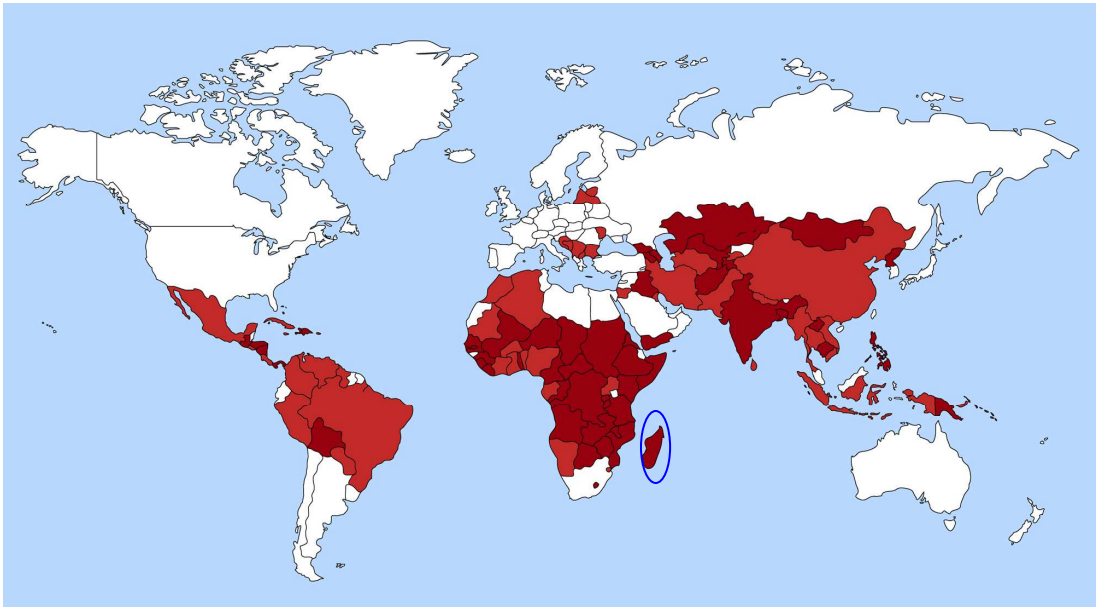

Figure 2. Carte montrant les zones au monde touchées par la malnutrition (rouge bordeau : avec 20-35 % de la population sévèrement malnutrie, rouge vif: avec 5-19 % de la population malnutrie, blanc : taux faible de malnutrition) (Trees For Life, 2013)

V.2. Origine de la malnutrition

La malnutrition à Madagascar peut être expliquée par la présence de plusieurs facteurs. La pauvreté est le premier facteur responsable de cette malnutrition. La variabilité des prix des aliments s'y ajoute et est devenue un problème important depuis la libéralisation des prix. Soumis aux fluctuations saisonnières et régionales, les prix peuvent tripler dans certaines régions pendant les périodes de soudure. En plus de l'insuffisance d'emploi, de la faiblesse des revenus et de l'inflation, les catastrophes naturelles (affectant 49 % des ménages) viennent accentuer le problème de la malnutrition en limitant l'accès aux aliments (affectant 56 % des ménages) (INSTAT, 2010). Chez les paysans cultivateurs, l'insuffisance de disponibilité provient d'une insuffisance en surface de plantation et donc d'une insuffisance de production agricole destinée à l'autoconsommation (Minten & Barrett, 2008).

D'après Galasso & Umapathi (2007), les causes immédiates de la malnutrition sont basées sur trois piliers interactifs : le rôle des nutriments à travers la prise alimentaire et la supplémentation, le rôle des services de santé et de protection contre les maladies, et le rôle de service de soin envers les enfants. Selon Ramakrishnan & Huffman (2008), dû au manque de moyen financier des ménages dans les pays sous-développés, les aliments sources de micronutriments, tels que les produits d'origine animale sont souvent chers et inaccessibles. Ceci entraîne un régime alimentaire de mauvaise qualité avec une consommation insuffisante,

par exemple, en vitamines A et B12, fer, folate et zinc. De plus, la biodisponibilité de la plupart des micronutriments est affectée par la combinaison des aliments consommés dans un même repas, la présence d'inhibiteurs (e.g., les facteurs anti-nutritionnels) et le mode de préparation. Quand un régime déficient en micronutriments touche les mères, il est responsable d'un état nutritionnel pauvre avant même que l'enfant naisse, et conduit à un retard de croissance au cours du développement de l'enfant (Figure 3).

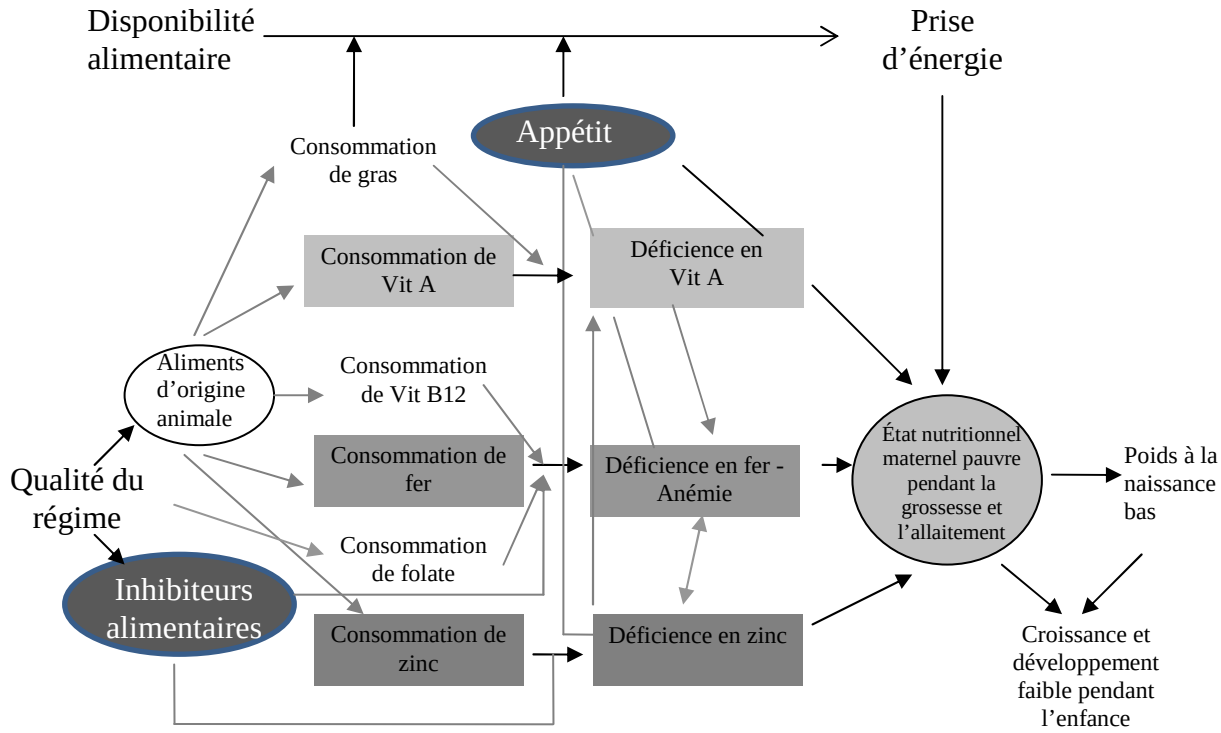

Figure 3. Origines et conséquences de la malnutrition multiple en micronutriments (Ramakrishnan & Huffman, 2008).

V.3. Programmes de lutte contre la malnutrition

Afin de lutter contre l'insécurité alimentaire, des programmes d'aide alimentaire ont été mis en place à Madagascar, tel que le SECALINE (SECurité ALImentaire et Nutritionnelle Elargie) avec comme composantes principales le PCN (Programme Communautaire de Nutrition), le FID (Fonds d'Intervention pour le Développement), la SNSALP (Stratégie Nationale de Sécurité Alimentaire dans la Lutte contre la Pauvreté) et le volet IEC (Information - Education - Communication). Depuis 1999, le Ministère de la Santé de Madagascar assure également la prise en charge des enfants sévèrement malnutris au niveau des CRENI (Centres de RENutrition) de 39 Centres Hospitaliers de Districts, avec l'appui de l'UNICEF et de la Banque Mondiale. En 2004, Madagascar a adopté la PNN

(Politique Nationale de Nutrition) pour combattre la malnutrition et ses conséquences, compte tenu des Objectifs du Millénaire pour le Développement, et assurer un développement rapide et durable. Le document du PNAN 2005-09 (Plan National d'Action pour la Nutrition), qui traduit la PNN en actions concrètes, a été validé en 2005. L'élaboration de la PNN et la validation du PNAN ont été réalisées d'une façon multisectorielle et pluridisciplinaire. Les partenaires de la lutte contre la malnutrition sont : la société civile, le secteur privé, les ONG nationales, des institutions nationales (groupes professionnels, universités) et la communauté internationale telle que la Banque Mondiale, l'UNICEF, l'OMS, la FAO, le PAM, l'UNESCO, l'USAID, l'Union Européenne, la Coopération Japonaise, le CARE et le Catholic Relief Services.

En matière de lutte contre les carences en micronutriments, la stratégie porte sur le développement et le renforcement des trois axes suivants : (1) la supplémentation en micronutriments (vitamine A et fer), (2) la fortification des aliments clés (par exemple, le sel iodé) et (3) la diversification alimentaire et l'amélioration de l'utilisation des aliments au niveau des ménages (pour augmenter l'apport alimentaire en micronutriments, en particulier en vitamine A et en fer). Ces trois axes nécessitent une amélioration et une diversification de la production, portant notamment sur la productivité vivrière, surtout dans les zones d'insécurité alimentaire, au travers du développement de jardins potagers et fruitiers, de la pisciculture, du petit élevage, et du renforcement des marchés locaux.

V.4. Etat nutritionnel des enfants

Le problème de malnutrition chez les enfants mérite une attention particulière puisqu'il est admis que toute forme de retard de croissance pourrait entraîner un déficit physique et cognitif irréversible (Behrman, 1996; Shrimpton, Victoria, de Onis, et al., 2001). De plus, la malnutrition met les enfants en position vulnérable face aux maladies, telles que les maladies respiratoires, les maladies liées aux carences (e.g., Beriberi, Kwashiorkor).

D'après les résultats récents des enquêtes de l'UNICEF en 2013, la prévalence du retard de croissance (malnutrition chronique[2]) est très élevée (48 % chez les enfants malgaches de moins de cinq ans), ainsi que l'insuffisance pondérale (13 %). Ces chiffres sont supérieurs aux pourcentages moyens dans la région de l'Afrique subsaharienne (37 % et 9 % respectivement), au Moyen-Orient (24 % et 8 % respectivement), mais se rapprochent de ceux

[2] Malnutrition chronique : défini comme un retard de développement de l'enfant, notamment un retard de croissance, d'après l'UNICEF

des pays de l'Asie du Sud (45 % et 14 % respectivement). Chez les enfants d'âge préscolaire, la prévalence de carence sub-clinique en vitamine A est de 6 % (FAO, 2005). Aucun recul important de la malnutrition n'a pu être observé depuis plus d'une décennie à Madagascar (FAO, 2005). Au contraire, avec la dernière crise politique, la malnutrition aigüe a augmenté de plus de 50 % (World Bank, 2013).

C'est en milieu rural que la proportion d'enfants accusant un retard de croissance est la plus élevée (51 % contre 43 % en urbain). Sous la forme sévère[3], 27 % des enfants en milieu rural sont concernés (World Bank, 2013). A Antananarivo ville, 36 % des enfants scolarisés dans des écoles primaires sont atteints d'un retard de croissance (Razafimanantsoa, Razafindramaro, Raherimandimby et al., 2013).

La proportion d'enfants souffrant de malnutrition chronique varie également de manière sensible avec le niveau d'instruction de la mère : c'est chez les enfants dont la mère a un niveau primaire que la prévalence de malnutrition est la plus élevée (52 %) (Galasso & Umapathi, 2007; INSTAT, 2010). Les mères ne connaissent pas intuitivement les bonnes pratiques alimentaires et la connaissance de ces bonnes pratiques ne leur vient pas automatiquement. Malheureusement, les mères ne reconnaissent pas toujours quand leurs enfants ne grandissent pas correctement ou souffrent de malnutrition modérée[4]. Afin de lutter contre la malnutrition chez les enfants, un des moyens serait d'améliorer la connaissance des mères en matière de nutrition, d'hygiène et de pratiques alimentaires (Galasso & Umapathi, 2007).

VI. Autres problèmes alimentaires à Madagascar

V.1. Problème d'hygiène

Le problème lié à l'alimentation malgache ne se limite pas uniquement à l'insuffisance de disponibilité en nutriments mais aussi aux mauvaises conditions d'hygiène dans les pratiques alimentaires. Chez les vendeurs d'aliments dans les petits restaurants appelés « gargottes » dans la ville d'Antananarivo, on trouve, dans la majorité des cas, une contamination fécale des aliments due à *Escherichia coli* et à *Salmonella* spp., responsables

[3] Le retard de croissance sévère : défini comme correspondant à un rapport taille/âge inférieur à -3 z-scores en dessous de la médiane indiquée par les normes OMS de croissance de l'enfant

[4] Malnutrition modérée : définie comme correspondant à un rapport poids/âge entre -3 et -2 z-scores en dessous de la médiane indiquée par les normes OMS de croissance de l'enfant. Elle peut être due à un faible rapport poids/taille (amaigrissement/emaciation) ou à un faible rapport taille/âge (retard de croissance) ou à une combinaison des deux

de toxi-infections alimentaires (Sarter & Sarter, 2012). Le non respect de l'hygiène se manifeste sous forme (1) de la non protection des aliments contre les contaminations pouvant être apportées par l'air, la présence d'objets incongrus et d'insectes, le non stockage des aliments au réfrigérateur, (2) de la non utilisation de produits désinfectants comme la chlorination d'eau, (3) du non accès à l'eau directe au niveau du lieu de vente, (4) du non lavage fréquent des mains, (5) de la réutilisation d'eau usée lors du nettoyage des mains et de la vaisselles, et (6) de l'association entre propreté et esthetisme (par exemple, à partir du moment où les couleurs claires dominent, les vendeurs jugent leurs locaux comme étant propres). En accord avec ces observations, les données de l'Organisation Mondiale de la Santé ont montré que 18 % des cas de mortalité sont dus aux maladies diarrhéiques, 3ème cause de mortalité après la malaria et les infections respiratoires dans les pays sous développés (WHO, 2006).

V.2. Interdits et tabous alimentaires

Les interdits et tabous (*fady*) s'insèrent dans les pratiques et choix alimentaires de certaines ethnies ou tribus. Ils peuvent être spécifiques à une ethnie ou à un village, voire une descendance familiale. Souvent, ils ont été créés par les « grands hommes » du passé (les ancêtres) et sont très respectés dans des zones enclavées où le niveau d'instruction est moins élevé. Le *fady* fait objet d'une ambivalence : d'une part, protéger certains aliments considérés comme étant des objets sacrés et, d'autre part, interdire une liste d'aliments pour consommation suite à des expériences négatives (Razafimpahanana, 1970 ; François, 1968). Par exemple, si une personne décède ou tombe malade après avoir mangé un aliment, ce dernier peut devenir interdit pour toute la société. Par faute de connaissance et de moyen de vérification, les gens préfèrent imposer cet aliment comme *fady*, pour éviter que celui-ci empoisonne encore d'autres personnes (Graeber, 2007). Selon François (1968, p.118) la base du mécanisme psychologique du *fady* malgache serait que « lorsque l'ouverture sur les sciences exactes et leurs schémas opérationnels est minime ou inexistante, les hommes en société recherchent une explication des phénomènes dans l'irrationnel conçu comme le domaine de forces occultes non totalement discernables, parfois bénéfiques, parfois nocives. »

Le *fady* intègre la culture malgache comme un moyen d'imposer également certaines règles de bonne conduite ou d'éducation. Le non respect de ces *fady* par une personne peut avoir des répercussions d'ordre mental, telle que la peur d'être frappé par le courroux des

ancêtres, ou de perdre la richesse, ou d'attraper la maladie, voire même la mort (Walsh, 2002).

Pour les ethnies *Antakarana* et *Sakalava* (peuples du nord où l'on constate des traces d'influence musulmane), la viande de porc fait partie des aliments *fady* (Gennep, 1904 ; François, 1968). Dans l'étude de Brown (1999) dans le nord de Madagascar, si la plupart des villageois ont tendance à agir de façon à ne pas violer les *fady*, c'est uniquement pour ne pas attraper la lèpre. Presque tous les gens dans cette étude ont été convaincus que la maladie est la conséquence d'avoir mangé un aliment fady. Ces tabous et croyances reliés aux aliments n'ont donc pas été mis en place pour des raisons nutritives, encore moins d'ordre gustatif.

B. Les facteurs impliqués lors des choix alimentaires

Il est admis que le répertoire alimentaire est lié à une culture : « Dis moi ce que ce que tu manges et je te dirai qui tu es. » (Rozin, 1996a). Bien que la nature offre une multitude d'aliments comestibles, seule une petite proportion de ces aliments est acceptée par une culture. Si les Occidentaux ne mangent pas d'insectes, ce n'est ni pour des raisons de disponibilité ni pour des questions d'éventuels effets toxiques voire physiologiques (Fishler, 1990). D'après Bisogni, Connors, Devine, & Sobal (2002), l'identité d'une personne, d'une ethnie ou d'un peuple se reflète à travers les aliments qu'il ou elle considère comme étant mangeable et la façon dont il ou elle les prépare. Savoir pourquoi un peuple consomme tel aliment mais pas tel autre a toujours préoccupé les sociologues, les psychologues, les chercheurs en santé, voire même les industriels de l'agroalimentaire.

I. Les déterminants du choix alimentaire

Selon Fishler (1990), si nous consommons certains aliments, « c'est tout simplement parce qu'ils sont **disponibles**, parce que nous **aimons leur goût**, parce que notre **corps les exige** ou qu'ils présentent des avantages pour lui. La disponibilité et le **coût** sont à l'évidence des conditions nécessaires à la consommation. » Plusieurs modèles (Khan, 1981; Land, 1983; Pilgrim, 1957; Randall & Sanjur, 1981; Shepherd, 1985) ont été introduits pour expliquer les choix alimentaires. Trois grands groupes de facteurs ressortent de ces modèles: les aliments, la personne et l'environnement extérieur (Figure 4).

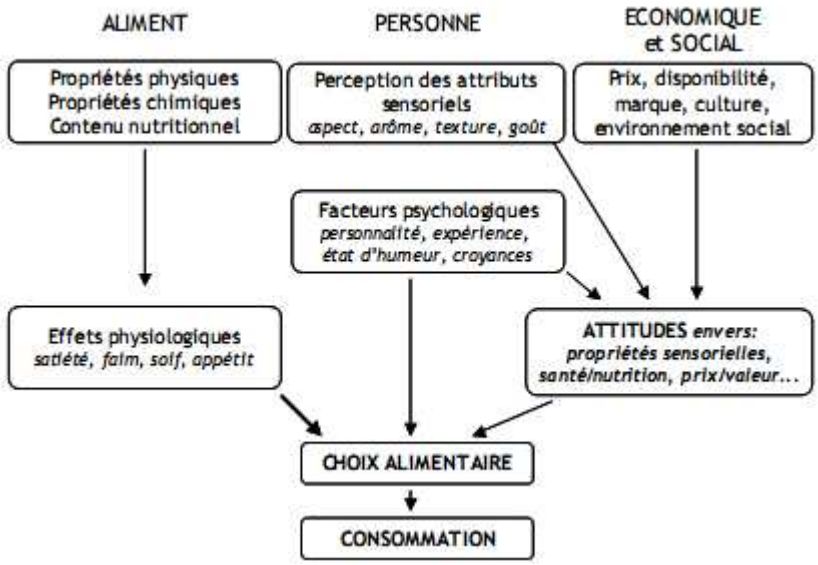

Figure 4. Modèle de Shepherd (1985)

I.1. L'aliment à choisir

Le déterminant « aliment » intervient dans le choix d'un aliment selon ses propriétés physico-chimiques et sa teneur en éléments nutritifs. La composition nutritionnelle de l'aliment entraîne des signaux physiologiques chez l'individu qui entraînent un ajustement extrêmement fin de la prise alimentaire pour satisfaire des besoins non seulement énergétiques, mais aussi métaboliques, contribuant ainsi à la régulation du bilan énergétique de l'individu (Bellisle, 2003). Comme exemple de signal physiologique, on peut citer la satiété et le rassasiement, la faim et l'appétit (Shepherd, 1985). Par définition, la satiété est un état d'inhibition de la faim (réduction de la sensation de faim). Quant au rassasiement, c'est le processus qui conduit à l'arrêt de la prise alimentaire et contrôle la taille de la prise alimentaire. D'après l'OMS, la faim se définit comme étant l'ensemble des sensations provoquées par la privation de nourriture, qui incitent l'homme ou l'animal à rechercher des aliments, et que l'ingestion de nourriture fait disparaître. La faim signale, de façon interne et innée, le besoin en aliments (Rozin, 2007). L'appétit se manifeste par un désir de manger.

Dès l'enfance, l'individu humain a une auto-capacité propre à choisir l'alimentation répondant à ses besoins nutritionnels (Davis, 1928) grâce à son système nerveux gastro-intestinal. Ce système est impliqué dans le contrôle de l'équilibre entre la faim et la satiété, ainsi que dans la stimulation de l'appétit et la consommation de nourriture (Houpt, 1982; Mithieux, 2013). Fishler (1990) appelle cette capacité la « sagesse du corps ». Le rassasiement intervient, par la suite, dans l'arrêt de la prise de nourriture en limitant la quantité d'aliment à

consommer (Cummings & Overduin, 2007). L'homme, comme tout animal, a le besoin de chercher suffisamment de sources énergétiques provenant des aliments pour maintenir ses fonctions vitales et pour supporter les activités de survie (De Graaf, 2007; Rozin, 2007).

Pouvoir rassasiant des aliments

Le pouvoir rassasiant d'un aliment est le facteur le plus important par rapport aux nutriments ou substances que le corps ingère (Booth, 2003; Halford, Hill, & Blundell, 2005). Ce pouvoir rassasiant peut être perçu par les consommateurs et mesurable quantitativement grâce à la connaissance de la composition de l'aliment.

Les participants de l'étude de Burns, Cook, & Mavoa (2013), provenant d'une population ayant un faible pouvoir d'achat, ont décrit un aliment rassasiant en termes de quantité et de provision d'énergie nécessaire pour les activités physiques. Cette représentation est cohérente avec des études physiologiques indiquant que le rassasiement est déterminé par le volume, le contenu en macronutriments, le goût et la densité énergétique de l'aliment (Booth, 2003). Les mêmes participants ont aussi décrit le pouvoir rassasiant en termes qualitatif ou par types d'aliments. Ils ont associé ce pouvoir aux aliments riches en glucides et aux produits amylacés (pain, riz, pomme de terre et pâte), bien que les glucides ne soient pas le macronutriment le plus rassasiant : ils le sont moins que les protéines d'après certaines études (Anderson, Tecimer, Shah, & Zafar, 2004; Fiszman, Varela, Diaz, Linares, & Garrido, 2014). L'association entre la catégorie d'aliments glucidiques et le rassasiement peut sans doute s'expliquer en termes économique : les glucides font partie des aliments rassasiants qui sont accessibles à cette classe de population (Raffensperger, 2008).

L'état de l'aliment joue également un rôle important dans le phénomène de rassasiement. Moins il y a d'eau dans l'aliment, plus il a un effet rassasiant. Les aliments solides ont donc un effet rassasiant plus élevé que les aliments liquides (Hulshof, De Graaf, & Weststrate, 1993; Mattes, 1996), à l'exception des soupes (Mattes, 2005).

Il existe également une autre forme de rassasiement qui régule les prises alimentaires : le **rassasiement sensoriel spécifique** (Rolls, Rolls, Rowe, & Sweeney, 1981). Il se traduit par une diminution de l'appréciation d'un aliment au cours de son ingestion pendant un repas, par rapport aux aliments qui n'ont pas été consommés. Ce phénomène est principalement lié aux propriétés sensorielles des aliments, et est très peu dépendant de leur valeur énergétique et nutritionnelle.

I.2. La personne lors de son choix alimentaire

Le mangeur est l'acteur principal du choix alimentaire, en agissant par rapport à la fois à ses préférences sensorielles, ses attitudes et croyances et ses habitudes.

Préférences sensorielles

Les propriétés organoleptiques sont souvent regroupées sous le terme « goût » dans le langage courant. Ces propriétés influent sur les préférences alimentaires. De nombreux travaux ont mis en évidence le rôle considérable joué par les propriétés organoleptiques des produits dans les choix alimentaires (De Graaf, 2007), notamment dans les pays industrialisés. Par exemple, Furst, Connors, Bisogni, Sobal, & Falk (1996) ont interviewé 29 adultes sur les critères qu'ils utilisent lors de leur achat d'aliments aux Etats-Unis. Les aspects sensoriels apparaissent en première position avant l'aspect économique, la santé et les bénéfices nutritionnels, la commodité, la relation sociale et la qualité des décisions de choix alimentaire. L'importance du goût a été également observée lors d'une enquête réalisée sur 2967 personnes par Glanz, Basil, Maibach, Goldberg, & Snyder (1998) à Hawaii, avant le prix, la nutrition, la commodité et le contrôle de poids quelques soient les facteurs démographiques. Plus récemment, Januszewska, Pieniak et al. (2011) ont mis en évidence lors d'une étude réalisée en Belgique, Hongrie, Roumanie et Philippines que l'aspect sensoriel reste le facteur le plus important par rapport à la santé, la commodité et le prix quelque soit le pays. Selon Sobal, Bisogni, Devine, & Jastran (2006), la prépondérance des propriétés organoleptiques dans le choix alimentaires pourrait s'expliquer par le fait que ces propriétés sont les premières à être en contact direct avec le consommateur pendant qu'il consomme l'aliment ou la boisson. En revanche, il est important de souligner que le « goût » n'est pas le seul et l'unique facteur qui guide une prise alimentaire (De Graaf, 2007; Rozin, 2007). Rozin (2006) illustre ceci à travers la consommation de bœuf. Si les Chinois peuvent préférer le bœuf comparé au riz, le riz reste toujours le plus consommé à cause des facteurs culturel, géographique et économique.

Attitudes

Dès 1935, Allport définissait l'attitude comme étant « un état mental de préparation, organisé au travers de l'expérience, exerçant une influence directrice ou dynamique sur la réponse de l'individu à tous les objets et situations avec lesquels il est en relation » (Allport,

1935, p.798). Plus tard, Kraus a défini les attitudes, comme des constructions psychologiques relativement permanentes et stables correspondant à des résumés évaluatifs d'un item (Kraus, 1995). Verbeke et Viaene (1999), quand à eux, ont parlé d'associations stockées en mémoire à long terme entre un objet donné et l'évaluation, positive ou négative, de cet objet.

Selon la Théorie du Comportement Planifié ou TCP (Ajzen, 1991), les attitudes joueraient un rôle important dans les comportements. Cette théorie postule que le comportement humain, pour être effectif, doit d'abord être décidé/planifié. La planification des comportements s'appuierait sur trois types de facteurs. Le premier facteur est l'attitude par rapport au comportement et se réfère aux jugements sur la désirabilité du comportement et de ses conséquences. Le deuxième est un facteur social, basé sur les normes sociales se referant aux considérations sur l'influence et l'opinion des proches par rapport au comportement. Et le troisième facteur est l'auto efficacité, qui renvoie aux croyances du sujet sur sa capacité à réussir le comportement (Figure 5).

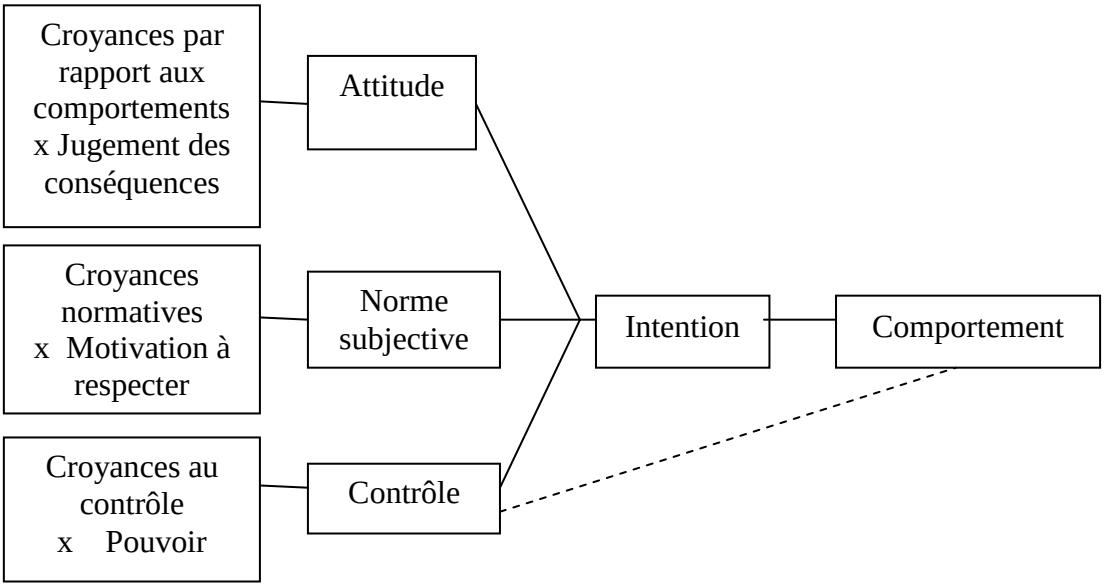

Figure 5. Représentation schématique de la théorie du comportement planifié (Shepherd & Raats, 1996)

La théorie du comportement planifié a été utilisée dans différents domaines : le marketing (Chiou, 1998), les interventions sur l'amélioration des pratiques sanitaires en alimentation (Milton & Mullan, 2012), la promotion des aliments bons pour la santé (Povey, Conner, Sparks, James, & Shepherd, 2000), etc. Ces études mettent toutes en évidence l'effet des intentions dans les comportements. Dans l'étude de Milton & Mullan (2012) par exemple la TCP a été appliquée dans une intervention pilote basée sur l'étude de comportement en lien

avec des problèmes sanitaires alimentaires. Cette étude a été réalisée pendant quatre semaines chez des jeunes adultes australiens et a montré qu'il est possible d'appliquer la TCP dans le cadre de l'amélioration du comportement hygiénique avec les aliments. Les mesures ont été faites en quatre étapes : La première mesure a consisté à observer le comportement des participants, à travers l'enregistrement de leurs gestes de nettoyage de mains, de la surface de travail et des ustensiles. Ensuite, les participants ont dû remplir un questionnaire de TCP incluant six composantes relatives aux attitudes, normes subjectives, contrôle du comportement perçu et à l'intention. La troisième mesure est une tâche informatique basée sur une intervention de la TCP. Cette tâche a pour but d'améliorer les connaissances, le comportement auto-déclaré et les variables de la TCP, afin de changer le comportement d'hygiène. Enfin, les participants remplissaient un questionnaire de suivi de la TCP incluant les quatre composants cités en étape 2. Cette étude a montré que les attitudes, les normes subjectives et le contrôle du comportement perçu prédisent de manière significative l'intention des participants à préparer les aliments de façon hygiénique. En termes de comportement, 28 % de la variance est expliquée par les intentions. Dans une autre étude sur la consommation de fruits et légumes, Povey, Conner, Sparks, James, & Shepherd (2000) ont trouvé que la TCP explique 57 % de variance dans les intentions de manger cinq fruits et légumes par jour.

A ces facteurs de choix alimentaire s'ajoutent également les habitudes et comportements passés (Booth & Shepherd, 1988; de Bruijn, Kroeze, Oenema, & Brug, 2008): on a tendance à refaire ce que l'on a l'habitude de faire. Pour comprendre les comportements alimentaires, il faut donc aussi s'intéresser aux habitudes des consommateurs.

Habitude

L'habitude peut être considérée comme étant un comportement fréquemment répété dans le passé (Triandis, 1977) ou comme un comportement automatique ou hors de la conscience du sujet (Ronis, Yates, & Kirscht, 1989). Les habitudes peuvent être déclenchées par plusieurs types de mécanismes. Par exemple, le fait d'écouter le journal le matin (indice environnemental) active le fait d'aller travailler (but) qui en retour, entraîne le fait de monter en voiture (comportement à but dirigé). Les habitudes peuvent être aussi déclenchées par des indices dans l'environnement social et psychologique, tels que la présence d'autres gens ou un état d'humeur spécifique (Adriaanse, Ridder, & de Wit, 2009).

Les habitudes jouent un rôle important dans le comportement et le choix alimentaire (Gardner, De Bruijn, & Lally, 2011; Tuorila & Pangborn, 1988). Le fait de manger devient un acte habituel et automatique et, dans plusieurs cas, les repas sont consommés aux mêmes endroits et moments (Conner, Norman, & Bell, 2002). Le rôle des habitudes a, par exemple, été démontré dans la consommation de snack (Verplanken, 2006), de fruits (Brug, de Vet, de Nooijer, & Verplanken, 2006), de légumes et fruits (Reinaerts, de Nooijer, Candel, & de Vries, 2007), de boissons hygiéniques (Chin a Paw, Singh, Brug, & van Mechelen, 2008), de viandes (Feldman & Mayhew, 1984), de poissons (Scholderer & Trondsen, 2008), de chips (Towler & Shepherd, 1991/1992) et l'intention de consommer des fruits de mer (Honkanen, Olsen, & Verplanken, 2005).

La robustesse d'une habitude alimentaire est très forte quand celle-ci est reliée à une tradition culturelle. Par exemple, Atkin (2013) a étudié le cas des Indiens qui migrent d'une région vers une autre. Ces migrants préfèrent continuer à acheter les produits qu'ils avaient l'habitude de consommer dans leur ville d'origine, même si ces produits sont relativement chers comparés aux produits alternatifs disponibles dans leur nouvelle ville. Cette robustesse de l'habitude croit quand le comportement est renforcé de façon répétée par des expériences satisfaisantes (Wood & Neal, 2007).

I.3. Les conditions économiques et l'environnement social dans lequel le choix s'opère

Les conditions économiques et l'environnement social, dans lequel le choix alimentaire intervient (prix, disponibilité, marque, culture…), représentent la troisième classe de facteurs intervenant sur les choix alimentaires. En revenant sur l'exemple des insectes, si certains Africains, Asiatiques ou Sud américains consomment des insectes, ce serait sous la pression de l'environnement, pour s'adapter à la pénurie ou à la famine, qui les pousserait à surmonter leur répugnance et à absorber des espèces qui ne sont pas habituellement considérées comme de la nourriture (Fishler, 1990).

Disponibilité

Plusieurs études se sont intéressées à l'influence de la disponibilité des aliments sur le choix alimentaire (Diez-Roux, Nieto et al., 1999; Forsyth, Macintyre, & Anderson, 1994; Raynor, Polley, Wing, & Jeffery, 2004). La disponibilité peut être en lien avec la proximité des lieux d'achat, l'accessibilité des aliments dans la zone d'habitation. Par exemple, chez les

enfants, plus les fruits et légumes sont disponibles à la maison ou à l'école, plus ils sont consommés (Hill, 2002). La disponibilité semble etre un facteur plus important que la préférence dans les comportements alimentaires. Selon Lyman (1989), dans la vie de tous les jours, nous mangeons plus frequemment un aliment à cause de sa présence que parce que nous l'aimons.

La disponibilité des aliments résulte de l'interaction de plusieurs facteurs : biologique, psychologique, social, culturel et historique (Rozin, 2006). Par exemple, les facteurs culturels co-déterminent, avec les facteurs environnementaux / économiques, ce qui est planté, pour les végétaux, ou élevé, pour les animaux, et ce qui est importé dans un pays (Rozin, 2006). Une étude sur les consommations alimentaires de la population en Tanzanie a montré qu'il existe des différences en termes de types d'aliments consommés entre zones rurale et urbaine, dues à la restriction de disponibilité alimentaire en zone rurale (Mazengo, Simell, Lukmanji, Shirima, & Karvetti, 1997). Les traditions peuvent déterminer le conditionnement de vente d'un aliment, qui modifiera sa disponibilité immédiate pour les ménages. Le riz est stocké dans le commerce dans des sacs de 50 kg à Madagascar, tandis qu'en France, des paquets d'un kg sont les plus courants.

Prix

Le prix des aliments joue un rôle important dans le comportement d'achat alimentaire. Il a été répertorié dans plusieurs travaux comme étant le déterminant majeur des choix alimentaires (Blanck, Yaroch et al., 2009; Glanz, Basil, et al., 1998; Ritson & Petrovici, 2001; Rozin, 1996a), surtout chez les ménages à faible pouvoir d'achat, les personnes sans emploi et les retraités, et aussi chez les personnes responsables de l'achat des aliments (Lappalainen, Kearney, & Gibney, 1998).

Le prix influence également le choix alimentaire dans le sens où les consommateurs construisent mentalement des prix de référence aux produits fréquemment achetés (Grunert, 2006). Si les prix rencontrés sur le marché dépassent les prix de référence attendus, le produit en question pourrait ne pas être acheté.

Culture

La culture est la caractéristique démographique la plus informative pour prédire le choix alimentaire d'une personne (Kittler, Sucher, & Nelms, 2001; Rozin, 2007). Si les Français raisonnent avec les aliments en termes de cuisine et de plaisir, les Américains pensent plutôt en termes de valeur nutritionnelle et risques liés à la santé (Rozin, 1996a). La

sagesse et la coutume de ce qui est mangeable et approprié à la consommation sont transmises d'une génération à une autre. Les cuisines spécifiques à une culture dictent ce qui est à manger, sous quelle forme et dans quelle combinaison. Elisabeth Rozin (1982) a proposé trois éléments majeurs pour décrire les différentes traditions culinaires : les aliments de base, les arômes caractéristiques à ajouter dans la nourriture (e.g., sauce soja) et les modes de préparation typiques. D'après le même auteur, les cultures imposent également à quel moment et dans quelle quantité il faut manger un aliment sous forme de « normes » de consommation (Rozin, 2007). Par exemple, dans la culture américaine il est approprié de manger au moins et au plus une unité de taille modérée d'un aliment donné : un seul bol rempli mais pas plus, une pomme entière mais pas deux, un sandwich et non pas une moitié de sandwich (Geier, Hankins, & Rusiniak, 1974). Les cultures dictent également l'importance des aliments dans la vie de façon plus générale. Pour les Indiens, par exemple, la nourriture assure un rôle social majeur, dans le sens où le repas crée des relations sociales entre les membres de la famille, en termes de qui mange avec qui et dans quel ordre (l'aîné mange en premier) (Khare, 1976). Les cultures dictent aussi les manières de manger, appelées « manières de table » : les comportements appropriés à table, les couverts à utiliser (fourchette ou baguette, voire même chez certaines cultures à la main) (Rozin, 2007).

II. Choix alimentaire chez les enfants

D'après Nicklaus & Issanchou (2007), les facteurs physiologique, génétique, sensoriel/affectif et l'influence sociale sont les déterminants influençant la prise alimentaire chez l'enfant (Figure 6). D'autres éléments ont été également répertoriés dans la littérature comme influençant le choix alimentaire des enfants: les media, les enseignants, les personnes proches telles que les frères et sœurs et les camarades (Holsten, Deatrick, Kumanyika, Pinto-Martin, & Compher, 2012; Rozin, 1996b). Cullen et ses collaborateurs (2003) ont également mentionné l'importance de la disponibilité et de l'accessibilité comme étant un facteur favorisant la consommation de fruits et légumes par les enfants. En plus de ces deux derniers facteurs, Reinaerts, de Nooijer, Candel, & de Vries (2007) ont ajouté les habitudes et la période dans la journée.

Chez les adolescents, aux Etats-Unis, les facteurs suivants ont été soulignés comme étant les plus importants : la faim et l'envie de nourriture, le goût, les considérations de temps et la commodité (Neumark-Sztainer, Story, Perry, & Casey, 1999). D'après McKinley et ses

collaborateurs (2005), les barrières majeures pour une alimentation saine chez les enfants entre 11 et 12 ans au nord de l'Irlande et de l'Angleterre sont le goût, l'apparence des aliments, le pouvoir rassasiant, le temps/effort, le prix, le choix/disponibilité, le risque, la rébellion, l'image du corps et le poids. Le rôle du prix dans le choix alimentaire des enfants a de la valeur seulement chez les plus âgés qui commencent à être conscient que le prix des aliments est un facteur limitant la capacité des parents à acheter certains aliments (Holsten, Deatrick, Kumanyika, Pinto-Martin, & Compher, 2012).

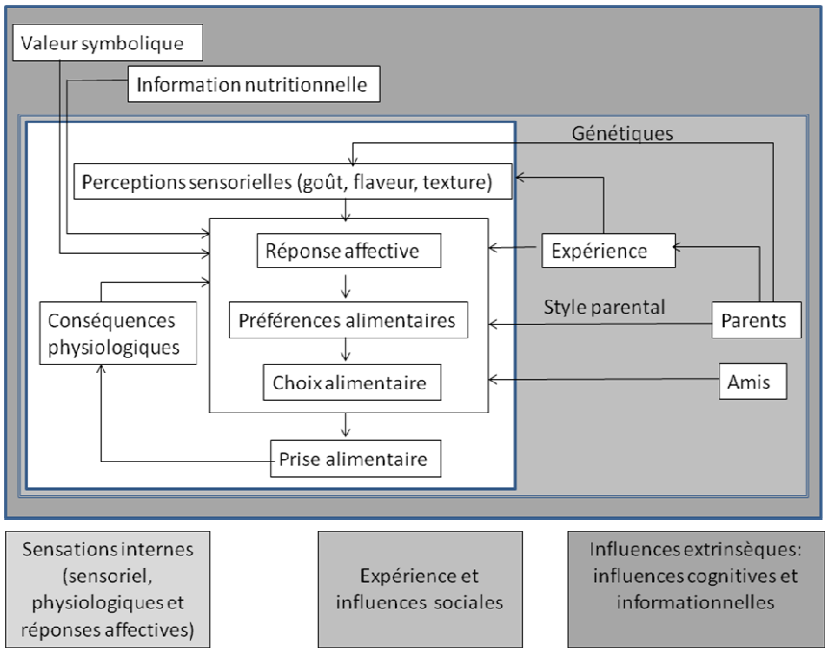

Figure 6. Structure conceptuelle des déterminants de choix alimentaire chez les enfants (Nicklaus & Issanchou, 2007)

Préférence alimentaire des enfants

Le choix alimentaire chez les enfants est dominé par la préférence (Nicklaus & Issanchou, 2007), qui peut être à la fois innée par l'intermédiaire de prédispositions génétiques et acquise grâce à l'expérience et aux apprentissages (Birch, 1999). La formation de la préférence alimentaire se fait dès la vie néonatale, via le liquide amniotique (Schaal, Marlier, & Soussignan, 2000) et se poursuit après la naissance, via le lait maternel (Mennella & Beauchamp, 1996a). L'enfance est la période critique de la formation des préférences alimentaires (Cashdan, 1994; Hendy, 1999). Les préférences qui sont établies à l'âge de 2-3 ans semblent être prédictives des préférences au début de l'âge adulte (Nicklaus, Boggio, Chabanet, & Issanchou, 2004). Skinner, Carruth, et al. (2002a) ont montré, par exemple, que les préférences alimentaires d'un groupe d'enfants âgés de 8 ans correspondaient à celles

qu'ils avaient à l'âge de 4 ans. Cooke, Wardle et al. (2004) ont trouvé que l'exposition précoce aux fruits et légumes pendant la période de sevrage est associée à une forte fréquence ultérieure de consommation de fruits et légumes chez les enfants entre 2 et 6 ans. Une étude similaire a montré que l'introduction très tôt d'aliments solides par les mères dans le régime de leur bébé est associée à un régime varié durant l'enfance (Cashdan, 1994).

Quant aux aversions, leur apparition, qui est rapportée chez 87 % des individus comme liée à des troubles gastriques ou intestinaux, remonte le plus souvent à un âge situé entre 6 et 12 ans (Garb & Stunkard, 1974). Une seule expérience alimentaire malheureuse suffit à induire une aversion durable, même si les troubles digestifs se sont produits plusieurs heures après l'ingestion (Garcia, Ervin, & Koelling, 1966).

Les enfants ont des préférences innées pour le goût sucré et une aversion pour les goûts amer et acide. La position de la préférence face au goût salé n'est pas claire (Birch, 1999; Desor, Maller, & Andrews, 1975; Desor, Maller, & Turner, 1973, 1977; Ganchrow, Steiner, & Daher, 1983; Garcia & Hankins, 1975; Steiner, 1977; Steiner, Hayne, & Lewis, 1979). Des solutions plus sucrées sont préférées par rapport à des solutions moins sucrées (Nisbett & Guswitz, 1970). Par contre, la prédisposition à préférer un goût sucré est modifiée par l'expérience avec l'aliment (Beauchamps & Moran, 1982; Sullivan & Birch, 1990). De même, la réponse de rejet face à l'amertume est modifiée par expérience, d'après une étude sur un hydrolysat de protéines formulé à goût amer (Mennella & Beauchamp, 1996b). L'aversion à l'amer peut être surmontée par apprentissage (e.g., boire de la bière, du café noir etc.). Quant à l'acide, certains jeunes enfants développent une préférence forte envers cette saveur (Liem, Mars, & de Graaf, 2004). Une préférence à la saveur salée ne peut être observée qu'après l'âge de 4 ans d'après Beauchamps, Cowart, Mennella, & Marsh (1994) et Beauchamps, Cowart, & Moran (1986). Chez les bébés, le niveau de sel préféré est plus élevé que celui préféré par les adultes (Beauchamps & Cowart, 1990; Beauchamps & Moran, 1985).Les enfants aiment les stimuli à forte intensité. Ceci est dû à une sensibilité moins développée que celle des adultes. Par exemple, il a été montré que les enfants discriminent moins bien des concentrations en saccharose que les adultes (De Graaf & Zandstra, 1999; Zandstra & De Graaf, 1998).

Les enfants plus jeunes se focalisent plus sur les indices visuels et texturaux que les plus âgés (Rose, Laing, Oram, & Hutchinson, 2004) et les adultes (Nicklaus & Issanchou, 2007). En effet, dans une étude menée par Rose, Laing, Oram, & Hutchinson (2004) sur les préférences sensorielles aux viandes, les jeunes enfants (6-7 ans) se sont focalisés sur les

attributs texturaux, tandis que les enfants plus âgés se sont focalisés sur les goûts et les odeurs. Thybo, Kuhn, & Martens (2004) ont également montré, à l'aide d'une cartographie de préférence de plusieurs variétés de pommes effectuée avec des enfants de 6 à 11 ans, que la préférence de ces variétés est influencée par leur texture. Concernant les perceptions texturales, les paramètres oraux, tels que la dentition et les forces liées à la mastication, ont un impact sur la préférence des enfants (Szczesniak, 1972).

Il a été également démontré que si un aliment est caractérisé en même temps par un goût prononcé et une densité calorique élevée, la préférence à ce goût particulier augmente (Birch, 1990a; Booth, Mather, & Fuller, 1982). Les enfants acquièrent plus rapidement des préférences aux aliments à forte densité énergétique, comparés aux aliments moins énergétiques (Birch & Deysher, 1985; Birch, McPhee, Steinberg, & Sullivan, 1990) grâce à un effet physiologique postingestif positif, tel que la sensation de rassasiement (Kern, Mc Phee, Fisher, Johnson, & Birch, 1993 ; Birch, 1998; Cooke & Wardle, 2005). Ce conditionnement pour des aliments énergétiques peut expliquer en particulier le développement de la préférence pour les aliments gras (Birch, 1992; Johnson, Mc Phee, & Birch, 1991; Kern, Mc Phee, Fisher, S., & Birch, 1993) et, à l'opposé, le fait que les légumes sont moins aimés (Skinner, Carruth, Bounds, & Ziegler, 2002b). La préférence d'aliments à forte densité énergétique chez les enfants et les adolescents s'explique également par leur besoin en énergie, en relation avec leur croissance et leur développement (De Graaf & Zandstra, 1999; Drewnowski, 1998).

La familiarité influence le choix alimentaire des enfants (Cooke & Wardle, 2005). Les enfants n'aiment pas les aliments qu'ils n'ont jamais goûtés (Aldridge, Dovey, & Halford, 2009; Birch, Brich, Marlin, & Kramer, 1982). « Ils aiment ce qu'ils connaissent et ils mangent ce qu'ils aiment » (Cooke, 2007, p.294). De même, le contexte dans lequel l'aliment a été présenté pour la première fois est très important puisqu'il constitue ce qui est familier ou du moins ce qui est acceptablement classé par les enfants en tant qu'aliments (Birch, 1990b; Mela, 1999). Par exemple, l'enfant peut être familier à un goût de fraise dans un bonbon, alors que l'expérience globale avec le fruit réel (fraise) peut être perçu discordante et donc rejetée (Aldridge, Dovey, & Halford, 2009). Ceci est dû au fait que la différence de formes entre les deux aliments (bonbon et fruit) n'est pas reconnue et comprise.

III. Comportement alimentaire dans les pays sous développés ou chez les communautés à faibles revenus

Il est évident que les déterminants des choix alimentaires sont différents dans les pays développés et dans les pays sous-développés. Tangtrakul (2010) illustre cela à travers la comparaison entre le Malawi, un pays sous développé, et la Pennsylvanie, un état représentant un pays développé. Si à Malawi, le choix alimentaire repose sur la question « Que planter ? », en Pennsylvanie, la question est plutôt « Que manger ? ». L'accès aux aliments est différent selon ces deux contextes. Dans les pays industrialisés, les aliments sont faciles à acquérir et à préparer, tandis que dans les pays en voie de développement, l'alimentation représente plus de la moitié du budget des ménages et représente des longues durées de préparation.

Un nombre limité d'études s'intéresse au choix alimentaire dans les pays en voie de développement et aucune n'a été trouvée sur Madagascar. En revanche, un nombre plus important d'études s'intéresse à la prise alimentaire chez les personnes issues des ménages pauvres des pays industrialisés (Burns, Cooke, & Mavoa, 2013; Temple & Steyn, 2011). La notion de pauvreté, dans le cas des pays industrialisés, est estimée en termes de pouvoir d'achat des ménages. Un ménage est considéré comme étant pauvre si son pouvoir d'achat est inférieur à celui de la majorité de la communauté considérée.

Le premier critère de choix alimentaire chez les ménages « pauvres » est le prix (Drewnowski, 2009; Pinstrup-Andersen, 1985). Le second critère est celui du caractère rassasiant des aliments (Alvina, Araya, Vera, & Pak, 2000; Burns, Cooke, & Mavoa, 2013). Selon Drewnowski et Darmon (2005), quand les ressources financières deviennent limitées, les consommateurs à faible revenu essaient de maximiser leur choix alimentaire en se procurant le maximum de calories pour une moindre dépense. Ceci se manifeste sous forme de priorisation des aliments rassasiants et glucidiques (Mazengo, Simell, Lukmanji, Shirima, & Karvetti, 1997). D'après Phororo (1999) et Pinstrup-Andersen (1985), les ménages à faible pouvoir d'achat dans les pays pauvres dépensent en général 50 % ou 60-80 % de leur revenu dans l'alimentation. Dans certains pays, un aliment de base correspond à 40-60 % des dépenses budgétaires alimentaires. Quand le prix du premier aliment de base augmente, par exemple le riz, les ménages pauvres substituent cet aliment par d'autres aliments de base considérés comme « inférieurs », tels que le maïs et le manioc, qui sont des sources de calories moins chères (Senauer, 1990). Par ailleurs, Behrman (1988) et Behrman, Deolalikar, & Wolfe (1988) ont suggéré que l'augmentation de revenu peut ne pas améliorer la prise de nutriments chez les ménages à faible revenu.

D'autres facteurs, tels que les facteurs environnementaux et comportementaux, influencent le choix alimentaire des familles pauvres. Ces facteurs incluent : l'accès aux aliments bons pour la santé (Cummins & Macintyre, 2006), le stress psychologique (Dallman, Pecorano, & la Fleur 2005), la difficulté à balancer les demandes exigées par le travail et l'alimentation de la famille (Devine, Connors, Sobal, & Bisogni, 2003; Devine, Jastran, Jabs et al., 2006) et le manque de connaissance nutritionnelle (Hendrie, Coveney, & Cox, 2008). Diverses études (Barker, Lawrence et al., 2008; Horton, 1986; Wolfe & Behrman, 1982), montrent que l'âge des parents et leur niveau intellectuel affectent l'état nutritionnel de leurs enfants. Le fait que les parents soient plus âgés et à niveau intellectuel plus élevé, notamment chez les mères, entraine des effets positifs sur l'état nutritionnel de leurs enfants. Le fait de vouloir satisfaire les enfants peut être un facteur de choix alimentaire dans le contexte de faible revenu. Tel est le cas d'une mère de famille qui continuait à nourrir ses enfants obèses de nourritures pas saines tout en sachant qu'ils étaient en surpoids, dans l'étude de Kaufman et Karpati (2007). Ceci vient du fait que la mère jugeait son comportement comme étant correct car ces nourritures procuraient du plaisir à sa fille. Les relations sociales jouent également un rôle dans le choix des aliments chez les adultes à faible ou moyen pouvoir d'achat. Devine, Connors, Bisogni, & Sobal (1998) rapportent que si les gens continuent à aimer les fruits et légumes c'est grâce à leur participation dans des activités et rituels familiaux incluant les fruits et légumes, les expériences de préparation de ces aliments et la mémoire de leur goût plaisant.

C. Introduction de nouveaux aliments

I. Néophobie

La néophobie est définie comme étant une réticence à ingérer de nouveaux produits. Elle est une caractéristique des omnivores, dont l'humain. Ce dernier est exposé aux risques d'un environnement dans lequel plusieurs sources alimentaires peuvent être toxiques. La présence de ces risques conduit l'individu à utiliser de nouveaux aliments avec précaution, et à privilégier des aliments familiers autant que possible. D'après Köster et Mojet (2007), la néophobie est apprise. Le fait d'apprendre que la consommation d'un aliment est sans risque peut donc aider à augmenter sa préférence (Nicklaus & Issanchou, 2007).

La néophobie engendre des comportements de rejet alimentaire (Pliner & Salvy, 2006). Fallon & Rozin ont fait état de trois phénomènes majeurs à l'origine du rejet d'un

aliment chez l'humain : (i) l'*aversion* due à ses caractéristiques sensorielles ; (ii) le *danger* ou la *peur* de ses conséquences négatives dues à sa consommation ; et (iii) le *dégoût*, qui surgit à l'idée de sa nature ou de son origine (Fallon & Rozin, 1983; Rozin & Fallon, 1980). Pliner, Pelchat, & Grabski (1993) ont montré que des produits nouveaux présentés devant des consommateurs dans un contexte de laboratoire étaient perçus comme étant légèrement plus dangereux que des produits qui leur sont familiers. Cette notion de dangerosité est un bon prédicteur de la volonté de goûter un produit. Le dégoût, quant à lui, est d'ordre émotionnel. Il est défini comme une répulsion face à l'incorporation d'un objet offensif (Rozin & Fallon, 1987).

La néophobie est un facteur individuel lié à l'âge. Les personnes plus âgées sont, en général, moins néophobes que les plus jeunes (McFarlane & Pliner, 1997; Pelchat & Pliner, 1995; Pliner & Loewen, 1997). Par ailleurs, Harper et Sanders (1975) ont montré que les enfants d'un an et demi sont moins néophobes que ceux de trois ans et demi. D'après Cashdan, la néophobie n'apparaît pas avant l'âge d'environ trois ans. L'âge de 2 ans est l'âge où les nouveaux aliments sont les plus acceptés (Cashdan, 1994, 1998). Cependant, Cooke, (2007) a observé un âge d'apparition de la néophobie plus précoce que celui trouvé par Cashdan. Cet âge correspond à la période où l'enfant acquiert sa mobilité, quand il explore indépendamment son environnement. C'est à ce moment qu'il décide ce qu'il mettra ou non en bouche. Selon l'étude de Loewen & Pliner (1999), la néophobie peut être dissipée après la consommation d'un nouvel aliment palatable chez les enfants entre 10 et 12 ans, mais non entre 7 et 9 ans.

II. Comment adopter une bonne habitude et changer une mauvaise habitude alimentaire chez les enfants?

Les habitudes alimentaires peuvent se former et varier à différentes périodes de la vie humaine (Köster & Mojet, 2007). Mais si l'enfance est l'âge critique pour former les préférences/aversions alimentaires (Cashdan, 1994; Hendy, 1999), elle peut être aussi considérée comme la période la plus adaptée pour les modifier. Plusieurs facteurs et paramètres peuvent être manipulés afin de faciliter la modification d'habitudes alimentaires.

II.1. Contexte de la prise alimentaire

Une façon de changer une habitude est de modifier le contexte situationnel dans lequel la prise alimentaire se fait habituellement. Selon Riet, Sijtsema, Dagevos, & De Bruijn (2011) l'environnement physique influence le comportement alimentaire, car plus un aliment est

disponible, plus il a de chances d'être consommé. Ainsi, Van Osch et ses collaborateurs (2009) ont montré que pour favoriser, par exemple, la consommation de fruits, une solution serait de les mettre sur une table, c'est-à-dire sur une zone de passage fréquent, facilement accessible. Plus de 45 % des comportements tendent à être répétés dans la même localisation physique presque tous les jours (Wood, Quinn, & Kashy, 2002).

Les moments de consommation jouent aussi un rôle important. Pour faire manger aux enfants des aliments bénéfiques pour la santé, par exemple les légumes, Williams, Paul, Pizzo, & Riegel (2008) ont proposé de créer plus d'occasions pour les consommer, comme pendant les moments de récréation. Ces moments correspondent aux moments où les enfants ont faim. La plupart des aliments sont plus acceptés pendant l'état de faim que quand l'individu est rassasié (Rolls, 1988).

II.2. Education nutritionnelle

L'éducation permet de modifier les comportements des enfants. Différentes formes d'éducation peuvent être rencontrées dans la littérature.

L'éducation à la santé et l'éducation nutritionnelle permettent de changer les habitudes alimentaires. Certains travaux suggèrent qu'en sortant des approches d'éducations traditionnelles, l'éducation à la santé est beaucoup plus efficace (Rothman, Sheeran, & Wood, 2009). Ceci peut se manifester, par exemple, à travers l'utilisation d'étiquettes nutritionnelles afin d'informer les consommateurs des apports caloriques, ou l'utilisation d'une technique d'autorégulation telle que proposée par Stadler, Oettingen, & Gollwitzer (2010). La technique d'autorégulation est une technique faisant intervenir des éléments cognitifs et comportementaux tout en impliquant l'intention de changement.

L'éducation nutritionnelle est généralement fondée sur des théories, telles que la Théorie de Connaissance - Attitude - Comportement (TCAC). Cette théorie s'appuie sur le fait que la connaissance est une condition nécessaire et probablement suffisante pour changer un comportement. Elle suggère qu'un moyen de changer un comportement serait de fournir aux individus des connaissances sur comment leur comportement influence leur santé. Ces connaissances influenceraient positivement leur attitude envers le comportement et éventuellement conduirait à la modification de comportement désiré. D'après Birch (1999), les connaissances à offrir aux parents doivent porter sur la façon dont les préférences alimentaires des enfants sont apprises. Elles doivent aussi se baser sur les prédispositions naturelles des enfants, concernant la préférence pour le sucré et salé et le rejet de l'acide et

l'amer, le rejet de nouveaux aliments, et l'apprentissage à aimer les aliments basés sur la fréquence d'expositions et les contextes et conséquences de l'ingestion.

Cependant, l'efficacité des connaissances sur le changement de comportement a été remise en cause par Lytle & Achterberg (1995). D'après Lytle (2005), la Théorie Sociale Cognitive (TSC) de Bandura (1986) s'avère plus efficace. Au lieu d'expliquer aux gens comment leur comportement affecte leur poids, le risque de cancer et de maladies cardiovasculaires ou d'autres maladies, la TSC se focalise sur les comportements spécifiques qui influencent le risque et aide les individus à atteindre le changement qu'ils souhaitent.

Les stratégies d'éducation nutritionnelle s'adaptent au type de population à éduquer. Pour les enfants en âge scolaire, par exemple, l'éducation peut se faire à l'école avec comme éducateurs les enseignants eux-mêmes (GOFN Education, 1995). Les matières, dans ce cas, couvrent une variété de thèmes, tels que le rôle des nutriments dans le corps, les sources alimentaires en nutriments, la production et les procédés alimentaires, les facteurs influençant les choix alimentaires et l'alimentation saine en générale (Society for Nutrition Education, 1982). L'utilisation de livres s'avère également efficace**.** De Droog (2014) a montré, par exemple, qu'un livre illustré avec des photos de légumes est un moyen efficace pour faire manger des légumes aux enfants de 4 à 6 ans si les enfants sont impliqués dans la lecture et s'ils répondent aux questions reliées à l'histoire racontée.

II.3. Education sensorielle

L'éducation sensorielle est une méthode initiée par Jacques Puisais pour sensibiliser les enfants au goût (Puisais & Pierre, 1987). Cette méthode a été utilisée plus tard dans le cadre des « Classes du goût », menée à Dijon avec le projet EduSens sur les enfants entre huit et dix ans (Reverdy, Chesnel, Schlich, Köster, & Lange, 2008). Il s'agit d'éduquer les enfants aux différents goûts des aliments à travers douze leçons. Le but de cette étude était d'évaluer l'effet de l'éducation sensorielle sur la néophobie en mesurant le niveau de néophobie chez les enfants avant et après le programme. L'éducation sensorielle a réussi à réduire la néophobie et à favoriser l'envie de goûter les nouveaux aliments. Mais malheureusement, ces effets ont disparu dix mois plus tard. L'éducation sensorielle ne semble donc être efficace qu'à court terme.

II.4. Rôle de l'exposition répétée via la familiarité

Il a été mentionné plus haut que la familiarité est l'un des facteurs importants dans la préférence alimentaires des enfants. Le processus permettant d'établir cette familiarité relève de la théorie de la simple exposition (« mere exposure » en anglais) qui initialise la transformation d'aliments redoutés et évités en aliments familiers et potentiellement aimés à travers le fait que plus on est exposé à un stimulus, plus on l'apprécie (Zajonc, & Robert, 1968). Des études faites en laboratoire confirment cette hypothèse : la préférence d'aliments et de flaveurs augmente avec une exposition répétée. Cet effet a été démontré tant chez les adultes (Pliner, 1982; Pliner, Pelchat, & Grabski, 1993) que chez les enfants (Sullivan & Birch, 1990, 1994, Wardle, Cooke et al., 2003). Le processus de simple exposition est décrit par Kalat & Rozin (1973) comme étant une « sécurité apprise » : l'ingestion répétée d'aliment non familier sans conséquences gastro-intestinales négatives permet d'augmenter l'acceptabilité de cet aliment. En outre, les réactions de rejet liées à la néophobie pourraient être limitées suite à une exposition répétée à l'objet du rejet.

Pour que le processus d'exposition soit efficace, il faut que l'enfant soit sûr dès la première expérience que l'aliment n'entraîne pas de conséquence postingestive déplaisante (Birch, Fisher, 1998). Il faut également éviter la monotonie, et pour cela le nombre d'expositions est un paramètre à prendre en compte et à adapter à l'âge de l'enfant (Aldridge, Dovey, & Halford, 2009). Or aucune règle ne permet d'établir le nombre optimal d'expositions. Wardle, Cooke, et al. (2003) ont trouvé que chez les enfants entre 3 et 7 ans, dix expositions à un nouveau légume sont nécessaires pour augmenter leur préférence, bien que la prise de ce légume commence à augmenter avant même la dixième exposition. Chez les enfants âgés entre 5 et 7 ans, huit expositions au piment rouge entraînent une augmentation de préférence et de prise (Wardle, Herrera, Cooke, & Gibson, 2003). Le nombre d'expositions nécessaires est entre cinq et dix d'après Birch (1999) chez les enfants de 2 ans. Par ailleurs, Sullivan & Birch (1990) ont trouvé que chez les enfants de 3 et 4 ans, huit à 15 expositions sont nécessaires avec du tofu sucré, salé ou fade.. Dans une autre étude avec des enfants de 7-9 ans et 10-12 ans, plus de 20 expositions ont été faites et l'envie d'essayer de nouveaux aliments n'a été observée que chez les enfants plus âgés (Loewen & Pliner, 1999). En revanche, Sullivan et Birch (1994) ont suggéré qu'une seule exposition au goût d'un nouvel aliment peut être suffisante pour augmenter radicalement la quantité consommée et l'appréciation d'un aliment.

Les expositions très tôt dans la vie humaine (depuis la vie prénatale) peuvent avoir des effets à très long terme, même plusieurs années plus tard (Schaal, Marlier, & Soussignan,

2000). Être exposé à une large variété de goûts très tôt dans la vie aide l'enfant à être moins néophobe et plus prêt à accepter de nouvelles flaveurs. Haller, Rummel, et al. (1999) ont montré qu'une exposition précoce avec l'arôme de vanille pouvait engendrer une préférence pour un ketchup aromatisé à la vanille à l'âge adulte.

II.5. Récompense

Dans certaines circonstances, l'exposition peut ne pas être efficace. Pour remédier à ce problème, Hendy, Williams, & Camise (2005) ont proposé de combiner exposition et récompense sociale pour augmenter la préférence et la consommation de fruits et légumes chez les enfants entre 6 et 9 ans. Un aliment peut, par exemple, être donné à l'enfant en récompense de ses bons comportements, et ainsi augmenter sa préférence pour l'aliment offert (Birch, Zimmerman, & Hind, 1980). Cependant, seul un nombre restreint d'aliments, bonbons ou aliments à haute valeur énergétique, engendre un effet positif de la récompense. Certains aliments, tels que les légumes, entraînent plutôt un effet négatif de la récompense et risquent de créer une aversion.

II.6. Rôle de l'influence sociale

L'influence sociale a un effet important sur l'acceptabilité et la préférence chez les enfants (Rozin, 1990) à travers des mécanismes d'imitation et de conformation, conscient et/ou inconscient, à la pression du groupe (De Graaf, 2007). De multiples études ont montré que la préférence à des aliments neutres ou non aimés peut augmenter si le jeune enfant peut observer un proche consommer le même aliment (Birch, 1980; Birch, Zimmerman, & Hind, 1980; Hobden & Pliner, 1995; Duncker, 1938; Marinho, 1940).

Les parents jouent un rôle important dans la formation des préférence et des comportements alimentaires de leurs enfants (Birch, Fisher, 1998; Rozin, 2006; Sherry, McDivitt et al., 2004). D'abord, ceci est dû au fait que ce sont les parents qui contrôlent la disponibilité et le choix alimentaire au sein du foyer (Rozin, 2006), en particulier les mères de par leur rôle dans l'achat et la préparation des aliments (Holsten, Deatrick, Kumanyika, Pinto-Martin, 2012). Ensuite, les enfants ont tendance à imiter la préférence alimentaire de leurs mères, s'il s'agit de filles, ou de leurs pères pour les garçons (Rozin, 1996b, 2006). Par exemple, les enfants acceptent plus facilement la consommation d'un nouvel aliment quand leur mère se montre comme modèle en premier (Harper & Sanders, 1975). Ces conclusions doivent toutefois être interprétées avec prudence car des travaux menés par Birch, (1988)

indiquent que la corrélation entre les goûts alimentaires des parents et ceux des enfants est faible et qu'elle n'est pas significativement différente de celle que l'on peut trouver entre les goûts alimentaires des enfants et ceux des parents d'autres enfants de la même école.

Après les parents, les pairs influencent également les enfants qui les prennent comme modèles. Cet effet est plus important si le modèle a le même âge, plutôt qu'un âge plus élevé (Hendy & Raudenbush, 2000). Selon Rozin (1996a), les personnes vivant avec l'enfant, surtout ses frères et sœurs, ont plus d'influence sur cet enfant que d'autres personnes. D'autres études ont montré que des camarades d'école jouent également un rôle non négligeable. Ces derniers deviennent dans ce cas le modèle que l'enfant imite. Cette imitation encourage l'enfant à essayer de nouveaux aliments une fois que celui-ci revient dans son cercle familial (Holsten, Deatrick, Kumanyika, Pinto-Martin, & Compher, 2012). Hendy & Raudenbush (2000) ont montré que les enseignants pouvaient être aussi des modèles efficaces pour les enfants préscolaires mais seulement quand ceux-ci jouent le rôle de modèle "enthousiasmant", en donnant des commentaires favorables sur les nouveaux aliments, mais pas en les consommant 'silencieusement'.

Problématique, objectif et questions de recherche de la thèse

La plupart des travaux sur les choix alimentaires indiquent que ces derniers sont influencés par trois grands groupes de facteurs liés respectivement à la personne, l'aliment et l'environnement socio-économique. L'objectif global de cette thèse est d'explorer l'importance de ces trois types de facteurs pour comprendre les choix alimentaires malgaches et proposer de nouvelles solutions pour réduire la malnutrition des enfants d'âge scolaire à Madagascar. Il s'agit de favoriser l'introduction d'aliments localement disponibles et à fort potentiel nutritionnel dans l'alimentation de la population malnutrie. Nous nous sommes intéressés particulièrement aux feuilles de MO qui sont des sources potentielles en nutriments tels que les protéines, les minéraux, ou les vitamines. Par rapport aux autres légumes feuilles, les feuilles de MO sont peu consommées à Madagascar. Pourtant, si cette plante est moins familière sur le haut plateau, elle pousse de façon très répandue sur les zones côtières.

Nous nous sommes intéressés aux enfants entre 7 et 13 ans, ce qui correspond à l'âge scolaire (classes primaires). Tout au long de la revue bibliographique, il a été observé que cette tranche d'âge a peu attiré l'attention des acteurs promouvant les programmes de lutte contre la malnutrition à Madagascar, alors qu'elle correspond à une période critique du développement chez l'enfant. Nous avons choisi de mener nos études en considérant deux zones différentes : Antananarivo (sur le haut plateau) et Antsiranana (une zone côtière) en contrastant les zones urbaines des zones rurales. En raison de la différence de leur position géographique, ces deux zones possèdent des caractéristiques différentes, en termes de culture, croyances et pratiques alimentaires, ainsi qu'en termes de végétation et disponibilité alimentaire.

Dans cette thèse, nous allons vérifier trois hypothèses principales.

La première hypothèse concerne les caractéristiques nutritionelles et organoleptiques des feuilles de MO d'origine malgache.

H1 : « Les caractéristiques des feuilles de MO, tant nutritionnelles qu'organoleptiques, sont différentes selon les zones d'origine » (Chapitre 2).

Les deux autres hypothèses concernent les croyances nutritionnelles des parents d'enfants scolarisés dans deux régions malgaches.

H2 : « La faible consommation de certains aliments à fort potentiel nutritif, tels que les feuilles de MO, et la consommation importante d'autres aliments peu nutritifs résultent des structures de croyances alimentaires développées dans différentes régions de Madagascar. » (Chapitre 3 et chapitre 4).

H3 : « Si les feuilles de MO ne sont pas assez valorisées à Madagascar, c'est à cause de l'importance que la population malgache donne aux habitudes alimentaires et au pouvoir rassasiant des aliments.» (Chapitre 4)

Pour tester ces hypothèses, des poudres de feuilles de MO d'origine malgache ont tout d'abord été caractérisées avec des méthodes instrumentales (analyses chimiques) et sensorielle (test descriptif). La composition en certains nutriments (protéines, matière grasse, acides gras, acides aminés, calcium, magnésium et fer) dans les poudres de feuilles de MO issues de cinq régions de Madagascar a été analysée. Les caractéristiques organoleptiques des mêmes poudres ont également été évaluées avec une méthode sensorielle descriptive : le Profil Flash. Ces deux études ont été regroupées dans le **chapitre 2**. Ensuite, pour pouvoir comprendre pourquoi la population malnutrie ne consomme pas certains aliments nutritifs disponibles, les pratiques et les structures de croyance nutritionnelle en général et concernant plus particulièrement le MO et le manioc par les parents d'enfants ont été étudiées en utilisant des méthodes d'entretien et d'enquête. Les données collectées sont décrites dans les **chapitres 3 et 4**. Enfin, cette thèse a pour finalité de proposer des aliments à base de ressources habituelles (racines de manioc) qui ont été enrichies nutritionnellement grâce à l'ajout de poudres de feuilles de MO pour essayer d'améliorer l'état nutritionnel de la population malnutrie malgache, notamment les enfants issus des ménages à faible revenu. Des goûters à base de manioc et de poudre de feuilles de MO ont été fabriqués. Le manioc a été choisi comme matrice incorporant les feuilles de MO puisqu'il est l'aliment de sécurité des ménages pauvres malgaches et qu'il est disponible toute l'année et à moindre coût. Plusieurs formulations de goûters ont été évaluées par la suite par des enfants en vue de vérifier leur niveau d'acceptabilité. Puis les apports nutritionnels apportés par les feuilles de MO ont été calculés. Les données sont présentées dans le **chapitre 4**.

Les entretiens et enquêtes ainsi que les tests sensoriels ont été réalisés à Madagascar, tandis que les analyses chimiques présentées dans cette thèse ont été effectuées en France, sur des produits collectés à Madagascar.

CHAPITRE 2 :

Caractérisation des poudres de feuilles de *Moringa oleifera* d'origine malgache

CHAPITRE 2 : CARACTERISATION DES POUDRES DE FEUILLES DE MORINGA OLEIFERA D'ORIGINE MALGACHE

Ce chapitre s'intéresse à la question suivante : Quelles sont les caractéristiques, tant nutritionelle que sensorielle, des feuilles de MO d'origine malgache ?

I. Introduction

MO est une plante originaire d'Inde, où elle est déjà largement connue par la population indienne. Elle pousse dans les zones tropicales et subtropicales (Figure 7).

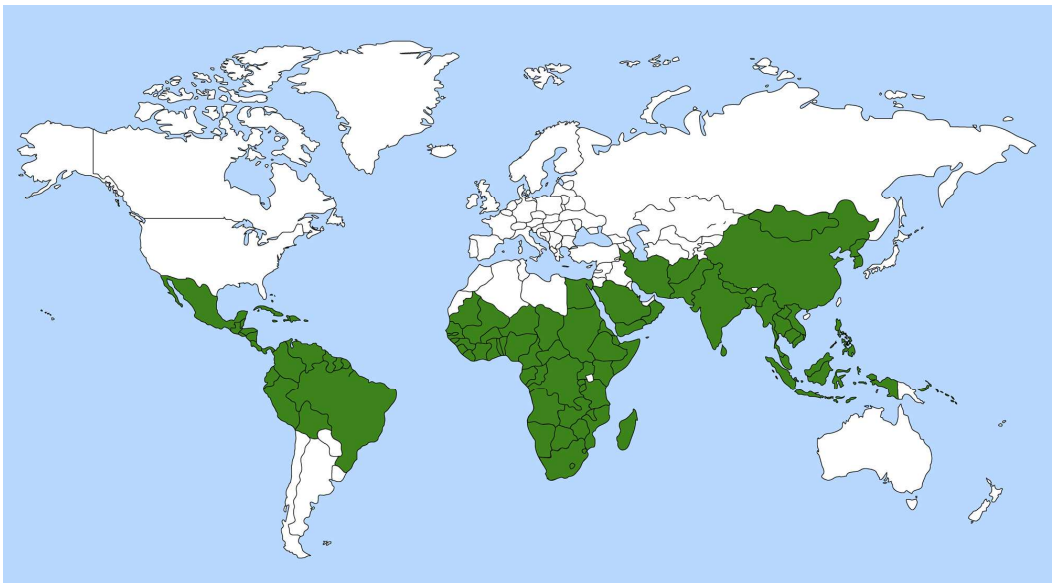

Figure 7. Zones au monde où pousse la plante *Moringa oleifera* (Trees For Life, 2013)

Les différentes parties de la plante (les feuilles, les fruits, les graines, les racines, l'écorce et les fleurs) ont de multiples usages, tant thérapeutique que nutritionnel (Fahey, 2005). Les différentes préparations issues de MO (e.g., extraits, décoctions, cataplasmes, crèmes, huiles, émollients, pommade, poudres, porridges) ont des activités antibiotique, antitrypanosomial, hypotensive, antispasmodique, antiulcéreux, anti-inflammatoire, hypocholestérolémiant, et hypoglycémique. Les graines sont également utilisées pour la purification d'eau par floculation, sédimentation, antibiose et éventuellement réduction de parasite *Schistosoma cercariae titer*. Concernant les feuilles, elles peuvent être consommées fraîches, cuites ou conservées sous forme de poudre séchées pendant des mois sans réfrigération (Fahey, 2005). Les feuilles de Moringa ont été incorporées sous forme de poudre

dans des aliments, tels que des cookies en Inde avec une concentration de 5, 10 et 15% (Dachana, Jyotsna Rajiv, Indrani, & Prakash, 2010) ou des bicuits secs à base de farine de manioc et de patates douces avec une concentration de 0,37 % et 1,82 % au Ghana (Owusu, Oduro, & Ellis, 2011) en vue de les enrichir en protéines, minéraux, vitamines et fibres. Elles ont également été utilisées dans l'alimentation animale, en tant que source protéique. Des feuilles séchées de MO provenant du Niger ont été incorporées à différentes proportions (12, 24 et 36 %) dans les régimes des poissons Tilapia en Allemagne (Richter, 2003). Au Nicaragua, en vue d'améliorer la production laitière des vaches, 2 et 3 kg par rapport à la matière sèche de feuilles de MO ont été ajoutées dans leur alimentation deux fois par jour en plus des foins habituels (Sánchez, Spönrdly, & Ledin, 2006).

Si l'incorporation de poudre de MO dans l'alimentation humaine et non humaine s'est avérée bénéfique, des facteurs antinutritionnels ont également été trouvés dans les feuilles : tannins, composés phénoliques, composés phytiques. A très haute concentration dans les régimes, les feuilles de MO ont entraîné un arrêt de croissance des poissons nourris au régime contenant 20 et 30 % de poudre de feuilles de MO durant la première semaine. Ceci est dû à la présence de saponines, de composés phénoliques et de phytates dans ces feuilles (Richter, 2003). Toutefois, l'effet des saponines reste à élucider puisqu'à plus faible proportion l'effet contraire a été observé (Francis, Makkar, & Becker, 2001). En revanche, aucun glucoside cyanogénique n'a été détecté dans les feuilles (Makkar & Becker, 1997).

Les études sensorielles réalisées sur les feuilles de MO repertoriées dans la littérature se sont limitées à des tests hédoniques. La plupart des études proviennent de l'Inde et des pays d'Afrique comme le Ghana ou le Nigéria. Par exemple, Nambiar et Parnami (2008) dans une étude menée en Inde, ont incorporé des feuilles fraîches blanchies de MO dans trois recettes traditionnelles indiennes à base de légumineuses. Les feuilles fraîches ont été ajoutées à différentes proportions, allant de 20 à 83 %. Douze sujets non entraînés ont procédé à l'évaluation de l'acceptabilité globale et par rapport aux critères suivants : apparence, arôme, goût, texture et arrière-goût. Les recettes incorporant 67 % de feuilles de MO ont été trouvées comme étant les plus acceptées. Plus récemment, Madukwe, Ezeugwu, & Eme (2013) se sont interéssés à l'évaluation hédonique de boisson fabriquée à partir de poudre de feuilles de MO provenant du Nigeria. Des sujets naïfs ont évalué l'acceptabilité globale, l'acceptabilité par rapport à la couleur, au goût et à l'arôme de trois boissons (extraits à partir de poudre de feuilles de MO et de poudre de thé *Lipton).* Chaque extrait a été obtenu en mettant 2 g de poudre dans 200 ml d'eau chaude. L'extrait de poudre de MO est plus accepté que celui de poudre de thé en ce qui concerne l'évaluation globale, et de l'arôme. Par contre, sa couleur est

moins acceptée que celle de l'extrait de thé. Aucune différence n'a été observée par rapport à l'acceptabilité vis-à-vis du goût. Ces études, bien qu'encourageantes restent toutefois limitées.

MO n'a commencé à attirer l'attention de certains chercheurs et organismes à Madagascar que très récemment (vers 2008). Bien que des études réalisées dans d'autres pays aient prouvé les différentes vertus de cette plante, tant nutritionnelle que thérapeutique, à notre connaissance, aucun article scientifique n'a porté sur la composition nutritionnelle des feuilles de MO recoltées à Madagascar, ni sur leurs propriétés organoleptiques.

Ce chapitre présente deux études. Dans un premier temps, la caractérisation nutritionnelle des feuilles de MO venant de Madagascar a été réalisée, à travers les analyses des protéines totales, matières grasses totales, minéraux (calcium, magnésium et fer), acides gras et acides aminés. Les caractérisations ont porté sur cinq échantillons de poudre de feuilles de MO, récoltés dans cinq villes différentes (Figure 8) : Antananarivo (centre), Antsiranana ou Diégo Suarez (nord), Mahajanga (ouest), Toamasina (est) et Toliara ou Tuléar (sud). Ces villes font partie des cinq plus grandes villes de Madagascar, et à cause de leur situation géographique, ont des caractéristiques différentes en termes de climat et de végétation.

Figure 8. Carte de Madagascar montrant les cinq villes d'origine des feuilles de *Moringa* récoltées

Dans un second temps, les propriétés organoleptiques des mêmes poudres de feuilles de MO ont été décrites par des sujets bilingues malgaches. Le fait de réaliser les tests avec des sujets bilingues (parlant la langue malgache et la langue française) nous a permis de vérifier l'effet éventuel des langues utilisées lors des tests descriptifs : existe-t-il une langue parmi les deux qui permettrait de mieux décrire les aliments du point de vue sensoriel ?

Ce chapitre a pour but de vérifier l'hypothèse: « Les caractéristiques des feuilles de MO, tant nutritionnelles qu'organoleptiques, sont différentes selon les zones d'origine » (H1).

La première étude est présentée dans l'**article 1** (« Effect of geographical origin on the nutritional composition and sensory properties of *Moringa oleifera* leaf powder from Madagascar »). La seconde étude est présentée dans l'**article 2** (« Role of languages in food description: contrasting Malagasy and French descriptors of *Moringa oleifera* leaf powder ») et le **poster A** ("Bilingual panels: A tool to evaluate the role of language in descriptive tasks").

II. Article 1:

Effect of geographical origin on the nutritional composition of *Moringa oleifera* leaf powder from Madagascar

[En preparation]

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Abstract

Nutritional composition of *Moringa oleifera* (MO) leaves was investigated as fonction of geographical origin. The leaves were collected from five different areas of Madagascar. Standard analytical methods were used: determination of proportions of crude protein (CP), crud fat (CL), aminoacids, fatty acids and minerals (calcium, magnesium and iron). This study showed that there are variations in chemical composition of MO leaf powder from different locations in Madagascar. The proportion of CP varied from 23.5 to 29.7%, CF from 5.2 to 7.5%, Ca from 974.5 to 2714.3 mg/100g, Mg from 271.5 to 460.7 mg/100g and Fe from 3.8 to 8.3 mg/100g. Sample from Antananarivo had higher quantity of polyunsaturated fatty acids (linoleic acid or LA: 1704.9 $\mu g.g^{-1}$, α-linolenic acid or ALA: 7940.9 $\mu g.g^{-1}$) than the one from Antsiranana (LA: 693.6 $\mu g.g^{-1}$, ALA: 2629.7 $\mu g.g^{-1}$). The quantities of essential amino acids into 100g of MO leaf powder were sufficient to cover the body need for adult. This finding might be a reference point in the selection and formulation of plant-based nutrients supplement in human nutrition.

Keywords

Moringa oleifera, chemical, nutrients, Madagascar

1. Introduction

Moringa oleifera (MO), Lam. (Moringaceae), commonly referred to as “The Miracle Tree” (Fuglie 1999), is a member of the Moringaceae family which grows world-wide in the tropics and subtropics (Booth and Wickens 1988). Madagascar has the climate and adequate conditions to grow MO. Yet leaves from this wild plant are only consumed by a limited proportion of population in Madagascar. So far, these leafy vegetables are less valorised in all Madagascar than in other countries where they grow. In the rural central part of the country, next to the capital, in 2011, only 29% of the population declares having already eaten its leaves (Ramaroson Rakotosamimanana et al, submitted).

Previous studies showed that MO leaves provide multiple benefits to human health (Iqbal 2006; Anwar 2007), such as bringing numerous nutrients (Thurber and Fahey 2009). These leaves have been shown to be rich in protein and amino acids, minerals and vitamins (Barminas 1998; Thurber and Fahey 2009; Sánchez-Machado, Núñez-Gastélum et al. 2010). According to Kidmose, Yang et al. (2006), they are the richest leaves in vitamin A among a whole set of wild leafy vegetables. As such, MO leaves need to be largely exploited because they can contribute to fight malnutrition (Thurber & Fahey 2009).

Nevertheless, like for all plants, different factors like genetic background, environment and cultivation methods can influence the nutritional composition of MO leaves (Brisibe, Umoren et al. 2009; Sánchez-Machado, Núñez-Gastélum et al. 2010). Broin (2006) and Thurber & Fahey (2009) showed that there is a wide variation in nutritional composition of these leaves depending on country of origin. Some other studies reported variations on mineral composition of MO leaves among different regions within a same country (Iqbal 2006; Anjorin, Ikokoh et al. 2010). There is however limited reports on the variation of other nutrients into MO leaves depending on regions within a given country. In addition, while general nutritional compositions of MO data are useful, information on Malagasy leaves is lacking.

The main objective of the current study was to investigate the role of harvest location on nutritional composition of MO leaf powders from Madagascar. In order to obtain an adequate representation of the variability of climate and environment of the country, leaf powders originating from five distant regions were studied. The finality of this work was to check if the nutitional properties of Malagasy MO leaves are as interesting as those of MO leaves previously studied in other countries, and to determine the interest of introducing MO leaves into Malagasy diet.

2. Materials and methods

2.1. Plant preparation

Fresh MO leaves were collected from five distant towns of Madagascar: Antananarivo (center), Antsiranana (northern coast), Toamasina (eastern coast), Mahajanga (western coast) and Toliara (southern coast). Two series of harvests were performed. The first batches of fresh leaves, for the analysis of dry matter, ash content, minerals, crude proteins, and crude fat, were harvested in April 2012 in the five locations. The second batches, for the analysis of fatty acids and amino acids, were collected only in Antananarivo and Antsiranana in June 2013. The green leaves were first separately cleaned, then sun-dried and finally milled into powder using mixer traditionally used in family kitchen. Manipulations of leaves when drying and grinding were similar to avoid variation due to sample preparation. The powders were then stored in well-dried plastic container and protected from light at about 6°C.

Moisture content was determined by drying of leaf powders in oven at 45°C for 24h and ash content was obtained after incineration at 600°C for 3h.

2.2. Major macronutrients, aminoacids and fatty acids quantification

Crude protein content (CP) was determined using Dumas Nitrogen Analyzer NDA 701 (Velp® Scientifica, Italy) (Wiles, Gray et al. 1998). Nitrogen-to-Protein conversion factor was 4.4 (factor used for tropical plant samples).

Crude fat (CF) was quantitatively extracted with a Randall Extractor SER 148 (Fisher Bioblock Scientific, France) which was used by Thiex, Anderson et al. (2003) and accepted as AOAC Official Method 991.36. Before extraction, acid hydrolysis was performed for 1h and hydrolyzed samples were dried. Petroleum ether solvent (Carlo Erba) was used to extract fat material.

The crude fat fractions obtained from leaf powders were submitted to transmethylation of the fatty acids using boron trifluoride in methanol according to Morrison and Smith (1964). Fatty acid methyl esters were subsequently extracted with hexane and analyzed using gas chromatography on a Hewlett Packard Model 5890 gas chromatograph (Palo Alto, CA, USA) using a CPSIL-88 column (100 m, 0.25 mm i.d., 0.20 µm film thickness, Varian, Les Ulis, France) equipped with a flame ionization detector. Hydrogen was used as the carrier gas (inlet pressure, 210 kPa). The oven temperature was held at 60°C for 5 min, increased to 165°C at 15°C/min and held for 1 min and then to 225°C at 2°C/min and finally held at 225°C for 17 min. The injector and the detector were maintained at 250°C. Fatty acid methyl esters were identified by comparison with commercial and synthetic standards (Sigma Aldrich, L'Isle

d'Abeau, France). The data were processed using the EZChrom Elite software (Agilent Technologies, Massy, France) and reported as a percentage of the total fatty acids. All other reagents and solvents were of analytical grade and obtained from Carlo Erba Reagents S.A.S. (Val de Reuil, France).

For total amino acids quantification, the method used follows the reglementation CE N°152/2009. The samples were hydrolysed with HCl for 23 h under vacuum. The hydrolysate was adjusted at pH 2.2. The amino acids were separated by ion exchange chromatography and quantified by reaction with ninhydrin using photometric detection at 570 nm.

For Tryptophan determination, the norm NF EN ISO 13904 was followed. After basic hydrolysis at 110°C for 20 h using Barium hydroxide, Tryptophane was quantified by Reversed-Phase High-Performance Liquid Chromatography using UV detector.

2.3. Minerals quantification

500 mg of leaf powders were incinerated at 600°C, weighed and desilicated with 1 mL of 37% chlorhydric acid (Panreac Quimica, Castellar del Vallès, Spain) and 1 ml of 1 $mol.L^{-1}$ of HCl (Panreac Quimica, Castellar del Vallès, Spain). The obtained solution was then evaporated at high temperature. The residue was mixed with distilled water and filtered. Detection of calcium (Ca), magnesium (Mg) and iron (Fe) were performed using flame atomic absorption spectrophotometry. Element concentrations were determined using specific calibration of 6 points for Ca and Mg and 7 points for Fe, in the range 0 to 5 mg/L for Ca, 0 to 2.5 mg/L for Mg and 0 to 30 mg/L for Fe.

2.4. Data analysis

Each analysis was performed in triplicate and all the results are reported as mean, except for the analysis concerning amino acids which was not repeated. Data were analyzed using one-way ANOVAs or Student t-tests. Newman Keuls test (SNK) was used to identify significant differences among treatment means. The software XLSTAT 2013 (Addinsoft, France) was used for statistical analysis. Data was considered significant at $p < 0.05$.

3. Results

Protein content in MO leaves from the five locations was from 23.5 to 29.7%. CF varied from 5.2 to 7.5%, Ca from 974 to 2714 mg/100g, Mg from 271 to 460 mg/100g and Fe from 3.8 to 8.3 mg/100g (Table 1). The ash contents were from 9.71 to 11.48% and the moisture content

from 6.34 to 8.46%. Total carbohydrates proportion was estimated by deduction to be from 44.7 to 54.8%. All the values are expressed on dry matter (DM).

The sample from Antsiranana had the highest quantity of crude protein (29.7%) and the leaf powder from Mahajanga the lowest (23.5%). The sample from Toliara had the highest quantity of crude fat (7.5%) compared to the dried leaves from the other locations whose fat content was similar.

The dried leaves from Antananarivo had the highest quantity of calcium (2714.3 mg/100g) and there was no significant difference of quantity of Ca between the four other samples. The highest quantity of magnesium was observed in the sample from Mahajanga (460.7 mg/100g), and the lowest quantity of Mg was observed in the samples from Antsiranana, Toamasina and Antananarivo. The highest quantity of iron was observed in the sample from Antsiranana (8.3 mg/100g) and the dried leaves from Toliara had the lowest quantity of Fe (3.8 mg/100g).

Table 1. Macronutrients and minerals composition of Malagasy *Moringa oleifera* leaf powders from different locations (means +/- S.D.)

Nutriment	Antananarivo	Toliara	Mahajanga	Toamasina	Antsiranana
Ash (g/100g DM)	10.9 [b]	10.5 [c]	9.7 [d]	10.6 [c]	11.5 [a]
CP (g/100g DM)	28.4 [b]	26.6 [c]	23.5 [d]	27.0 [c]	**29.7** [a]
CF (g/100g DM)	5.5 [b]	**7.5** [a]	5.3 [b]	5.2 [b]	5.7 [b]
Ca (mg/100g DM)	**2714.3** [a]	974.5 [b]	1327.7 [b]	1387.7 [b]	1156.7 [b]
Mg (mg/100g DM)	289.9 [c]	360.8 [b]	**460.7** [a]	280.0 [c]	271.5 [c]
Fe (mg/100g DM)	6.2 [b]	3.8 [c]	6.2 [b]	5.4 [b]	**8.3** [a]

(The highest values for each nutrient were in bold. Means bringing the same letter were not significantly different from Neuman Keuls test at $\alpha = 0.05$. DM: Dry Matter, CP: Crude Protein and CF: Crude Fat)

As the protein contents of Antananarivo and Antsiranana samples were the highest (see Table 1), the amino acids contents analysis was restricted to these two samples. The analysis of fatty acids was also performed with these same samples.

The dried MO leaf powders were found to contain 14 fatty acids of which seven saturated and five monosaturated (Table 2). Fatty acids into MO leaf powder were dominated by alpha-linolenic acid (ALA = 7.9 and 2.6 $mg.g^{-1}$ into samples from Antananarivo and Antsiranana respectively). Both of the two samples were rich on palmitic acid (more than 2 $mg.g^{-1}$). Some fatty acid quantities in MO leaves varied significantly between Antananarivo and Antsiranana. The most important difference was observed for the polyunsaturated fatty

acids (α-linolenic and linoleic acids), which were in higher quantity in MO leaves from Antananarivo. On the contrary, dried MO from Antsiranana contained about twice the quantity of oleic acid (656.7 $\mu g.g^{-1}$) than the one from Antananarivo (380.2 $\mu g.g^{-1}$). The quantities of the other fatty acids were less important (less than 0.4 $mg.g^{-1}$ of powder).

Table 2. Fatty acids composition of dried *Moringa oleifera* from two locations

	Proportion (% of total fatty acids)		**Quantity (mg.g-1 of powder HM)**	
Fatty acids	**Antananarivo**	**Antsiranana**	**Antananarivo**	**Antsiranana**
Myristic acid (C14:0)	1.4	1.8	0.2	0.1 **
Palmitic acid (C16:0)	**19.0**	**27.4**	**2.7**	**2** *
Hypogeic acid (C16:1c9)	1.4	2.0	0.2	0.1 *
Palmitoleic acid (C16:1c7)	tr	tr	-	-
Margaric acid (C17:0)	tr	tr	-	-
Stearic acid (C18:0)	2.5	4.9	0.4	0.4 n.s.
Oleic acid (C18:1c9)	2.7	**8.9**	0.4	**0.7** ***
Vaccenic acid (C18:1c7)	tr	tr	-	-
Linoleic acid [a] (C18;2c9,12(n-6)	**12.0**	**9.3**	**1.7**	**0.7 *****
Arachidic acid (C20:0)	0.7	1.8	0.1	0.1 n.s.
Alpha-linolenic acid [a] (C18:3c9,12,15(n-3)	**56.0**	**35.3**	**7.9**	**2.6** ***
Behenic acid (C22:0)	1.3	2.6	0.2	0.2 n.s.
Erucic acid (C22: 1c9)	tr	tr	-	-
Lignoceric acid (C24:0)	2.0	4.3	0.3	0.3 n.s.
Total SFA	27.2	43.1	3.8	**3.2**
Total MUFA	4.7	12.2	0.7	0.9
Total PUFA	**68.0**	**44.7**	**9.6**	3.3

([a] : essential fatty acids. HM: Humid Matter, tr: traces, SFA : saturated fatty acids, MUFA : mono-unsaturated fatty acids and PUFA: poly-unsaturated fatty acids)
n.s.: quantities not significantly different between samples from the two sites, from t-test at $\alpha = 0.05$
*: quantities significantly different at $\alpha = 0.05$
**: quantities significantly different at $\alpha = 0.01$
***: quantities significantly different at $\alpha = 0.001$

The quantity of each amino acid of the two samples is about similar. The eight indispensable amino acids (IAA) were observed (threonine, methionine, valine, phenylalanine, isoleucine, leucine, lysine and tryptophan) into the samples from Antsiranana and Antananarivo (Table 3). The most abundant IAA was Leucine, 2.26% and 2.76% in Antsiranana and Antananarivo respectively. The least abundant one was methionine (0.48 and 0.57% respectively).

Table 3. Amino acids composition of dried *Moringa oleifera* leaves from two locations. Comparison with the IAA composition of reference protein and requirements for adult and chidren aged 3-14.

Amino acids	Amino acids composition of dried MO leaves (mg/g protein)		Adult indispensable amino acid + his requirements [a]		Indispensable amino acid requirements of children between 3 and 14 years [a] (mg/kg per day)
	MO leaves from Antsiranana	MO leaves from Antananarivo	(mg/g protein)[b]	(mg/kg per day)	
His	22	23	15	10	12
Ile	41	49	30	20	22-23
Leu	76	97	59	39	44
Lys	49	62	45	30	35
Val	53	61	39	26	29
Met	16	20	Met + Cys: 22	15	Met + Cys: 17-18
Phe	64	65	Phe + Tyr: 38	28	Phe + Tyr: 30
Thr	42	52	23	15	18
Trp	23	27	6	4	5
Cys	13	20			
Asp + Arg	104	121			
Pro	35	43			
Ser	44	50			
Glu + Gln	134	137			
Gly	43	53			
Ala	55	63			
Arg	61	67			

IAA: Indispensable amino acids (in bold)

[a]: FAO/WHO/UNU. 2007. Protein and amino acid requirements in human nutrition. Report of a joint FAO/WHO/UNU Expert Consultation. World Health Organ. Tech. Rep. Geneva. Report No.: 724

[b]: Mean nitrogen requirement of 105 mg nitrogen/kg per day (0.66 g protein/kg per day).

4. Discussion

The objectives of this paper was to evaluate the effect of geographical origin on the nutritional content of MO from Madagascar and to compare the nutitional properties of Malagasy MO leaves with those of MO leaves previously studied in other countries. The results showed important difference between samples collected in different areas as well as some differences between MO leaves from Madagascar and MO leaves from other countries. These differences are discussed below by nutrient groups. For each nutrient group three points are considered: The effect of area on MO nutritional content, the difference between MO leaf powders from Madagascar and those from other countries and finally the interest of introducing MO leaves into Malagasy diet.

Protein and aminoacids

Protein content of MO leaf powders differed according to harvest areas. The sample from the north was the richest in protein followed by the sample from the center. The sample from the west had the smallest in protein content but no difference was observed between the samples from the south and the east. The difference in protein content was probably due either to soil composition and/or plants maturity (Anjorin, Ikokoh, & Okolo, 2010; Bamishaiye, Olayemi, et al., 2011). It was difficult to determine clearly the link between protein content and climate because between the south and the east areas the climate difference includes quite numerous variations. Moreover, Shih, Chang et al. (2011) reported that there is no season effect on the chemical compositions of MO leaves.

When comparing protein content of MO leaves with previous works, the quantities of protein in the five Malagasy samples of this study were higher than dried leaves from Mexico (Sánchez-Machado, Núñez-Gastélum et al. 2010). On the contrary, the quantities of CP measured in our work were lower than those of dried leaves collected in South Africa, where protein level was 30.3% (Moyo, Masika et al. 2011). The leaves from Nicaragua (Makkar and Becker 1997) had about the same quantity of protein (26.4%) as the sample from Toliara and Toamasina but had lower quantity than the samples from Antsiranana and Antananarivo and had higher quantity than the sample from Mahajanga.

Compared to other protein source foods, MO leaves can be considered as a high source of protein: protein content of certain meats is lower. For example, meat of goat fed on grass hay in Limpopo Province of South Africa had a proportion of protein of 14% DM (Qwele, Hugo et al. 2013), about half the protein content compared to MO dried leaves of the present study. This shows the interest of MO leaves as a good potential source of protein for undernourished population in developing countries like in Madagascar, where the prevalence of proteino-energetic malnutrition is high.

Result obtained from amino acids determination was compared to recommended daily intake of essential amino acids by WHO. According to the quantity of each essential amino acid determined in our samples from Antananarivo and Antsiranana, 100 g DM of leaf powder of MO per day is sufficient to satisfy the body need of adult for all essential aminoacids and the half of this quantity for a 3-14 years old child. For example, the daily requirement amounts for a children weighting 30 kg are 0.9 g (Lys), 1.12 g (Leu), 0.6 g (Ile), 0.78 g (Val), 0.45 g (Thr), 0.75 g (Phe+Tyr), 0.12 g (Trp), 0.45 g (Met+Cys) and 0.3 g (His) (WHO, 2007). Protein from MO leaves contain these amino-acids in quite similar ratios,

except for Trp which is most abundant than others. Thus, there is no limiting amino-acid in MO leaves proteins, which seem to be high quality protein.

Lipid and fatty acids

A difference in crude fat content was observed only between the sample from the south and samples from the four other areas. However, so far, we do not have a clear explanation for this difference.

A comparison of our samples with MO from other countries indicate that the Toliara sample had a higher quantity of CF than dried leaves from South Africa analysed by Moyo, Masika et al. (2011) which contained 6.5% of CF. This quantity however is higher than those of the four other samples from Madagascar. 7.85% of CF was found in MO leaf powder from Senegal (Ndong, Wade et al. 2007), which is close to quantity found in the sample from Toliara.

A high proportion of alpha-linolenic and palmitic acids had already been observed in MO leaves in previous work (Sánchez-Machado, Núñez-Gastélum et al., 2010) carried out in Mexico.

The high amount of polyunsaturated fatty acids, especially alpha-linolenic acid, into our samples makes these leaves nutritionally interesting. This fatty acid is generally difficult to find into diets, contrary to the other fatty acids which are present in most fat foods. The recommendation about ALA daily intake is 1.77 g for a child, thus 100 g MO leaf powder from Antananarivo would participate to about 45% of this recommendation. Compared to walnuts, which is known as a good source of ALA, MO leaf powder from Antananarivo and Antsiranana contains a higher proportion of ALA compared to global quantity of fatty acids: ALA into walnuts represents only 14% of total fatty acids. Elsewhere, the quantity of linoleic acid (LA) into MO leaf powder is desequilibrated according to ideal ratio (LA/ALA = 5). To complete the lack of LA into diet, it can thus be recommanded to add other food sources of LA, like colza or soybean oil, in addition to MO leaves. In these conditions, MO leaves could prevent various diseases if frequently consumed (Fahey 2005).

Minerals

Important differences in minerals contents of MO leaf powder have been observed among the five locations: twice the contents for Mg and Fe and three times for Ca. The sample from the center was the richest on Ca, the one from the west was the richest on Mg and the one from

the north was the richest on Fe. These differences were probably due to soil composition, which is the main cause of plant mineral content.

Dried MO leaves recolted from Madagascar contained a high quantity of calcium and magnesium, compared to foods in general. This finding is in accordance with Moyo, Masika et al. (2011)'s observation. Calcium content in MO leaves is higher than the level observed in other African non conventional leafy vegetables: *Adansonia digitata, Cassia tora, Colocasia esculenta, Corchorus tridens, Amaranthus spinosus, Ficus sycomorus* and *Ficus asperifolia* (Barminas 1998; Nkafamiya, Osemeahon et al., 2010). The level of iron was low in MO leaves (less than 10 mg/100g DM). This finding about iron content does not concern only leaves from Madagascar; a similar level was observed by other researchers in Nigeria (Barminas, 1998; Nkafamiya, Osemeahon et al., 2010). Elsewhere, the result of Moyo, Masika et al. (2011) was not in accordance with our finding on iron level (49 mg/100g). The MO leaves from Madagascar are thus at least six times poorer in iron than those from South Africa.

50 g of dried powder of MO from Antananarivo can complete the recommended daily intake of calcium for adequacy for a child between 9 to 13 years old (Institut of Medicine 2011).

To sum up, the results from the three nutrient groups showed that as in other countries growing MO, Malagasy MO leaves can be used as as a good source of nutrients. The specific content in the three nutrient groups depends on location and so the selection of the optimum leaves depends on the nutrient which is the most deficient in the population of interest. If the main deficience is in protein, it is adequate to choose MO leaves from Antsiranana or Antananarivo. Conversly, to promote essential fatty acids consumption by population to decrease cardiovascular diseases, MO leaf powder from Antananarivo can be used as a good source of this category of fatty acids.

5. Conclusion

This work shows that the Malagasy diet can satisfy daily recommanded nutrients if local nutritious foods like MO leaves are valorized. MO leaf powder can be used to enrich foods deficient on protein, essential fatty and amino acids, calcium and magnesium. They should be valorized to combat malnutrition in children.

Drying the leaves allows concentrating the nutrients, facilitating conservation and consumption. Dried leaves can be used during the time when feed is scarce or can be transported to areas where it is not cultivated. In addition to the medicinal and therapeutic properties of MO, the leaves can be used to improve health and nutrition in sub-Saharan countries like Madagascar.

The variation of nutritional composition of MO leaves between different locations can be due to environmental factors (soil composition and climate), age of the leaves, mode of conservation between collection and analysis. The study of the specific roles of these factors, however, needs deeper investigations in the future.

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III. Article 2:

Role of languages in food description: contrasting Malagasy and French descriptors of *Moringa oleifera* leaf powder

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ABSTRACT

Language might have an effect on the quality of sensory profiles on food description. In cross cultural studies, it was observed that the effect of language and cultures cannot be easily separated. The aim of this work is thus to separate these two effects by working with bilingual assessors speaking Malagasy and French languages. Twenty-nine assessors were recruited to form four different panels: the two first panels performing the descriptive test in French condition and the two others in Malagasy condition. Five samples of dried *Moringa oleifera* leaf powder from different locations and different drying methods were evaluated by Flash profile method. There was no significant effect of language on the global quantity of words generated between the two conditions. But a significant difference was observed in the quantity of meta-descriptors for odour / aroma category only. A qualitative analysis showed that the preciseness of the terms in a given category depended upon the language. Malagasy terminology was richer than the French one for several categories. Higher between (0.85) than within language RV coefficients (0.78) were observed for the taste / odor descriptors categories. For the other descriptors no effect of language was observed on the positioning of the powders.

PRACTICAL APPLICATIONS

This study offers new insight into the effect of languages on the description of food. When performing sensory analysis in bilingual countries, the choice of the language should be based on the sensory category which will be focused on. This effect of language on the odor/taste category can be put in perspective with previous results showing a strong effect of culture on aroma descriptors (e.g. Tu *el al.* 2010) and suggest that such an influence might be due to language availability effects.

KEYWORDS

Language, Description, *Moringa oleifera*, Malagasy, French

INTRODUCTION

Language is at the heart of sensory description and yet only a few studies focus directly on this issue. Most of these studies discuss the difficulty to use language to describe sensations and the need of definitions (Giboreau 2007), references (Rainey 1986; Krasner 1995) and training (Meilgaards *et al.* 1999; Chambers 2004) to improve communication. Cross-cultural studies trying to relate sensory profiles established in different languages suggest that language might have an effect on the quality of sensory profiles. For example Blancher *et al.* (2007) showed that a Vietnamese panel generated less descriptor than a French panel to describe a set of fruit jellies. Likewise, Yang *et al.* (2012) found that a Korean panel generated more attributes than a Chinese and an American panel to describe oils made from Perilla seeds. In both cases the observed differences concerned mostly odour descriptors. The authors interpreted these results in terms of product familiarity as Vietnamese are more familiar with fruit jellies than French and Korean are more familiar with Perilla seeds than Chinese and American. Another explanation could be that the difference comes from the structure of language itself. The idea that language might determine the way people perceive, analyse and act in the world was first defended by Whorf (1956) under the name of Linguistic Determinism. Although the view that thought and action are entirely determined by language has been abandoned, some studies have shown that language characteristics such as grammatical gender can influence product experience and description (Fenko *et al.* 2010). The problem, however, in interpreting such results is that participants in cross cultural studies often have different food experiences as well as different languages, and so the effects of language and cultures cannot be easily separated (Tu *et al.* 2010). In a first attempt at separating these effects, Varela *et al.* (2008) compared the performance of panels speaking the same language but coming from different countries. They showed that same terms (crunchy/ crispy) could have different meanings for two panels from Spain and Uruguay or evoke different perceptions depending on the country.

The aim of the present work was to separate language effect from cultural experience effect by working with bilingual assessors. Madagascar is a good candidate to perform such a study as two languages coexist in this country: Malagasy, the native language of Malagasy people, and French which is used in administrative and educational communication. Most educated Malagasy people are bilingual as they use Malagasy in their family life and French in their professional life.

To avoid a potential effect of variation of familiarity with the food tested we chose to work with a novel food product: *Moringa oleifera* leaf powders. *Moringa oleifera* grows in

tropical and subtropical countries in the world, including Madagascar, but only a small part of the population already tasted its fresh leaves. An additional interest to work with *Moringa oleifera* leaves is that they have been shown to have high nutritional properties (Barminas 1998; Moyo *et al.* 2011). Knowing the sensory properties of *Moringa oleifera* leaf powders could then help introducing these leaves into the Malagasy food repertory.

Because we wanted to evaluate the effect of language on sensory description we did not want to use a descriptive method requiring a training period such as Quantitative Descriptive Analysis but a more spontaneous method in which panellists generate their own descriptors. At the same time we wanted a method based primarily on language and not on sensory similarities like free sorting (Chollet *et al.* 2011) or perceptual mapping (Risvik 1997; Pages 2005). So we opted for the flash profile method which was proposed by (Dairou and Sieffermann 2002; Sieffermann 2002) and showed to be efficient at accurately capturing consumer's perceptions (Veinand *et al.* 2011). This method was also proved to be adapted with consumers using different languages (Moussaoui and Varela 2010)

In our research, Flash profiles were carried out in duplicate in two language conditions (French and Malagasy) by four panels. We hypothesized that if the language in which the flash profiles are performed affects the descriptions of the products then greater differences should be observed between the panels using different languages than between the panels using the same language.

MATERIALS AND METHODS

Panels

Twenty-nine Malagasy untrained assessors were recruited among the panel database of the sensory laboratory (LAS Ambatobe) of FOFIFA Antananarivo. To warranty bilingualism, all of them had a university background. They were randomly divided into four panels of seven or eight assessors (TABLE 1).

TABLE 1. DEMOGRAPHIC INFORMATION OF ASSESSORS

Panel	FR1	FR2	MG1	MG2
Age	33,1 ± 18,4 y.o.	24,3 ± 1,4 y.o.	34,1 ± 11,5 y.o.	24,5 ± 1,9 y.o.
Gender	3♀, 4♂	5♀, 2♂	3♀, 4♂	7♀, 1♂

Assessors were not informed of the aim of the study but were aware that powders of leafy vegetables would be evaluated.

Products

Six batches of *Moringa oleifera* leaves were used. Leaves were sun-dried or dried under the shade by using plastic strainer usually found in family kitchen. Then, dried leaves were grinded by using a domestic blender (Auto-control Turbo GENIUS 2000) during 10 min at the maximum speed level. The drying and grinding processes can be reproduced by rural housewives easily. The first five products were sun-dried and came from five different regions of Madagascar: Antsiranana or Diégo Suarez (SunDiégo), Mahajanga (SunMahaj), Toamasina (SunToam), Antananarivo (SunTanà) and Toliara (SunToli). The sixth product was dried under the shade and came from Toliara (ShadeToli). We chose these five locations, which are the five out of six biggest towns of the island, to represent its five corners: the north, the west, the east, the center and the south respectively (FIG. 1).

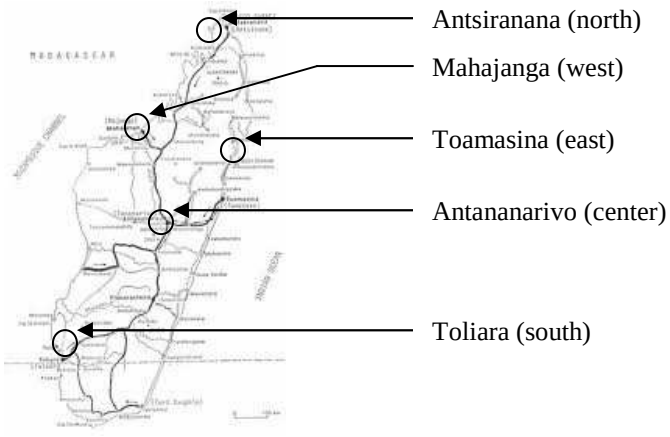


FIG. 1: FIVE REGIONS OF ORIGINS OF MORINGA OLEIFERA LEAVES COLLECTED IN MADAGASCAR

All products were stored in labelled polypropylene films placed in a clean well-dried black container at ambient temperature after powder making process. For testing, they were distributed into other polypropylene films and coded with three digit numbers. Each sample weight was 0.5 g.

Procedure

The Flash profile methodology was used to describe the six samples of *Moringa oleifera* leaf powders. Four sessions were held in four different days, without repetition of measure, in the sensory laboratory (LAS Ambatobe) of FOFIFA Antananarivo in Madagascar. Two panels (FR1 and FR2) performed the Flash profile in French language and the two others (MG1 and MG2), in Malagasy language. Assessors evaluated the products under white light

using Fizz Réseau (Biosystemes 2012). The four sessions were animated by the same bilingual panel leader, who used only the language of the test from the beginning to the end of each session. In the French sessions, a French assistant helped the panel leader. This strategy was used to force indirectly panellists to use only the French language.

At the beginning of each session the aim and the principles of flash profile were explained to the assessors. Each session included three steps and lasted about two hours. In the first step assessors were presented simultaneously with the six samples. They were asked to write spontaneously on a sheet of paper a list of sensory attributes that described best the difference between samples before, during and after consumption, focussing on all their characteristics: appearance, texture, taste, aroma, tactile and auditory sensations. They had to categorize the terms according to these six sensory modalities. The six modalities will be referred to as "categories" throughout the paper.

In the second step, attributes generated by all assessors in the six categories were written on a board to make all assessors of the group aware of what the other assessors found and eventually complete their own list. When all terms had been written on the board, assessors rewrote their own lists organized by sensory categories. They were allowed to add words to their initial list or to replace some of their own words based on the terms generated by the other panellists. This new list was used by assessors as a draft for the next step.

In the third step, panellists had to rank the six samples according to the attributes of their own list on linear scales. To facilitate the analysis of attributes by category, panellists were asked to write before each attribute their panellist number and at the end the initial of the sensory category related to the attribute ("V" for visual or appearance category, "T" for tactile category, "B" for texture in mouth, "AR" for aroma, "OD" for odour and "S" for sound or auditory). For example, the first panellists' appearance attribute dried leave was coded as "1feuillesècheV". In this last step, samples were presented in a different order for each panellist according to a Williams Latin square. Each panellist evaluated all the six samples. Panellists were free to taste the samples as much as they liked and as often as they wanted to complete the evaluation.

Data analysis

Data analysis was conducted in two steps. In the first step, the vocabulary generated by the panellists was analysed. Attributes from the two panels using the same language were first merged. Synonymous and antonymous were then grouped in "meta-descriptors" to reduce the number of terms. The frequency of meta-descriptors was then computed for each language

condition and chi-square tests were used to test for a potential language effect. All analyses were performed in the original language by a bilingual researcher.

In the second step, four multiple factor analysis (MFA, Escoffier and Pagès 1998) were performed, one for each panel (FR1, FR2, MG1, MG2). Each assessor constituted one group in the MFA. Statistical analyses were performed in SPAD version 5.5 (Coheris, France). Visual examination of the MFA spaces and correlation coefficients between the MFA dimensions were used to compare the four panels.

RESULTS

Comparison of the vocabulary generated in the two language conditions

Summary statistics. To describe the six samples, panellists in the French condition generated from nine to 20 descriptors and panellists in the Malagasy condition from eight to eighteen. The average numbers of generated descriptors were 13.14 (std 3.37) in the French condition and 11.46 (std 3.09) in the Malagasy condition. A t-test showed no significant difference between the two conditions ($t(27) = 1.4$ ns). Thus language had no significant effect on the global quantity of words generated.

After merging synonymous and antonymous, we found a total of 50 meta-descriptors in the French condition and 41 in the Malagasy condition. Among the meta-descriptors generated in the French and Malagasy conditions, 30 were common, 20 specific to the French condition and 11 to the Malagasy condition. T-tests performed for each category showed no significant difference between French and Malagasy conditions, except for the odour / aroma category ($t(27) = 2.7$, $p<0.05$).

FIG. 2 shows the repartition of the meta-descriptors generated for each sensory category as a function of language condition. The general pattern is similar in the two language conditions ($\chi^2(5) = 1.33$ ns). In both languages, the number of odour/aroma meta-descriptors was the highest. Meta-descriptors related to sound were the least generated.

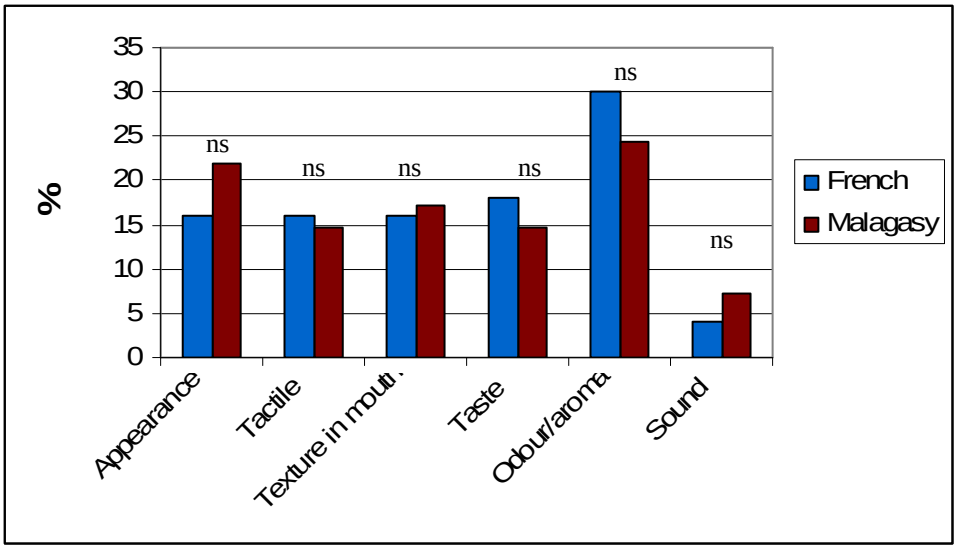


FIG. 2. PROPORTION OF META-DESCRIPTORS GENERATED IN EACH SENSORY CATEGORY IN THE FRENCH AND MALAGASY CONDITIONS (EXPRESSED AS FONCTION OF TOTAL NUMBERS OF META-DESCRIPTORS)
ns: no significant difference between the two percentages according to adjustment Khi-square test at 5%

FIG. 3 shows the repartition of meta-descriptors specifically generated in each language condition. The categories with the highest amount of specific meta-descriptors were the odour/aroma category followed by the texture in mouth category in both conditions. Compared to the Malagasy condition, more specific meta-descriptors were generated in the French condition for the taste category. Inversely, more specific meta-descriptors were generated in the Malagasy condition compared to the French one for the appearance and auditory categories.

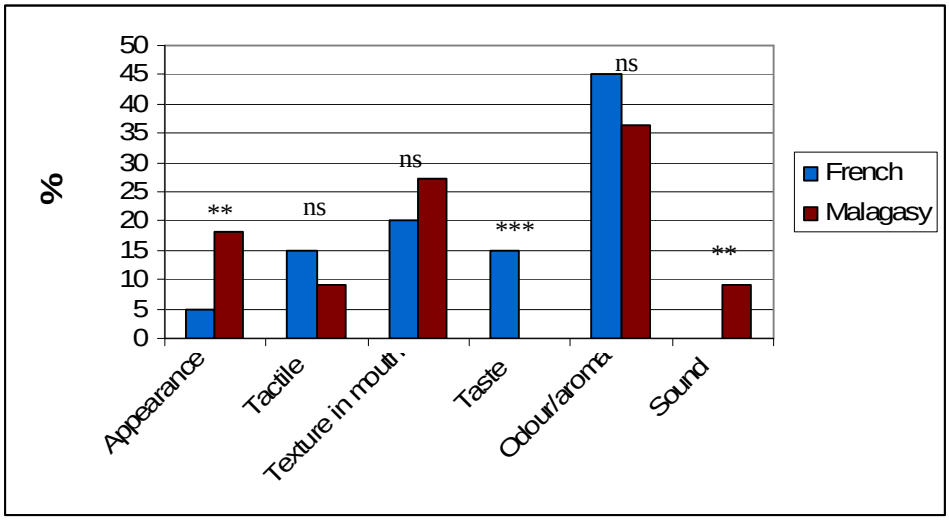


FIG. 3. PROPORTION OF SPECIFIC META-DESCRIPTORS GENERATED IN EACH SENSORY CATEGORY IN THE FRENCH AND MALAGASY CONDITIONS (EXPRESSED AS FONCTION OF TOTAL NUMBERS OF SPECIFIC META-DESCRIPTORS)
ns: no significant difference between the two percentages according to adjustment Khi-square test at 5%;
: significant difference at 1%; *: significant difference at 0.1%

Descriptor analysis. TABLE 2 shows the list of meta-descriptors generated by panellists in the French and Malagasy conditions. For the Appearance category, the colour “black” and the aspect “spread out” appeared only in the Malagasy condition, whereas the appearance “limpid” appeared only in the French condition. For the tactile category, the common meta-descriptors were related to powder, hardness, granularity, roughness and dryness. More specific meta-descriptors were generated in the French condition (“insoluble”, “unctuous” and “grinded”) than in the Malagasy condition (“stay in finger”). For the texture in mouth category, four of the meta-descriptors were common to the two languages conditions and seven of them specific. For this texture in mouth category, the specific meta-descriptors mentioned by the French panel were “soluble/insoluble” “dry”, “powdery”, “soft”. In the Malagasy condition, specific meta-descriptors were related to roughness and associated to swallowing phase. In the taste category, basic tastes, aftertaste and trigeminal descriptors were distinguished, and the descriptor “tasteless” was cited in both language conditions. But French panels detailed more the sensations related to basic tastes by using specific meta-descriptors (“sweet”, “acid” and “salty”). In the aroma / odour category, common meta-descriptors were related to green notes (dry leaves, cassava leaves, raw), or fermented notes (acid, fermentation and dry fish). Aroma and odour of Moringa leaf powder were compared to those of cassava leaves in both conditions. More specific meta-descriptors were generated in the French condition (“tamarind”, insect”, “honey”, “argillaceous”, “woody”, “cigarette”, “hay”, “seweed” and “Moringa”). In auditory category, only two or three meta-descriptors were generated expressing dryness and crunchiness.

Some attributes generated by assessors were associated with qualifiers which specified the meaning of the attributes (TABLE 3). Three types of qualifiers were used. The first one was related to the intensity of the attribute (e.g. “clair/foncé” meaning “light/dark”). The second one denotes spatial aspects (e.g. “ivelany” which precises that the cited colour was different in the middle and on the edge of the powder). And the third type of qualifier was related to affective evaluation (e.g. good/bad). Language differences were observed in the use of qualifiers. In Malagasy language most of the qualifiers were generated in the visual category whereas in French the qualifiers appeared equally in all categories. Qualifiers associated to the tactile, texture in mouth and odour/aroma categories were generated only in the French condition.

TABLE 2. LIST OF META-DESCRIPTORS GENERATED IN FRENCH AND IN MALAGASY (Meta-descriptors in bold were generated only in one language)

	List of meta-descriptors		
Sensory categories	FR	MG	English translation
Appearance	Jaune	Mavo	Yellow
	Vert	Maintso	Green
		Mainty	Black
	Homogène/ Hétérogène	Tsy ranoiray	Homogeneous/ Heterogeneous
	Fin	Madinika/ Mitambaingambaingana	Lim/Granulated
	Broyé	Potika/Torotoro/Voatoto	Grinded
	Feuilles sèches	Ravina maina	Dried leaves
	Fibreux	Matsiraka/Fakaina/taho	Fibrous
	Limpide		Limpid
		Mivelabelatra/Miparitaka	Spread out
Tactile	Poudreux/Poussiereux	Vovony	Powdery
	Mou/ Pateux	Malemy/ Malefaka/ Mahery	Lim/Hard
	Granuleux/ Sableux	Mamasipasika/ Mitambaingambaingana	Granular/ Sandy
	Fin	Malamalama/ Maisamaisatra	Brandy/ Rough
	Sec	Maina	Dry
	Insoluble		Insoluble
	Onctueux		Unctuous
	Broyé		Grinded
		Manara-tanana	Stay in finger
Texture in mouth	Fin	Malemy	Brandy
	Collant	Maditidity	Sticky
	Des fils qui restent	Mamakafaka	Fibrous
	Granuleux/Sableux	Mitambaingana	Granular/ Sandy
	Soluble/ Insoluble		Soluble/ Insoluble
	Sec		Dry
	Poussiereux		Dusty/Powdery
	Léger		Soft
		Mora atelina	Easy to swallow
		Manaikitenda	Irritating throat
		Maisamaisatra	Rough
Taste	Amer	Mangidy/ Mafaika	Bitter
	Sucré		Sweet
	Fade	Manganana/ Matsatso	Tasteless
	Acide	Marikivy	Sour
	Aigre		Acid
	Salé		Salty
	Astringent	Masaika	Astringeant
	Piquant	Masiaka	Hot
	Arrière-goût	Faratsiro	Aftertaste
Odour & Aroma	Feuilles sèches	Ravina maina	Dry leaves
	Feuilles de manioc	Ravitoto	Cassava leaves
	Cru	Manta	Raw
	Tamarin		Tamarind
	Aigre	Marikivy	Acid
		Masiatsiaka	Hot
	Insecte		Insect
	Poisson sec	Patsa	Dry fish/ shrimp
	Miel		Honey
	Fermenté	Masiso	Fermented/ Rotten
	Argileux		Argillaceous
		Voanjo	Peanut
	Boisé		Woody
	Cigarette		Cigarette
	Foin		Hay
	Algue		Seweed
	Moringa		Moringa
		Fofona	Odour
		Tsiro tono	Grilled
Auditory	Feuilles séchées	Maina	Dry
	Non croquant	Mikarepoka	Crunchy
		Mikasokasoka	Rustle

TABLE 3. LIST OF WORDS RELATED TO QUALIFIERS USED BY PANELLISTS

Sensory categories	List of words bringing preciseness		Sens of preciseness
	FR	MG	
Appearance	Colors		
	… clair / ... foncé (… light / … dark)	... tanora / … antitra (… young / … old)	Intensity
		… be (… very)	Intensity
	... algue (… seweed)	… lomotra (… seweed)	Nuance of colour
		… ivelany (… outside)	Différence of colour according to spatial dimension
	... avec ... (…with…)	*2 colors*	Mixture of colors
		Loko mifangaro (Mixture of colours)	Mixture of colors
	...-âtre (…-ish)	Manopy… (Turn …)	Color switches to another colour
	Texture in appearance		
	presque ... (almost …)		Intensity
	Pas assez … (Not sufficiently …)		Intensity
	… mais pourvu de … (… but equipped of …)		Another way to say "heterogeneous"
		Misy… / Tsy misy… (With … / Without …)	Presence / Absence
		Roots of the words cited 2 times	Effect of accentuating or reducing the intensity
		… vaventy / … madinika (… crude / … fine)	Size
		…tsara / ratsy… (… well / badly …)	Affective aspect
Tactile	**Non … (Not …)**		Opposite
	Finement ... (Finely …)		Size
	Légèrement ... (Lightly …)		Intensity
Texture in mouth	**Moins ... (Less …)**		Intensity
Taste	**Légèrement... (Finely …)**		Intensity
		Roots of the words cited 2 times	Effect of accentuating or reducing the intensity
Odour & Aroma	**Fort / Faible (Strong / Weak)**		Intensity
	Léger (Light)		Intensity

Comparison of the product descriptions obtained with the four panels

Four criteria were used to compare the panels: agreement among panellists (pairwise R_v coefficients), structure of the MFA (Eigenvalue distribution), MFA configurations (description of products) and correlation between principal components (pairwise correlation coefficients between dimensions).

Panellist consensus. To examine panellist's consensus we computed R_v coefficients between each panellist and the rest of the panel. MG1, MG2, FR1 and FR2 were considered separately. The R_v coefficient (Robert and Escoufier 1976) is a simple way of measuring the similarity between two sets of variation which have been measured on the same samples. R_v coefficient has values between 0 and 1 with numbers closer to 1 indicating greater similarity. R_v coefficients were calculated for all possible combinations of panellists.

To test panellists' consensus, we considered means of R_v coefficients from the four panels. These means varied from 0.62 to 0.77, indicating a good agreement between panellists (Chollet *et al.* 2011). A one-way ANOVA showed a significant effect of panels ($F_{ddl=3} = 8.2$, $p < 0.05$). A pair comparison using a Newman-Keuls' test showed a session effect but no

language effect: No significant difference was found between FR1 and MG1 or between FR2 and MG2 panellists but FR1 and MG1 were significantly different from FR2 and MG2 (FIG. 4).

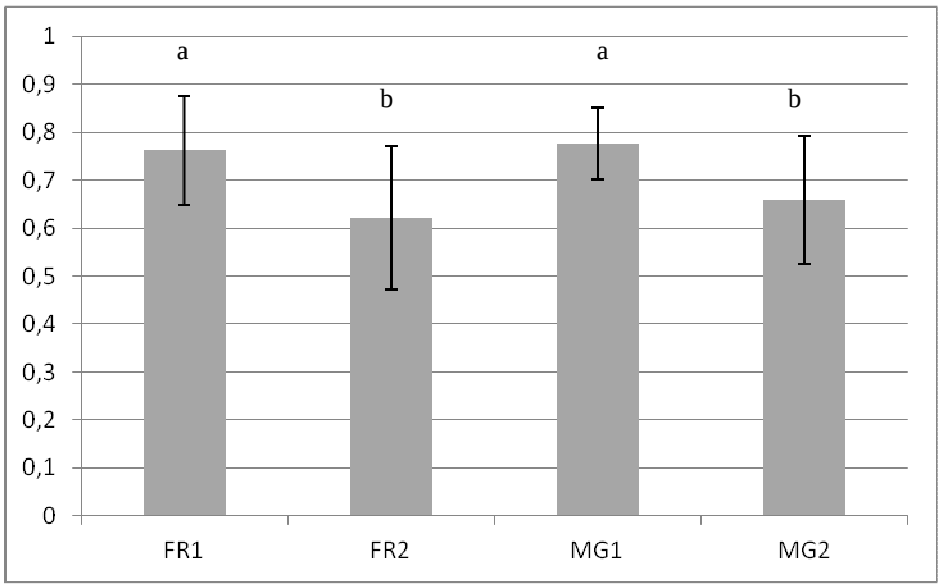


FIG. 4. MEANS AND STANDARD DEVIATION OF R_V COEFFICIENTS COMPUTED BETWEEN PANELLISTS WITHIN EACH PANEL. THE ERROR BARS REPRESENT THE STANDARD DEVIATIONS

MFA space structures. To compare the complexity of the MFA spaces obtained for the four panels, we examined the scree plot of the MFA (FIG. 5). Globally the scree plots were identical for the four panels. A slight language effect was observed only for the first component with a higher value for the MG1 and MG2 panels (value corresponding to 6.15 and 6.07 respectively) than for the FR1 and FR2 panels (value corresponding to 5.17 and 5.26 respectively)**.**

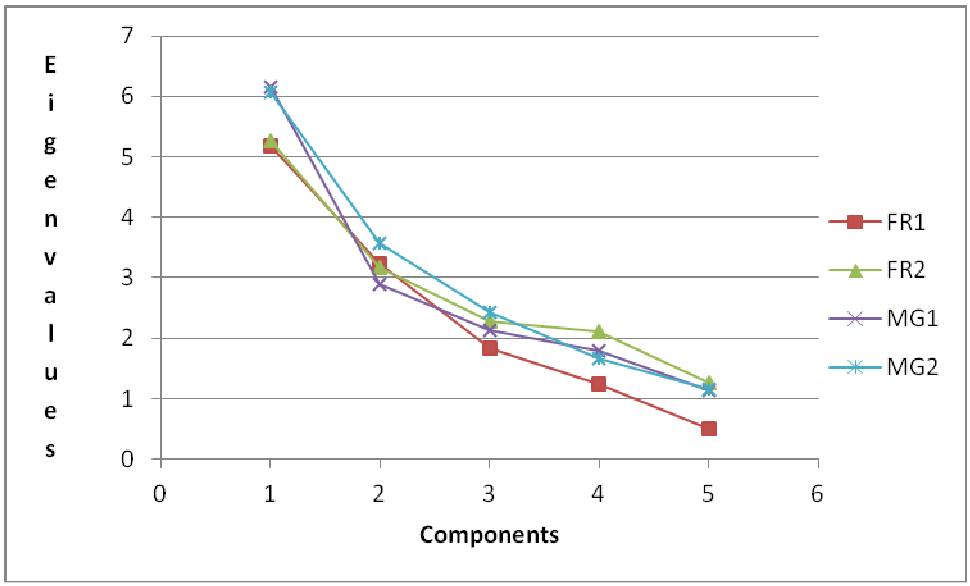


FIG. 5. SCREE PLOTS OF THE FIRST FIVE FACTORS OF THE MFA COMPUTED FOR THE FOUR PANELS

MFA configurations. For the four panels, the first four components were analysed as they explain more than 90 percent of explained variance. As one of the disadvantages of using Flash Profile is to obtain numerous descriptors, to simplify the MFA spaces, we represented only attributes which contributed the most to the components (contribution values higher than the average contribution).

Panel FR1. The first four dimensions explained 90.64% of the variance (FIG. 6). The first dimension (43.37% of variance) opposes SunToam, which was described as homogeneous (appearance), sandy/granular and, bitter to ShadeToli which was characterized as dry (texture in mouth), insoluble and tasteless. The second dimension (18.05% of variance) opposes SunToli to SunToam and ShadeToli. These two last samples were characterized as green and did not smell dry leaves, hay, nor wood. The third dimension (17.24% of variance) opposes SunDiégo and SunMahaj, which were characterized as having an aroma of cassava leaves and being unctuous in touch, to the other samples. The fourth dimension (11.98% of variance) opposes SunTanà, which is described as bitter in taste and aftertaste and astringent, to SunToli.

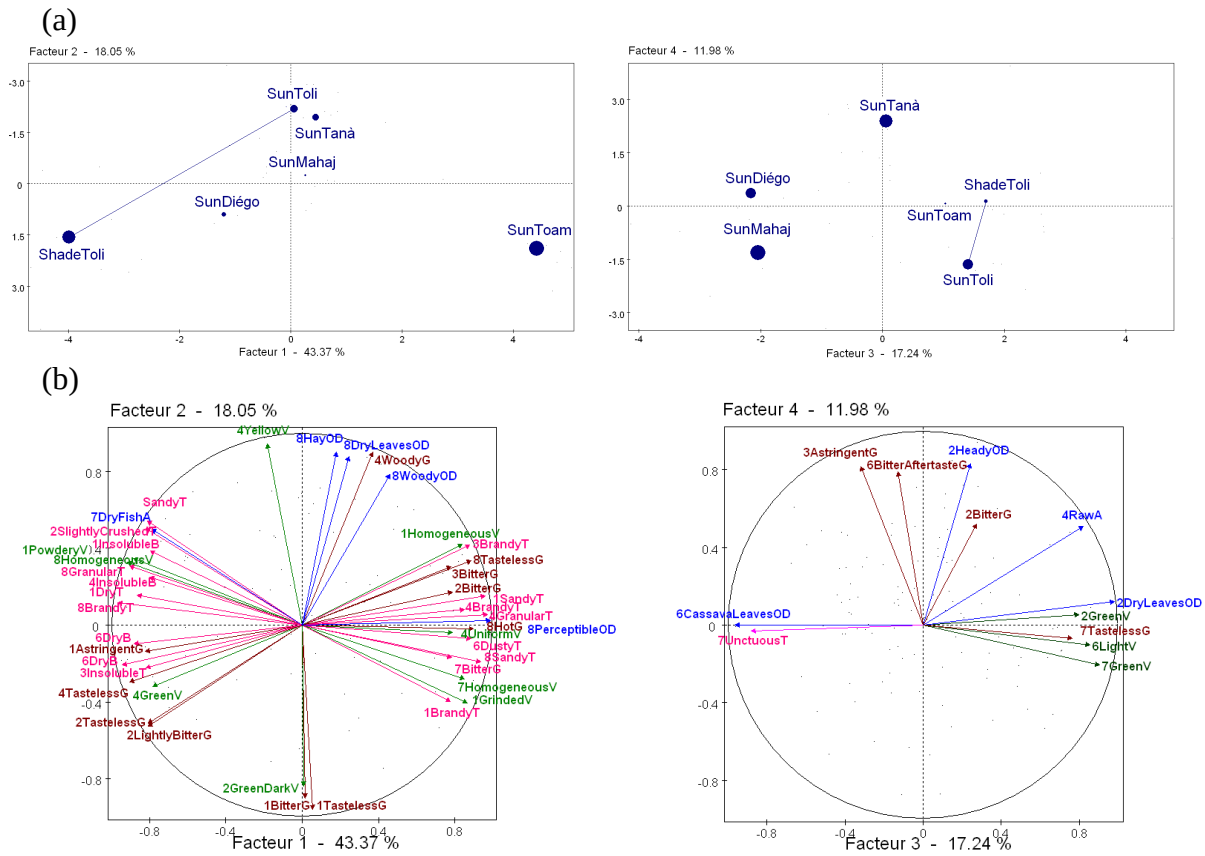
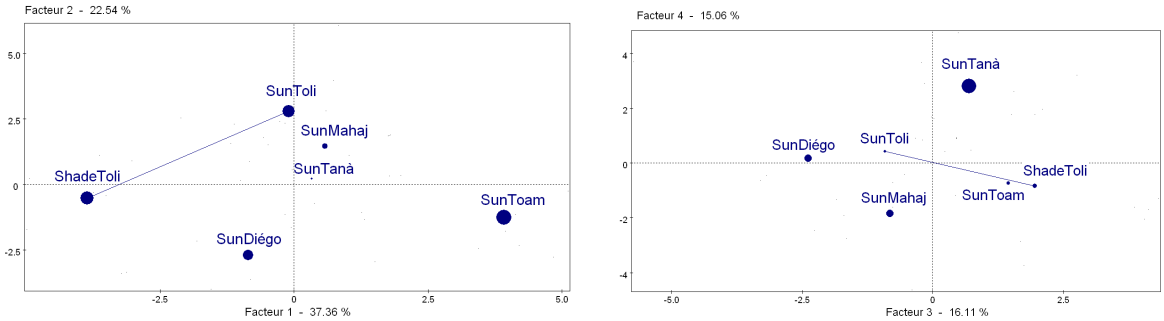


FIG. 6. MULTIPLE FACTORIAL ANALYSES OBTAINED FROM PANEL FR1 SHOWING MAP OF PRODUCTS (A) AND CORRELATION CIRCLE (B) IN THE FIRST FOUR DIMENSIONS. Point size is proportional to cos² of angle. Only attributes having high contribution values were represented. Color codes : green (appearance), pink (tactile and texture in mouth), brown (taste) and blue (odour/aroma)

Panel FR2. The first four dimensions of MFA for the panel FR2 explained 91.07% of the variance (FIG. 7). The first dimension (37.36% of variance) opposed SunToam, which is described as bitter, astringent, powdery and homogeneous in appearance, to ShadeToli, which was characterized as granular in tactile texture and woody, dry leaves and cassava leaves in aroma/odour. The second dimension (22.54% of variance) opposed SunToli, which was characterized as having dry leaves aroma, to SunDiégo, which had the odour of tamarind. The third dimension (16.11% of variance) opposed SunDiégo, which was characterized as tasteless and having an aroma of dried leaves, to ShadeToli. And the fourth dimension (15.06% of variance) opposed SunTanà to SunMahaj, which was characterized as greenish.

(a)



(b)

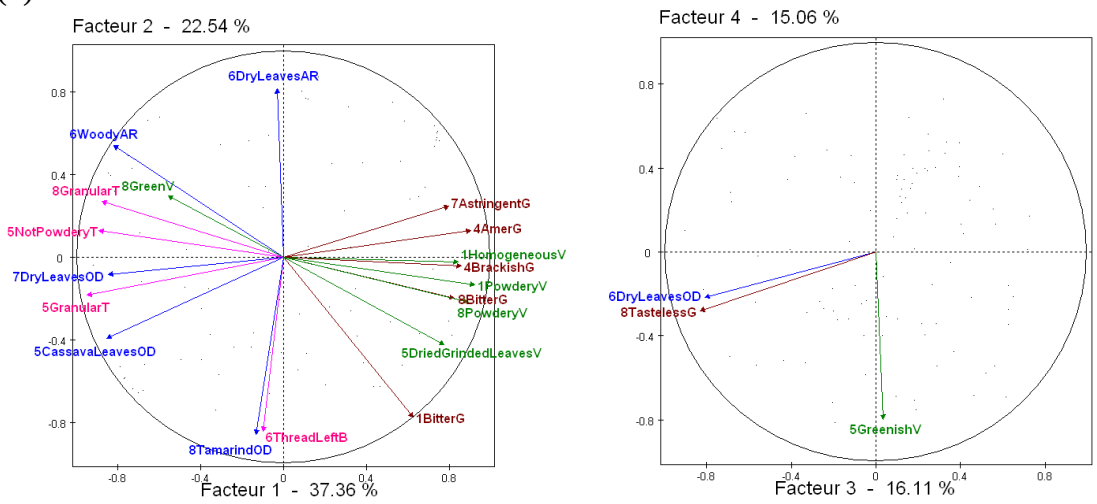
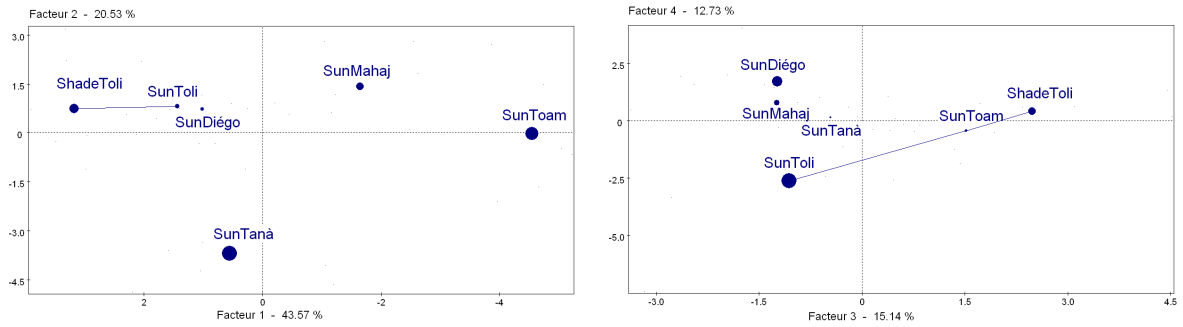


FIG. 7. **MULTIPLE FACTORIAL ANALYSES OBTAINED FROM PANEL FR2 SHOWING MAP OF PRODUCTS AND CORRELATION CIRCLE IN THE FIRST FOUR DIMENSIONS. Only attributes having high contribution values were represented. Color codes: green (appearance), pink (tactile and texture in mouth), brown (taste) and blue (odour/aroma)**

Panel MG1. The first four dimensions explained 91.97% of the variance (FIG. 8). The first dimension (43.57% of variance) opposes ShadeToli, which was characterized as green, not well grinded, with stem in appearance, sandy, hard, with nervure and stay in finger in tactile and astringent in taste, to SunToam, which was described as well crushed, powdery and without stem in appearance, bitter, easy to swallow and rustle. According to the second dimension (20.53% of variance), the sample from SunTanà was characterized as irritating throat. The third dimension (15.14% of variance) represents well ShadeToli, which was defined as bitter and having an aftertaste. Finally, the fourth dimension (12.73% of variance) opposed SunToli, which had an aroma of potion (dried leaves traditionally used by the population to treat diseases), to SunDiégo, which was characterized as green yellow.

(a)



(b)

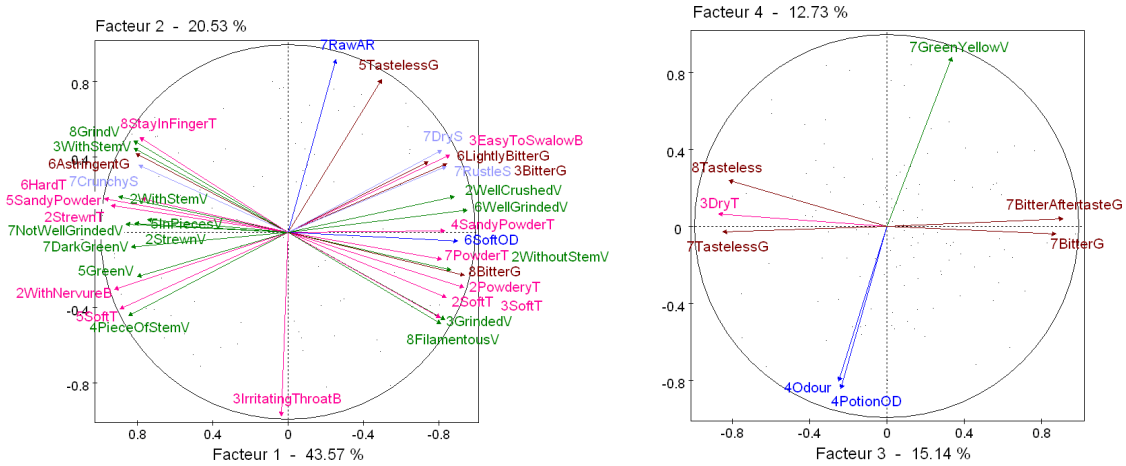
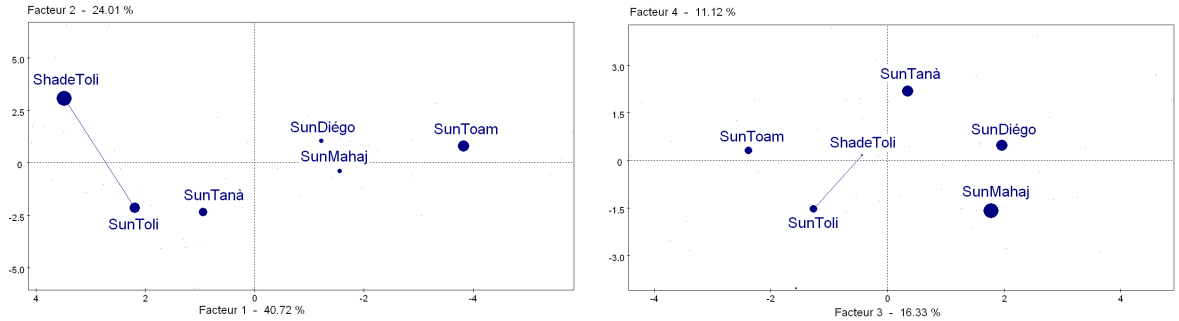


FIG. 8. MULTIPLE FACTORIAL ANALYSES OBTAINED FROM PANEL MG1 SHOWING MAP OF PRODUCTS AND CORRELATION CIRCLE IN THE FIRST FOUR DIMENSIONS. Only attributes having high contribution values were represented. Color codes : green (appearance), pink (tactile and texture in mouth), brown (taste) and blue (odour/aroma), purple (auditory)

Panel MG2. In MG2, the first four dimensions explained 92.18% of the variance (FIG. 9). The first dimension (40,72% of variance) opposes SunToam, which was characterized as rough in touch, dark green, granulated in appearance, sour and having aftertaste, and ShadeToli, which was characterized as smooth in touch, bitter, light green and squeezed in appearance. In the third dimension (16.33% of variance), SunToam was opposed to SunDiégo, which was tasteless. The fourth dimension (11.12% of variance) opposes SunMahaj to SunTanà, which had an aroma of dried leaves.

(a)



(b)

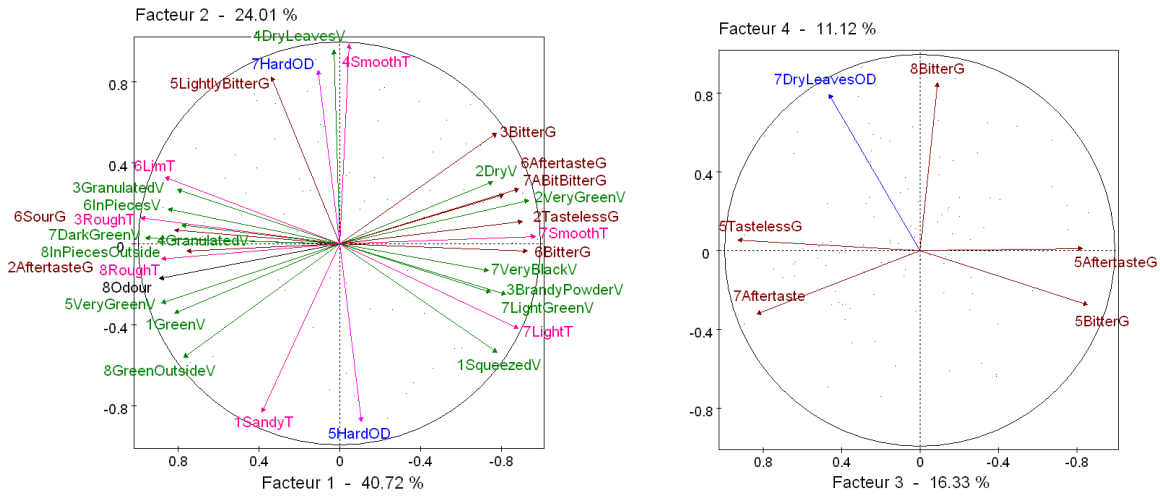


FIG. 9. MULTIPLE FACTORIAL ANALYSES OBTAINED FROM PANEL MG2 SHOWING MAP OF PRODUCTS AND CORRELATION CIRCLE IN THE FIRST FOUR DIMENSIONS. Only attributes having high contribution values were represented. Color codes : green (appearance), pink (tactile and texture in mouth), brown (taste) and blue (odour/aroma)

Similarities and differences between the four configurations. The similarities and differences between the four configurations were explored by visual comparison of the relative positions of the products on the MFA (FIG. 6-9) and the computation of correlation coefficients between the dimensions of the MFA (TABLE 4).

Visual comparison of the MFA maps showed high similarities of the first dimension emerging from the four MFA (about 40% of total variance). For the four panels the main difference between products is the opposition of SunToam to ShadeToli. This observation is confirmed by correlation coefficients higher than 0.79, except for the couple FR2-MG2 where r = 0.59. This similarity between panels decreases with the other dimensions. For the second dimension the positioning of the six samples was comparable only for the panels FR1 and MG2 (r = 0.91) with an opposition of the samples from the north (Antsiranana) and the south (Toliara). For the third dimension, a high similarity was observed only for the panels FR1, MG2 (with an opposition of SunToli to SunDiégo and SunMahaj) and FR2, MG1 (with an

opposition between SunDiégo and ShadeToli). These similarities are confirmed by high correlation coefficients (0.88 and 0.9 respectively). And for the fourth dimension, a high similarity was observed for the panels FR2, MG2 (with an opposition of SunTanà to SunMahaj, r = 0.9), FR1-MG2 (r = 0.98) and FR1-FR2 (r = 0.89).

TABLE 4. CORRELATION COEFFICIENTS WITH THE FOUR DIMENSIONS (a, b, c and d) BETWEEN PANELS (Coefficients indicated in bold characters were significant at the10% level - dd l= 4, α = 0.10, theoretical value = 0.729)

a

Dimension 1	FR1-1	FR2-1	MG1-1
FR2-1	**0,93**		
MG1-1	**-0,94**	**-0.83**	
MG2-1	**-0,79**	-0.59	**0.90**

b

Dimension 2	FR1-2	FR2-2	MG1-2
FR2-2	0.75		
MG1-2	-0.42	0.04	
MG2-2	**-0.91**	-0.48	0.48

c

Dimension 3	FR1-3	FR2-3	MG1-3
FR2-3	0.58		
MG1-3	0.72	**0.90**	
MG2-3	**0.88**	0.59	0.67

d

Dimension 4	FR1-4	FR2-4	MG1-4
FR2-4	**0.89**		
MG1-4	-0.3	0.07	
MG2-4	**0.98**	**0.90**	-0.35

To summarize visual inspection of the MFA map, two panels in the French condition described the products in a similar way but not the two panels in the Malagasy condition. This could be taken as an indication that descriptions in the French condition were more stable than descriptions in the Malagasy condition. However, the first panel in the French condition was also very similar to the second panel in the Malagasy condition and to a lesser extent the second panel in the French condition to the first panel in the Malagasy condition. The smaller similarities were found between the two panels in the Malagasy condition.

DISCUSSION

Effect of language on generated vocabulary. A comparison of the terms generated in the two languages failed to show an effect of language on the global number of generated terms. However an analysis taking into account the nature of the terms showed that participants in the French condition generated more specific terms in the odour/ aroma category than participants in the Malagasy condition. This result is reminiscent of previous result (Tu *et al.* 2010) showing that French panellists generated more aroma descriptors than Vietnamese panellists. The absence of language effect observed in the four other sensory

categories (appearance, tactile / texture in mouth, taste and sound categories) is in agreement with the result of Blancher *et al.* (2007) who reported in their study on fruit jellies a high similarity between two sensory profiles of visual appearance, texture by hand and texture in mouth established in France and Vietnam.

This work also showed that globally, in the two language conditions, the number of odour/aroma terms was higher than the number of other descriptors. Interestingly, the number of qualifiers generated in this category was also higher than for the other categories. Following Tu *et al.* (2010), we hypothesize that because panellists were not familiar with the odour of the tested products, they had difficulties pining down the specific notes associated to the product, and thus had to use a larger number of attributes to somehow characterize those notes. This phenomenon did not extend to the appearance, tactile and texture categories as these aspects of *Moringa oleifera* leaf powder are similar to that of other leaf-vegetables powder. An alternative explanation can be stated in terms of culture as suggested by Fenko *et al.* (2010). These authors stated that culture may play a role in determining the relative importance of sensory categories. They showed for example that the visual system is the most important for Western societies, where there is a higher exposition to books, television, and computers that require major input from the visual modality. Likewise odour might be the most important category for Malagasy people which would explain why a large number of odour descriptors were generated, compared to other sensory categories. Yet these interpretations do not explain why the number of generated terms was higher in the French condition than in the Malagasy condition.

A plausible explanation can be stated in terms of use of language: whereas Malagasy language is used in everyday life, French language is used in scientific and administrative context. According to Antmann *et al.* (2011), who compared consumer's texture vocabulary in three Spanish-speaking countries, consumers elicited terms according to their familiarity and the importance they gave to them in their everyday life. Odour vocabularies belong more to everyday life context than to scientific or administrative context. So, it may be that panellists generated more odour/aroma terms in the French than in the Malagasy condition because they had more difficulty expressing their sensations in this language, as if they need to do it in front of a foreign French person. In this case, panellist referred to terms which are not used in everyday life and that they thought more familiar to this virtual foreign person.

Effect of language on product description. No clear evidence of language effect on the description of the product was observed in our results. A common dimension which

opposed the ShadeToli to the SunToam products emerged from all four panels. Discrepancies were observed for the other dimensions but these discrepancies cannot be attributed to a language effect.

Our results seem rather to reflect inter panel variability independently of the language used by the panels. The majority of the descriptors were used by only one panel to describe one sample. Only a small number of descriptors were common to two, three or four panels: The sample SunToam was characterized as homogeneous by FR1 and FR2, powdery on appearance by FR2 and MG1 and bitter by the four panels. ShadeToli was viewed as green by MG1 and MG2 and had an aftertaste by FR1 and MG2. SunDiégo was tasteless by FR2 and MG2. We can interpret that as if the flash profile method was less efficient to bring reproducibility of results. This is due to the fact that terminology used was not common and consensual like on QDA. This lack of reproducibility had been accentuated by the screening process of descriptors which contributed more.

CONCLUSION

This research investigated the language effect on sensory description. The results showed that only odour and aroma category was affected by language with bilingual Malagasy panellists. The numbers of descriptors from the other categories were about equal in French and Malagasy conditions. Yet, French descriptors tended to bring more preciseness than Malagasy ones through qualifiers. Despite these small differences, the choice of language (Malagasy or French) does not seem to be a crucial issue and the two languages can be used for descriptive analysis in Madagascar.

This work shows that it was possible to separate the cultural effect from the language effect by working with bilingual panels.

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IV. Poster A:

Bilingual panels: a tool to evaluate the role of language in descriptive tasks

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Introduction

Moringa oleifera is a plant which leaves were proved to be nutritionally rich. It is available in different regions of Madagascar, where malnutrition is high. In order to value *Moringa oleifera* leaves in food repertory, their sensory properties should be investigated.

Sensory analysis should be performed with assessors from the location where tested foods are available. Then the sensory properties of *Moringa oleifera* had to be studied in Madagascar. In this country, two languages coexist: Malagasy and French.

→ **Which language is best suited for descriptive sensory studies?**

In previous studies, a language effect was observed, but in the context of cross-cultural studies, where culture and language are embedded.

To focus on the effect of language, our study was performed with four panels of Malagasy assessors (two panels working in French (FR) and two panels working in Malagasy (MG)).

Hypothesis:

If language is important, then more differences of sensory terms would be observed between panels using different languages compared to panels using the same language

Materials & Methods

Flash profile was used by four panels to describe *Moringa oleifera* leaves powders originating from five different regions of Madagascar

4 panels

***Moringa oleifera* leaves powder**

6 samples were studied: 5 sun- dried *Moringa oleifera* leaves from Antsiranana (SoD), Mahajanga (SoM), Toamasina (SoTa), Antananarivo (SoAA), Tuléar (SoTu) and 1 dried under the shade from Tuléar (Otu)

Each descriptor obtained by Flash profile was translated in English before comparing terms issued from the two languages.

Results

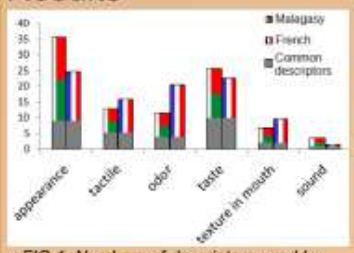
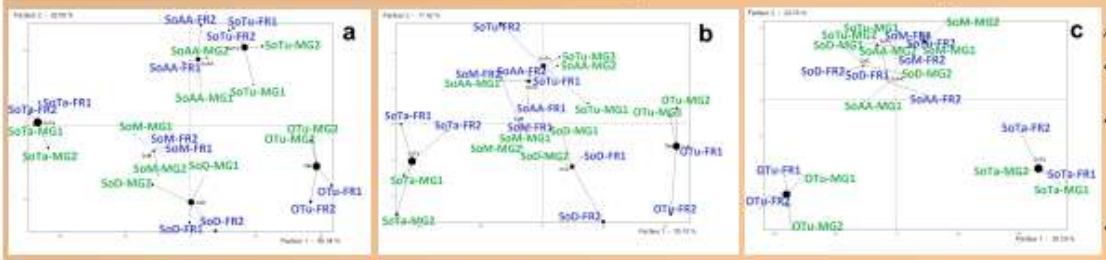


FIG 1. Numbers of descriptors used by assessors in two languages

• The global number of descriptors did not differ between the two languages (χ^2 at α=0.1) and about one third of the terms were common.

• When considering the non common descriptors, more **appearance** descriptors were generated in Malagasy than in French. And more **odor** descriptors were generated in French than in Malagasy. For other modalities the number of descriptors did not differ between the two languages (χ^2 at α=0.1).

→ **FR and MG generated the same number of terms but the repartition of these terms between sensory modalities was not the same**



Abreviations: DrOr-Pa, with:

- *Dr: drying mode*
  - *O: dried under the shade*
  - *So: sun dried*
- *Or: Origin*
  - *AA: Antananarivo*
  - *D: Antsiranana*
  - *M: Mahajaga*
  - *Ta: Toamasina*
  - *Tu: Tuléar*
- *Pa: Panels (MG1, MG2, FR1,FR2)*

FIG 2. MFA of the 4 panels for appearance (a), texture in mouth and tactile perception (b) and flavor (c) descriptors. Product map including products positioning by the four panels

→ **Products positioning was more affected by *Moringa oleifera* origin than by panels' language.**

TABLE 1. Average RV coefficients for sensory modalities appearance, tactile & texture and flavor

Sensory modality	Average RV within language groups	Average RV between language groups
Appearance	0.92	0.90
Texture & Tactile	0.87	0.87
Taste & Odor	0.85	0.78

• Globally RV coefficients were high. → **Good stability of data, both within and between language groups**

• **Appearance, texture and tactile**: no difference between the two average RV coefficients → **there is no effect of language (FR = MG).**

• **Taste & Odor**: the average RV coefficient within language groups was higher than the average RV coefficient between language groups → **there is an effect of language (FR ≠ MG).**

Conclusion

Language did not affect the global characterization and positioning of *Moringa oleifera* leaves powders from different origins. Yet, the description of the products differed slightly between the two languages.

The importance of the effect of language was not the same depending on sensory modalities. Malagasy vocabulary for appearance was richer than French, but the product positioning was the same for the two languages. More odour descriptors were generated in French than in Malagasy and the resulting odour description showed more differences between the two languages than the other sensory modalities.

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Pangborn 2013

Dans le but de valoriser les feuilles de MO dans le repertoire alimentaire de la population malgache, il a été étudié leurs propriétés organoleptiques. Les tests sensoriels ont été réalisés à Madagascar, où les feuilles testées sont disponibles. Or dans ce pays, deux langues différentes coexistent : malgache (langue natale) et français (langue administrative et d'éducation). Dans le but de voir l'effet des langues utilisées, il a été étudié laquelle des deux langues est la plus adaptée lors des études sensorielles descriptives. Deux groupes de panels ont été formées : un divisé en deux panels utilisant la langue malgache (MG1 et MG2) et un autre divisé en deux autres panels utilisant la langue française (FR1 et FR2). Il a été considéré comme hypothèse que si l'effet des langues est important, cela serait visible sous forme de différences par rapport aux termes sensoriels utilisés par les deux groupes de panels.

Cinq échantillons de poudre de feuilles de MO ont été évalués. Les cinq feuilles récoltées puis séchées au soleil proviennent de cinq villes différentes de Madagascar : Antsiranana au nord (SoD), Mahajanga à l'oeust (SoM), Toamasina à l'est (SoTa), Antananarivo au centre (SoAA) et Toliara au sud (SoTu). Un sixième échantillon, qui est issu des feuilles récoltées à Toliara séchées à l'ombre (OTu). La méthode descriptive Profil Flash a été utilisée.

Cette étude a montré que, d'après la Figure 1, les panels FR et MG ont généré le même nombre de termes, mais c'est la repartition de ces termes qui diffère entre les modalités sensorielles. Le nombre global de descripteurs ne diffère pas entre les deux langues et environ un tiers des termes est commun. En considérant les termes non communs, plus de descripteurs d'apparence ont été générés en malgache qu'en français. Contrairement à cela, plus de descripteurs d'odeurs ont été générés en français qu'en malgache. Pour les autres modalités sensorielles, les nombres de descripteurs ne sont pas différents entre les deux langues. Le résultat présentant les positionnements des échantillons par les quatres panels, en Figure 2, a montré que ces positionnements sont plutôt affectés par les origines des MO que par les langues utilisées par les panels. D'après le Tableau 1, les calculs des coefficients RV ont montrés des valeurs globallement élevées montrant une bonne stabilité des données en même temps entre chaque pair de panels utilisant la même langue et entre différentes groupes de panels utilisant deux langues différentes. Les deux moyennes des coefficients RV ont montrées aucune différence avec les modalités Apparence et Texture/tactile, se traduisant par l'absence d'effet des deux langues. Mais avec la modalité Goût/Odeur, la moyenne des coefficients RV entre chaque pair de panels utilisant la même langue est supérieure à celle des

coefficients RV entre deux sortes de panels utilisant deux langues différentes. Ceci se traduit par la présence d'effet des deux langues avec la modalité Goût/Odeur.

Pour conclure, les langues n'ont pas affecté la caractérisation globale et le positionnement des échantillons de poudres de feuilles de MO issues de différentes origines. L'importance de l'effet des langues n'est pas identique selon les modalités sensorielles. Les vocabulaires malgaches d'apparence sont plus riches que ceux en français, mais le positionnement des produits ne sont pas identiques pour les deux langues. Plus de descripteurs d'odeur ont été générés en français qu'en malgache et le résultat de description d'odeur a montré plus de différences entre les deux langues qu'avec les autres modalités sensorielles.

V. Conclusion

Le second chapitre a permis de vérifier que les poudres de feuilles de MO d'origine malgache ont des propriétés nutritionnelles intéressantes. Il a été également montré que les teneurs en macro et micronutriments analysés et les propriétés organoleptiques sont variables selon les villes d'origine. Les poudres de feuilles de MO venant d'Antsiranana et d'Antananarivo sont les plus riches en protéines (plus de 28 % par rapport à la masse sèche). En plus de cela, l'échantillon issu d'Antsiranana est le plus riche en fer tandis que celui venant d'Antananarivo est le plus riche en calcium et en acide α-linolénique. Les feuilles de MO issues de ces deux villes peuvent donc être largement valorisées à Madagascar afin de réduire les problèmes de malnutrition protéino-énergétique et l'anémie ferriprive touchant les enfants malgaches.

Des variations au niveau des propriétés organoleptiques ont été également observées entre les échantillons issus des différentes villes. L'échantillon venant de Toamasina est caractérisé par une saveur amère et a une apparence homogène, poudreuse, sans nervures, avec une texture en bouche facile à avaler et une texture tactile lisse. L'échantillon de Toliara a une texture sèche et insoluble en bouche, une texture au toucher dure et granuleuse due aux nervures et présente une arôme de feuilles sèches, boisé et de feuilles de manioc. L'échantillon d'Antsiranana présente un arôme de tamarin et a une couleur jaune vert. L'échantillon issu d'Antananarivo a un arôme de feuilles sèches et a une caractéristique irritante en bouche. L'échantillon de Mahajanga n'est caractérisé que par son apparence verdâtre.

Ces résultats confirment l'idée que les feuilles de MO sont des ressources alimentaires méritant d'être valorisées à Madagascar afin de réduire le problème de la malnutrition. Avant de les valoriser, il est important de comprendre les habitudes et croyances alimentaires des Malgaches pour pouvoir ensuite développer un produit conforme à ces habitudes et croyances.

CHAPITRE 3 :
L’étude de pratiques et structures de croyances alimentaires à Madagascar

CHAPITRE 3: L'ETUDE DE PRATIQUES ET CROYANCES ALIMENTAIRES A MADAGASCAR

I. Introduction

Avant de pouvoir proposer des stratégies facilitant l'introduction de feuilles de MO dans le repertoire alimentaire des Malgaches, il est important de connaître leurs pratiques et croyances alimentaires.

Pour cela, une étude a été réalisée avec des parents d'enfants scolarisés dans deux régions de Madagascar. Cette étude combine deux approches : une approche qualitative (groupes focus) et une approche quantitative (enquête sur questionnaire). La méthode des groupes focus est bien adaptée à l'étude des attitudes (Byers & Wilcox, 1991). Par exemple, en République du Tchad, la technique de groupes focus a été utilisée pour connaître les perceptions, attitudes et pratiques alimentaires dans le département du Guéra (Laoukole, Lacsala, & Djingue, 2005). Mais l'une des limites de cette méthode est le fait de ne pas pouvoir généraliser les résultats obtenus car les données collectées ne sont pas traitables statistiquement. Une enquête sur questionnaire a donc complété les données qualitatives des groupes focus. Les infomations issues des groupes focus ont été utilisées pour genérer les questions fermées du questionnaire.

Cette étude vise à vérifier l'hypothèse suivante : « La faible consommation de certains aliments à fort potentiel nutritif, tel que les feuilles de MO, résulte des pratiques et des structures de croyances alimentaires développées dans différentes régions de Madagascar. » (H2). Elle est présentée dans l'**article 3** ("Studying the nutritional beliefs and food practices of Malagasy school children parents. A contribution to the understanding of malnutrition in Madagascar") et le **poster B** ("Food choice factors in developing countries: The case of Madagascar").

II. Article 3:

Studying the nutritional beliefs and food practices of Malagasy school children parents. A Contribution to the Understanding of malnutrition in Madagascar

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Abstract

Madagascar is severely affected by the problem of children malnutrition. The present study aimed at exploring school children Malagasy parents'food practices and beliefs structures about the nutritional value of foods, to better understand the causes of this malnutrition. A combination of Focus Groups (72 participants), and questionnaires (1000 interviewees) was used to evaluate the food beliefs and the nutritional habits of low income parents of school age children in urban and rural areas of Antananarivo and Antsiranana. The respondents' beliefs were shown to focus not only on the nutrient and energetic composition of food, but also to involve more general relations between food and health and particularly the sanitary properties of food. Compared with such sanitary properties, nutrient content was not considered to be the priority in food choice and food preparation. The food category considered to be the most nutritive was cereals, ahead of protein foods, or vegetables and fruit. Nutritional beliefs were not the same in the Antananarivo and Antsiranana areas, nor between urban and rural areas of Antsiranana. Different socio-economic contexts, food availability and information may explain these differences. This study could guide actors involved in nutrition promotion to adapt to specific areas their nutrition programmes in the fight against malnutrition.

Keywords

Food believes, Food choice, Nutrition, Focus Group, Survey, Developing country, Madagascar

Introduction

Madagascar is a country of contradiction: on one hand, a developing country with a high percentage of its population under the poverty line, and on the other, a country rich in natural resources. Two thirds of the population live in rural areas, where the main activity is agriculture (Dostie, Haggblade & Randriamamonjy, 2002). Like most developing countries, the island is severely affected by the problem of malnutrition, especially in rural areas (Devine, Connors, Sobal & Bisogni, 2003; Smith, Ruel & Ndiaye, 2005, WFP & UNICEF, 2011). The term malnutrition is used to refer to suboptimal nutritional health. Two anthropometric indices are commonly used to define children malnutrition: low height for age (stunting) and low weight for height (wasting). A very low weight for height (below -2 z scores of the median WHO growth standards) is considered as a malnutrition state. If the difference with the median WHO growth standards is below -3 z scores, and/or in the presence of nutritional oedema, it is termed severe malnutrition (Shroeder, 2008). In 2008-2009, Madagascar had the sixth highest incidence of stunted growth in the world, according to UNICEF. Stunting is more prevalent in rural areas (prevalence of 48.7%) than in urban areas (WFP & UNICEF, 2011).

Fifty-three per cent of households in rural Madagascar have an insufficient consumption of nutritious foods to maintain an active and healthy life (WFP & UNICEF, 2011). The Malagasy diet is based mainly on rice, with an average consumption of 6.2 times a week, vegetables (4.4 times) and tubers (3.9 times), principally cassava. Proteins from vegetable and animal sources are rarely consumed (once and 2.3 times per week respectively) (WFP & UNICEF, 2011). Thus, the proportion of carbohydrates in the dietary energy supply is between 77% and 79%, which is high compared with recommended dietary allowance. Protein consumption is low: about 45g per person per day, while theoretical needs are 56 g per person per day, and fat consumption extremely low: about 20 g per person per day (theoretical needs: 77 g per day) (FAO, 2005b). This chronic under-nutrition is worsened by seasonal poverty (the period between the two rice harvests), during which the caloric intake of poor rural households decreases by 12% (Dostie, Haggblade & Randriamamonjy, 2002). This problem particularly affects children, with 45-50% of under-fives suffering from stunted growth (Fotso, 2006, WFP & UNICEF, 2011).

Food insecurity can result from insufficient food availability, distribution problems, the low purchasing power in poor households or inappropriate food consumption in families

(FAO, 2005b). The Malagasy government has launched different nutritional policies and programmes to reduce malnutrition problems, but most funds have been attributed to a limited number of communities and policies have remained short term (Repoblikan'i Madagasikara 2012).

Healthy and nutritive foods such as fruits, legumes or leaf vegetables are plentiful in Madagascar. It is not yet understood why these resources are not mainstays of the Malagasy food repertory, as they are available and relatively cheap. According to Rozin (1996), although nature provides a very large variety of products potentially rich in nutrients, only a small subset of these products is considered as food within any given culture. As summarized in Shepherd's food choice model (Shepherd & Raats, 1996), food choice is determined by three classes of factors: foods, individuals and external environment. The first class involves the sensory attributes and anticipated consequences of a food, for example whether it might be poisonous or, on the contrary, healthy. The second class of factors includes psychological factors such as mood or neophobia as well as physiological factors such as sensitivity to tastants. The third class of factors involves the economic and social environment and includes costs, availability of food products as well as social pressure. These three classes of factors interact with one another and are likely to be mediated by the beliefs and attitudes held by the individuals. Beliefs are the simplest form of mental representation (or mental construct) and are defined as a psychological state in which an individual holds a conjecture or premise to be true. They are thought to play a causal role in the production of behaviour. For example, beliefs about the nutritional benefits or harm in eating a food may be more important than the actual nutritional quality and health consequences in determining an individual's choice. When considering children, factors related to parents are also involved. As gatekeepers, parents influence children's food choices by setting rules, providing information, and modelling behaviours. In return, food preference communicated by children affects parents' food choices (Holsten, Deatrick, Kumanyika, Pinto-Martin & Compher, 2012). While these factors have been widely studied in the context of industrialized countries, there have been very few studies aimed at understanding food choice in developing countries, especially in Madagascar.

Our first hypothesis was that in Madagascar, children under-nutrition may be linked not only to general food availability but also to food practices yielded by parent's beliefs towards food nutritional values as well as to the adequation between parent's beliefs and

children preferences." Given the importance of environment reported in the literature, we also hypothesized that parent's food practices and beliefs structures depend on geographical and social context.

To test these hypotheses we used a combination of focus groups and questionnaires. Focus groups are typically used to elicit information and insights from small groups of participants representing the population under investigation (Neumark-Sztainer, Story, Perry & Casey, 1999; Dammann & Smith, 2010). The questionnaire survey, although furnishing less information than the focus groups, is helpful in improving the generalization of results. The focus groups and questionnaires were conducted with parents of school age children in urban and rural areas of Antananarivo (AU and AR, respectively) and Antsiranana, also known as Diégo-Suarez (DU and DR, respectively). Antananarivo, the capital of Madagascar, is located in the central part of Madagascar, and is characterized by a heterogeneous population. Antsiranana, the seventh most populated urban area, is located on the northern coast of the island. The choice of these two locations was based on their differences in climate, rain failure and natural resources, resulting in different food availability. Economic status and ethnicity of the population also vary (Repoblikan'i Madagasikara, 2003a and 2003b), as well as the food intake typology of the population in the two provinces (Madagascar ISFP, 2008). Fifty per cent of under-five children are affected by chronic malnutrition at Antananarivo, compared with 37% at Diego (Repoblikan'i Madagasikara 2012). Important differences exist between rural and urban population in these two provinces (Repoblikan'i Madagasikara, 2003a and 2003b).

Materials and methods

Participants

Focus Group

Seventy-two parents (six to eight participants per group) of children enrolled in public primary school were recruited in three neighbourhoods (Ambatobe representing AU, Ambatolampy Tsimahafotsy representing AR and Labigorne representing DU) to participate in the discussions. The number of participants totalled 22 in AU (23 women and one man), 26 in AR (24 women and two men) and 24 in DU (23 women and one man).

The recruitment was carried out through the headmasters or teachers of the public primary schools to reach low income parents. Parents who had agreed to discuss the subject of "children's eating habits" took a screening interview. This selection step helped the investigators to balance chattier and less chatty participants in forming the discussion groups. The age range of the participants was between 19 and 62 years old. While the participant selection methods used here cannot be considered likely to yield representative data for the population as a whole, housewives, who are those most likely to be preparing food, comprise the largest proportion of the Focus Groups. Some participants occasionally worked on farms or as domestic help and a few were employed in unskilled jobs (e.g. manual worker in textile fields, selling vegetables). Only a few of them had been educated beyond primary school.

Questionnaire

The questionnaire was administered to 1000 parents (797 women and 206 men) of school age children from different social classes using a face-to-face interview-assisted technique in four different areas: 300 participants were interviewed in AU, 300 in AR, 200 in DU and 200 in DR. The difference between the Antananarivo and Antsiranana sites in the number of interviewees was related to differences in the total number of inhabitants in these two areas. The interviewees' characteristics are shown in Table 1.

To ensure even representation of each area, the questionnaires were administered in 24 neighbourhoods in AU, 18 in AR, 11 in DU and five in DR. Interviewees resided in the neighbourhood of the interviewing location. AR sites were located about 20 km from downtown Antananarivo, and DR sites were located about 20 - 50 km from downtown Antsiranana.

Table 1

Respondent characteristics in four areas

		Areas[a]			
		AU	AR	DU	DR
Age					
	18-25 years old	16	29	37	12
	26-40 years old	221	232	120	135
	41-55 years old	60	36	36	39
	> 56 years old	27	3	7	14
Sex					
	Men	95	65	10	33
	Women	205	235	190	167

Education level					
	Primary	86	135	21	48
	Secondary	107	106	103	115
	High school	84	44	54	36
	University	23	13	22	1
Number of children in household					
	1	34	48	37	14
	2 - 3	196	166	115	94
	4 -5	61	71	37	71
	6 - 8	9	15	8	15
	> 9	0	0	3	4
Number of children in primary school					
	1	132	155	133	75
	2 - 3	155	140	60	117
	4 -5	11	5	4	8
	> 6	2	0	3	0
Kind of school frequented by children					
	Public	78	133	55	128
	Private	222	167	145	72
Remunerative activities					
	Agriculture	46	108	10	163
	Farming	34	63	8	123
	Fishing	1	8	1	0
	Manual worker	9	45	14	5
	Domestic work	17	14	34	9
	“Road” salesman	157	146	64	47
	Independent	104	92	43	30
	Salaried	155	79	90	45
	Executive	10	7	4	4
	Hired man	9	55	2	10
Monthly household income					
	< Ar 50 000 (<USD 22.04)	10	30	48	37
	Ar 50 000 – 100 000 (USD 22.04 – 44.09)	53	113	50	51
	Ar 100 000 – 200 000 (USD 44.09 – 88.17)	91	94	47	56
	Ar 200 000 – 300 000 (USD 88.17 – 132.26)	85	28	18	41
	Ar 300 000 – 500 000 (USD 132.26 – 220.43)	48	20	24	14
	> Ar 500 000 (>USD 220.43)	13	14	13	1

([a]AU: Antananarivo Urban; AR: Antananarivo Rural; DU: Antsiranana Urban; DR: Antsiranana Rural)

Procedure

Focus Group

Nine Focus Groups, three in each location, were held between March and July 2011 in a focus groups room for AU, and in classrooms for AR and DU. Each group discussion lasted from 75 to 90 minutes. The discussions were conducted by a moderator in participants' native language (the official Malagasy language for AU and AR and the north dialect for DU). The Focus Group procedure (planning, questioning and moderating) followed recommendations (Morgan, 1998).

At the beginning of the Focus Group discussion, participants were encouraged to participate actively in the discussion and to share their experience. It was explained to the participants that the discussion concerned their own ideas and that there was neither right nor wrong answers. The moderator informed participants that the conversation would be audio recorded but that the tapes would be used only in the framework of academic research and that participants would remain anonymous. Participants then briefly introduced themselves to break the ice.

To access to parents' food practices we first asked them a question on their habits (*what are the foods that you frequently consume?*) Then, to access parents' food beliefs structures, we used an association task in which participants were prompted with a stimulus word (nutrition) and were asked to indicate all the words that came to their minds (*What comes to your mind when I say nutrition?*). The free association task reflects the relative strength (measured by how many participants produced a given word) of automatic associations between concepts. The comparison between the terms generated in the four groups of participants gives some insights into the main beliefs associated with the nutritional value of food in the different areas of Madagascar.

Then we focused on participants' food choice criteria to evaluate the link between their implicit beliefs (association task) and the criteria they explicitly declare using when buying their food and their children's food (*What are the most important criteria you use to decide what to eat? For you and your children?*).

Questionnaire

The focus groups allowed us to assess school children parents'food practices and beliefs structures about the nutritional value of foods. The beliefs structures and food practices that emerged from this technique were then validated using close-ended questionnaire with a larger population.

The questionnaire was first elaborated in French as French was the common language among the researchers involved in the study, and then translated by the first author into the Malagasy language. To ensure that the original meaning had been maintained, the translation was verified by a bilingual person who was not involved in the conception of the questionnaire.

A pre-test was carried out with 40 interviewees. This first trial led to a reduction in the number of questions and to changes in the formulation of the questions. As a non-negligible proportion of the interviewees had difficulty reading, the interviewers had to read the questions aloud to them, which caused some memory problems in terms of the ranking questions. To avoid such problems, ranking questions were replaced by multiple choice questions in which interviewees had to select three items from among seven possibilities. The final version of the questionnaire consisted of three parts and included 31 main questions (29 close-ended, two open-ended questions) as well as 11 socio demographic questions. Only the questions related to food beliefs, food habits and socio demographic information are presented in this paper (Fig. 1).

Ten interviewers were recruited and trained to use identical questioning techniques. Each interview lasted for about 15 minutes. Interviewees were encouraged to give responses related to their own experiences and were told that there was neither right nor wrong response.

All interviews were carried out in July 2011.

Concept of "nutrition" by parents

Q1: From your mind which of them is the 3 words you use to describe "nutrition"?

Expensive	*Satiating*	*Tasty*
Clean	*Nutritious*	*Other: _____*
Balanced	*Well cooked*	

Q2: Cite 3 foods you think having high nutritional value

_____ _____ _____

Most important criteria considered by parents in food choice

Q3: From your mind, when you do your food shopping, which of these are the 3 most important criteria?

Diversity	*Availability*	*Habits to buy*
Budget	*Children liking*	*Health*

Q4: From your mind, when you prepare meal for children, which of these are the 3 most important criteria?

Cleanliness	*Diversity*
Vitamins and Calcium brought	*Children liking*
Satiety	*Energizing*

Children food preference

Q5: Cite 3 most liked foods by your children:

_____ *(1)*

_____ *(2)*

_____ *(3)*

Fig. 1. Questionnaire

Data analysis

The audio-recorded discussions of all the Focus Groups were fully transcribed on the days after discussion. The moderator and the assistants independently analysed each transcription using the notes taken by the assistants to supplement the tape recordings. The results were then compared and adjusted after consensus had been reached.

Survey data were first analysed by compiling the frequency count for each question in each interviewing area (AU, AR, DU and DR). The effect of interviewing area was then tested using Pearson and McNemar's (χ^2) chi-square tests with an α risk set at 5%. A Bonferroni's correction was applied to correct the alpha inflation problem caused by multiple tests.

Finally, a Factorial Correspondence Analysis using SPAD version 5.5 (Coheris, France) was performed to visualize relationships among the questions.

Results

Results from focus groups and questionnaires are presented conjointly in order to avoid redundant information. Verbatim taken from the focus groups are used to explain the quantitative data obtained in the questionnaire. We start by presenting respondents' food practices and we follow with participants' food beliefs and food choice criteria.

Respondents' food practices

When asked to indicate the kind of food they eat, some focus group participants declared that they ate three times a day (breakfast, lunch, dinner). They indicated that their diets were largely composed of rice – *"Especially rice, three times a day in our case" - eaten with "laoka", made up of vegetables or leafy-vegetables and possibly meat or fish on the days when there was enough money*". The questionnaire confirmed that rice is consumed everyday by 99% of the respondents, and even two or three times a day by some of them (68% and 27% respectively). Salads of raw vegetables and fruits as desserts were sometimes added: "*We make salad once a week; during the week just rice and laoka"*. Breakfast varied depending on the habits of the households. For example, rice or other kinds of food were cited: "*In the morning we don't eat rice but just tea [infusion] and bread"*.

Tubers like cassava roots in rural areas of Antananarivo, and plantain banana in Antsiranana, were most often cited after rice: "*For us [from the north coast], food that can replace rice might be: plantain banana with meat, with coconut…. Very tasty! It can replace rice"*. This may be eaten instead of rice in a meal or as a snack between main meals.

Low-income parents' beliefs towards food nutritional value as a function of geographical origin (centre vs north) and urbanization(rural vs urban areas)

The words that were more frequently cited in the association task during the focus groups were "clean", "balanced", satiating", "nutritious", "well cooked", "tasty" and "expensive". The frequency of citation of these terms obtained via the questionnaire is shown in Fig.2 as a function of the interviewing areas. A χ^2 analysis revealed an effect of interviewing area with the main difference appearing between DR and the three other areas. In DR, the seven items were almost equally cited with a proportion of citation of around 40%, except "Nutritious" which exceeded 50%. This finding should be interpreted with caution, however, as it might reflect either the fact that respondents in DR did not understand the question and answered randomly, or that they found all the items equally important.

In AU, AR and DU, the most frequently cited item was "Clean" (more than 80%), before "Nutritious" (between 61% and 80%) and "Balanced" (between 64% and 69%). A large number of participants related nutrition to hygienic concerns ("*Cleanliness"*). In AU and AR, focus group participants' discussions revealed how important cleanliness was in the handling, preparing and eating of foods. "*The most important aspect is cleanliness (…). When meals*

are served, the plates have been previously cleaned well, hands should be washed… that's cleanliness… Even during consumption, cleanliness is necessary". In line with the importance

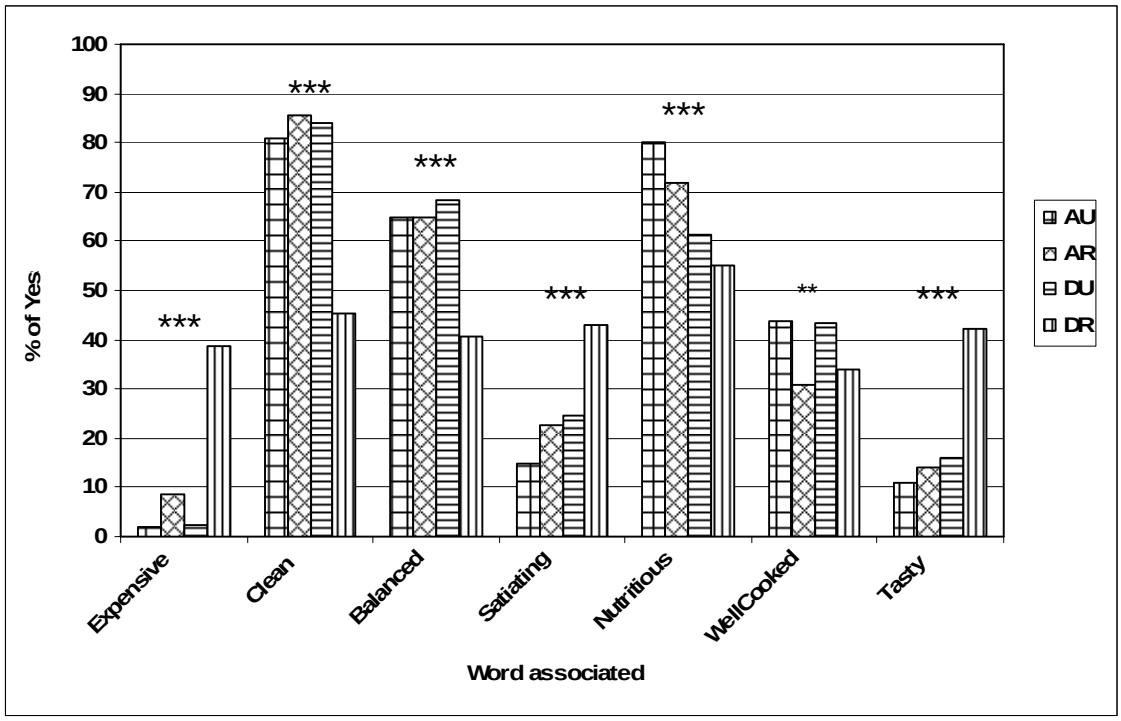

Fig.2. Frequency distribution of terms given by participants related to the word "Nutrition" in 4 areas (**: p<0,01 and ***: p<0,001)
(AU: Antananarivo Urban, AR: Antananarivo Rural, DU: Antsiranana Urban and DR: Antsiranana Rural)

Qualitative aspects of foods (supply of important nutrients and "balanced") were also important. "Balanced" meals, which can be understood as a diversity of foods, were related to variety in nutrients: "*Changing menus corresponding to the six kinds of foods [carbohydrates, fats, proteins, water, vitamins and minerals]"*. One way to obtain a balanced intake was to make a different meal each day: "*For me, the thing to do: when I do [cook] this one today I should not repeat it the next day if I can afford it."* But some participants understood "balanced" in a different way: for them it corresponded to using the same ingredients in different recipes. "*Diversity is like that: with vegetables… I can buy for example vegetables every day, but I modify my way of cooking them"*. "Satiating", "Tasty" and "Expensive" were the items cited the least frequently: between 16% and 24% in AU, between 11% and 16% in AR and between 2% and 9% in DU.

To further understand participants' food beliefs, we considered the three food products cited as being the most nutritive together, for each participant. Results indicate that a total of 86 food products were generated by participants in the questionnaire as being nutritive. The items most frequently cited as being nutritive were meat, fish and rice. The lists of foods

produced by parents were grouped into 11 categories (Fig. 3). Leafy vegetables and vegetables were separated into two different categories because leafy vegetables represent a specific category in the Malagasy food repertory. Among those categories, cereals were more often cited as nutritionally good (16% of the interviewees). This category includes rice, pasta, and maize. Rice was the most frequently cited food in this category. The second class included foods positioned in the middle: beans, dairy products, vegetables, meat, seafood and fruit.

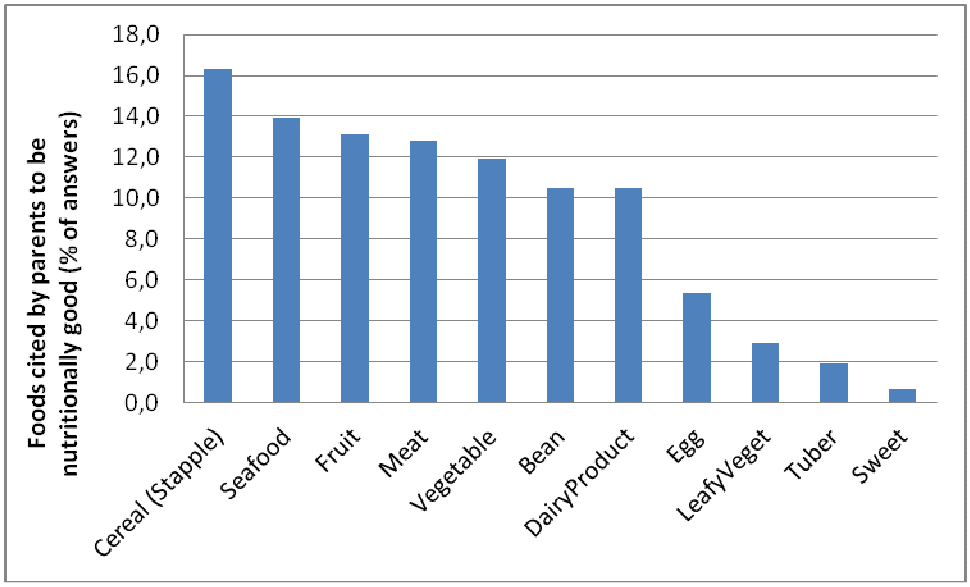

Fig.3. Foods considered by parents as nutritionally good

The last class included categories which were spontaneously less cited as having high nutritional value by parents: sweets, tubers, leafy vegetables and eggs. Tubers, such as cassava roots, were considered as incomplete, judging from focus groups discussions: *"If cassava is eaten alone, it is not a healthy food... only if you prepare it by adding other ingredients."* This category of food was identified by the respondents as lacking in certain nutrients. It may be surprising to find that eggs and leafy vegetables were as negatively judged as tubers and sweets. Indeed, eggs are the most complete source of amino acids and leafy vegetables are a source of vitamins, minerals and fibres. The second class included foods positioned in the middle (cited about twice as often as liked by children and four times as often as being nutritive than the first class): beans, dairy products, vegetables, meat, seafood and fruits. The last class was made up of cereals, such as rice, pasta, maize …, which were viewed as nutritive (16% of the interviewees) and preferred by children (28%). Rice was the most frequently cited food in this category.

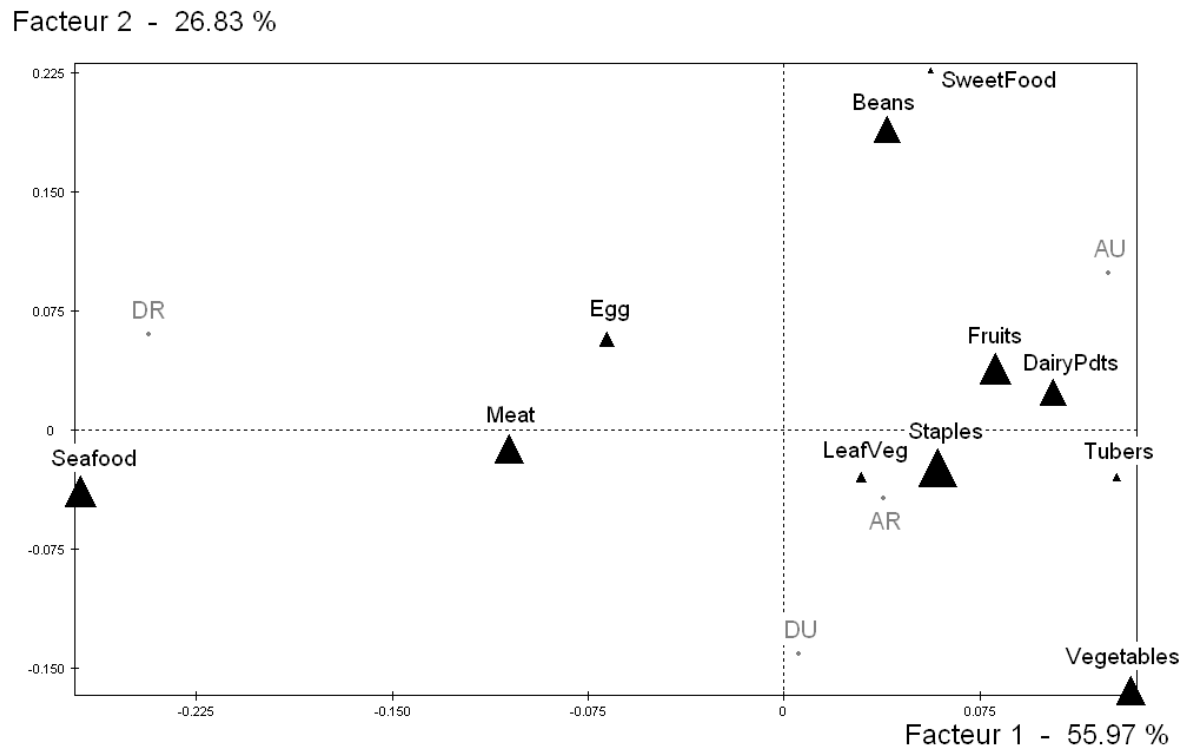

Fig.4. Factorial analysis of categories of foods viewed as nutritious (▲) by parents in four areas(●) (AU: Antananarivo Urban, AR: Antananarivo Rural, DU: Antsiranana Urban and DR: Antsiranana Rural)

Figure 4 presents the two first components of the correspondence analysis showing the categories of foods judged nutritive by parents in the four areas. Factor 1, which represents 56% of the variance, opposes the Antananarivo areas (AR and AU) to the rural Antsiranana area (DR). Rural Antsiranana households cited protein rich foods, and more particularly seafood, meat and eggs. Factor 2, which represents 27% of the variance, opposes the urban Antsiranana area (DU) to urban Antananarivo (AU). DU households more often cited vegetables as nutritionally sound foods, and less often beans, than households from other areas. In AR and AU, parents more often cited fruit, dairy products, tubers and staples as nutritionally sound.

As no individual food can be considered to be nutritionally complete on its own, after having looked at individual foods, we explored the associations of foods cited by the respondents to evaluate whether their beliefs structures take into account this necessity of association foods. To do that, cited food products were categorized into six groups, corresponding to the six classes of nutrients they contained (on the basis of the French food pyramid (Absolonne, Sirjacobs, Guggenbühl, & Colin, 1999): (1) products high in complex carbohydrates (cereals, legumes and tubers), (2) products with a high protein content (meat, seafood and eggs), (3) dairy products, (4) fruits/vegetables, (5) sweets, and (6) fats. Next, the

number of groups corresponding to the three food products cited by each participant was determined (Table 2). The contingency table revealed a very significant link between areas and number of food groups (p = 0.0003). Respondents from rural areas, especially from DR, more often cited three foods belonging to the same group than interviewees from urban areas. Compared with other areas, respondents from AU cited more frequently foods from three groups.

Table 2
Number of food groups considered by the interviewees as good nutritionally (expressed in percentages)

	AU	AR	DU	DR
Frequency of citation of foods belonging to only one group	5 [a]	9 [b]	5 [a]	13 [b]
Frequency of citation of foods belonging to two groups	51 [a]	56 [b]	61 [c]	62 [c]
Frequency of citation of foods belonging to three groups	44 [c]	35 [b]	34 [b]	25 [a]

[a-c]: Chi-square results at a confidence level of 95%. Different letters in a raw indicate that results are significantly different between areas.

Respondents' food choice criteria

In general, the mother of the family or the maid takes care of preparing food in Malagasy households. Shopping for food is a daily activity, due to the lack of refrigeration. Figure 5 shows the percentages of global citation of food purchase criteria when shopping and when preparing meals for children in the four areas. Considering food purchase criteria when shopping, "Price" was frequently cited (> 80%). Monetary considerations were often mentioned during the Focus Group discussions; for example: *"I look at everything and the lowest price is the one I buy"*. Most households interviewed cannot afford to buy certain categories of food like meats, except on the days when they receive their salary (once or twice a month): *"When we find a bit of money we buy a bit of meat, after work [temporary work]"*.
"Health" and "Diversity" were frequently cited (more than 60%). Health may be interpreted either as related to a food's nutrient content or to its sanitary properties. In the focus group discussions, health was related to food content. A mother said: *"For me, when I go shopping, I aim at making meals complete [nutritionally], which means providing energy and force for children, to make them healthy"*. Another mother said: *"About vegetables, when we go to the doctor - we go to the doctor frequently - he always says that we should give children vegetables and fruits. If meals contain vegetables and fruits, for me it's alright"*.

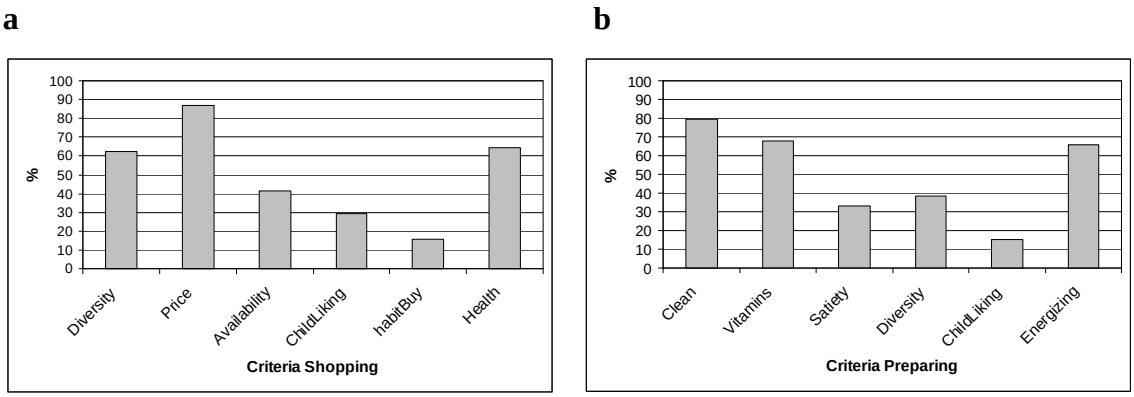

Fig.5. Percentage of food purchase criteria considered by parents when shopping (a) and when preparing meals for children (b)

"Availability" (about 40%), "Children liking" (30%) and "Habit of buying it" (about 15%) were the least frequently cited items.

In terms of food purchase criteria when preparing meals for children, "Cleanliness" was the most frequently cited item. Parents interviewed in focus group discussions related that foods sold in small restaurants were not safe because they are very exposed to microbiological contamination. Consequently, parents preferred preparing their meals themselves in order to control hygienic conditions during cooking. After "Cleanliness", food content in terms of vitamins and minerals ("Vitamins"*)* and caloric content ("Energizing"*)* were also frequently cited (>65%). "Satiety" and "Diversity" were cited by between 30% and 40% of parents. "Children liking it" was the criterion least cited by parents.

Chi square calculation with Bonferroni correction (corrected $\alpha = 0.044$) revealed highly significant differences among the four areas concerning both food purchase criteria and food preparation. Fig. 6 shows the first two components of the corespondence analysis carried out on the food purchase and meal preparation criteria by geographic area contingency table. The first dimension, which represents about 61% of the variance, opposes the Antsiranana areas to the Antananarivo areas. Participants from Antananarivo (AU and AR) seemed to use similar criteria and emphasized health concerns more ("Health", "Clean", "Vitamin and mineral contents", "Energizing") and "Children Liking it" (when shopping) than participants from the Antsiranana areas (DU and DR). The second dimension, which represents about 36% of the variance, opposes mostly DU participants who seemed to favour "Children Liking it" and "Diversity" (when preparing meals) to DR participants who seemed to rely more on "Availability", "Habit of Buying it" and the "Satiating" power of foods.

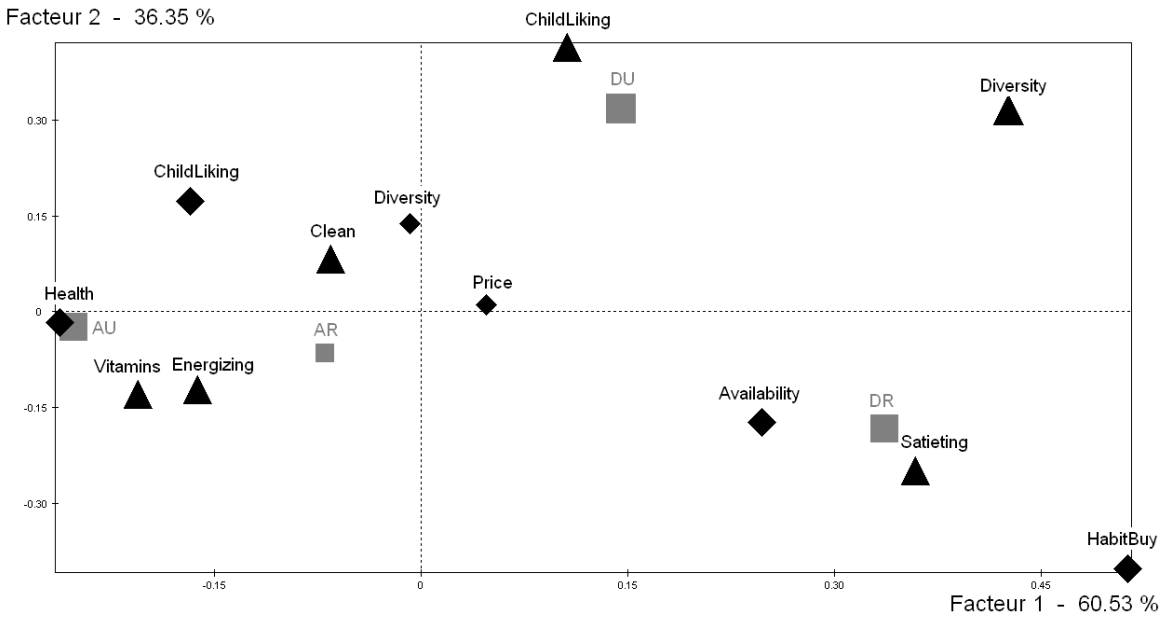

Fig.6. Factorial analysis of food purchase in four areas when shopping (♦) and when preparing meals (▲) (AU: Antananarivo Urban, AR: Antananarivo Rural, DU: Antsiranana Urban and DR: Antsiranana Rural)

Discussion

Our first hypothesis was that in Madagascar, children under-nutrition may be linked not only to general food availability but also to food practices yielded by parents' beliefs. In agreement with this hypothesis, our study highlighted the role of parents' beliefs structures in children malnutrition. In all four areas, "cleanliness" was one of the words most closely related to the prompt "nutrition" in the association task and one of the most often cited criterion when preparing meals. It has been pointed out that in Madagascar, food contamination has serious health effects: the lack of hygiene, inadequate hand washing and ignorance of risk are at the origin of microbiological toxicity in Madagascar (Sarter & Sarter, 2012). Respondents were aware of the importance of this problem. This association between cleanliness and nutrition probably comes from the well-known synergy of malnutrition and infection as the leading cause of morbidity and mortality in developing countries. Indeed, malnutrition reduces resistance to infection and infection affects nutritional status (FAO, 1997). The importance of the beliefs that a nutritive food is a food that does not make you sick was shown to lead to food preparation habits detrimental to nutritional quality, such as overcooking foods. This was revealed in our study by the item "well cooked", which was chosen by 30–45% of the respondents in each area. It is well known that lengthy cooking decreases certain vitamin contents in foods; this is the case with vitamins C, B1, B2, B5, B6 and B12. So, whatever the initial nutritional value of the foods eaten by the Malagasy

population, the cooking process reduces available nutrients and tends to worsen nutrient deficiencies in the population.

The nutritional composition of foods seems to play the second role, after cleanliness, but before satiating potential, in Malagasy food beliefs structures. The fact that respondents did not particularly associate the satiating property of foods with the concept of nutrition, suggests that they believe that they have enough food to satisfy their hunger. Yet, Malagasy food supplies are considered to be hardly enough to cover the energetic needs of the population (FAO, 2005a) and for this study, the respondents were chosen among the poorest households in zones highly and moderately concerned by malnutrition. One explanation is that while not meeting energetic needs, Malagasy meals are nonetheless sufficiently satiating. This assumption is plausible because of the very high proportion of complex carbohydrates in Malagasy meals. Indeed, the products consumed the most are cereals and tubers, which are at once satiating and poor in energy and essential nutrients. In contrary, leafy vegetables, which are described in the literature as good sources of protein as well as some vitamins and minerals (Uusiku, Oelofse, Duodu, Bester, & Faber, 2010) and are not expensive and largely available in Madagascar were believed by parents to have a low nutritional value.

Our study also showed that school children Malagasy parents' beliefs led to food practices that could be linked to children malnutrition. Rice, which is central in Malagasy meals, was one of the foods most spontaneously cited by the respondents as being nutritionally valuable. It has previously been observed among poor households suffering from malnutrition that the diet consists predominantly of cereals, with very few "protective" foods like fruits, pulses and milk (Gopalan, 2000). In Madagascar, rice provides 53% of consumed energy and 50% of consumed proteins (FAO, 1993). The highest percentage of food expenditure is spent on rice (32% in 2010), followed by tubers (8%) (WFP & UNICEF, 2011). But this important cereal consumption does not cover nutritional needs, especially those of children. Indeed, among the major nutritional problems prevalent in rice-consuming countries, imbalanced dietary intake is the most important one. The protein content of rice is the lowest among the cereals. In combination with other factors, it leads to the prevalence of protein-energy malnutrition, iron deficiency, vitamin A deficiency and iodine deficiency disorders. This analysis is in agreement with the reports of NGOs which have observed that the highest occurrence of stunting is not among the very poor, as they eat the vegetables that they grow instead of selling them, and these are rich in nutrients. "The worst cases are those who can afford white rice" (IRIN, 2012).

However, beliefs towards food nutritional value are not the only food determinant. Our results showed that food availability can modulate the impact of beliefs on food practices. As an example, while most respondents believed that tubers are not good nutritionally, tubers are still widely consumed, depending on location. Food availability can explain this phenomenon. Indeed, previous work reported that tubers are consumed by poor households in the centre of the country between two rice harvests, for example, when they cannot afford to buy rice (Dostie et al., 2002). During the lean season, the simple substitution of rice by cassava cannot provide balanced nutrients. Tubers and particularly cassava have extremely low protein content (less than 1%) (FAO, 1997). Thus, cassava is especially unsuitable as the main source of energy for young children.

It also lacks lipids and certain vitamins and minerals. It seems thus that parents' food beliefs structures interact with food availability to give rise to food practices that may lead to children under-nutrition. Changing these food practices, and thus decrease the rate of children under-nutrition, would therefore require to act both at the level of food availability and of parents' beliefs.

Our second hypothesis was that parents' food practices and beliefs structures depend on geographical and social environment. In agreement with this hypothesis we observed some differences between the studied areas. The differences might be explained by food availability in the four areas. Antsiranana (north) and Antananarivo (centre) climate and geographical situation are different, resulting in different natural resources and food availability. Differences in economic status between the four areas may also be responsible for differences in access to food.

First, a difference between rural and urban areas of Antsiranana was observed. Among the four studied areas, urban area of Antsiranana is the wealthier, resulting in a higher availability of food products of different groups. In DU, children's liking a food was taken most often into account, as if people could afford to fulfil their children's expectations because their access to healthy food was higher than in the other three locations studied. On the contrary, the rural area of Antsiranana is poor, but it is a farming region, where crops are more available than animal products. As a result, DR respondents particularly valued meat and seafood as nutritive foods, compared with other areas. That is probably why they considered nutritive food to be expensive. DR respondents emphasized availability as a criterion of food choice, showing the diversities of situations concerning access to food from different groups. As a result of this limited access, satiating properties and diversity were more a source of preoccupation in DR than in other locations. When defining "nutrition", respondents in DR

did not give as much importance to cleanliness as other respondents. This relative lack of concern for cleanliness could be due to the absence of household facilities in this area (having neither electricity nor running water), as well as a reduced education about sanitary properties of food. Thus, beliefs towards nutritional value of food are clearly different in DR and DU.Such differences between rural and urban areas were not observed at Antananarivo, probably for two reasons. First, in Antananarivo, the rural areas chosen for the study were closer to the urban areas (20 km) than in Antsiranana, where the nearest rural commune was 40 km away from the city. Secondly, in the capital (Antananarivo), rural migration is frequent, making the urban population quite similar to the rural one.

Differences were also observed between Antananarivo and Antsiranana. Despite the relative poverty of their region compared with Antsiranana, parents from Antananarivo seemed to be more sensitive to health concerns than parents from Antsiranana.

This is probably due to the fact that in the capital there is more access to media and residents have higher levels of education than in the rest of the country. There are also more educational programmes devoted to food and nutrition than in the provinces, and this situation could be responsible for the differences observed between the centre and the northern areas in terms of beliefs towards food. In agreement with this interpretation parents in Antananarivo cited foods belonging to more classes than parents from Antsiranana, when asked to cite “nutritive foods”, suggesting they knew more about nutrients contained in foods. As no individual food can be considered to be nutritionally complete, each answer highlights the nutrients that respondents consider to be important in a healthy diet. Respondents who only cite items belonging to a single group either do not know nutrients and cite current foods, or believe that particular nutrients are intrinsically good or bad. On the contrary, respondents who cite items from three different categories might know that particular nutrients are not intrinsically good or bad but that the key issue is to balance their meals. Another result in favour of the role of nutritional education in the capital is that parents from Antanaraviro cited foods frequently mentioned in nutritional education programmes while in the north (DU and DR) parents who have probably not received nutritional information cited foods which were familiar and/or locally available (e.g. seafood, tubers).

Conclusion

This study showed that current food practices in Madagascar are underlined by an interaction between food availability and food beliefs structures. Recommendations aiming at

changing food practices to decrease children under-nutrition must take into account these two factors. Nutritional information focusing on the complementarity between foods should be associated with the promotion of local production. These recommendations should be adapted to the geographical areas as we showed rural vs urban, as well as geographical, differences in both food availability and beliefs structures. Yet, this study focuses only on two areas of Madagascar and thus need to be extended to other areas to provide a wider picture of food practice and beliefs in Madagascar

Acknowledgements: The authors warmly thank Louisette Razanamparany, who initiated this research programme, for her contribution to this study. The authors would also like to thank Mary Bouley for English proofreading and the supervisor of EPP Ambatobe, Labigorne and Ambatolampy Tsimahafotsy for collaborating in the recruitment of parents, students who carried out the interviews and all the collaborators who offered advice and aid.

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III. Poster B :

Food choice factors in developing countries: The case of Madagascar

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Introduction

Madagascar, a developing country, suffers from seasonal poverty. Although some natural resources exist, malnutrition problems continue to affect a large proportion of the population especially in rural areas. The main purpose of the study was to evaluate the effect of geographical and economical environments on food choice determinants in Madagascar. The trade-off between nutrition and taste in food choice was investigated. along with the effect of geographical and economical environments on food habits

Material and methods

Focus group with 72 parents of schoolar age children (67 ♀ and 5 ♂, 19 – 62 years old)

+

Questionnaire survey with 1000 parents of children interviewed (797 ♀ and 203 ♂, 18 – 59 years old)

4 areas

- Antsiranana Urban (DU) — North
- Antsiranana Rural (DR — North
- Antananarivo Urban (AU) — Center
- Antananarivo Rural (AR) — Center

Results and discussion

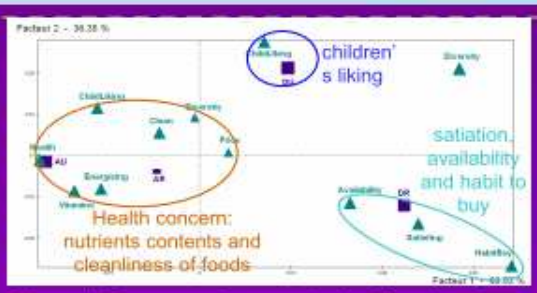

Figure 1: Correspondence analysis of food purchase motivation

Dim 1: Antananarivo participants emphasized more health concerns than those from Antsiranana.
Dim 2: DU participants rely more on children preference and diversity whereas those from DR rely on food availability and satiating power as well as habits

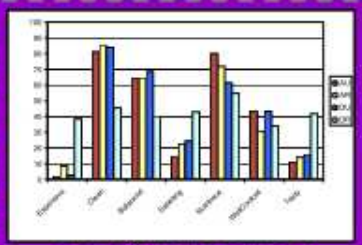

Figure 2: Terms related to "Nutrition" in 4 areas

In DR the seven items were almost equally cited.

In AU, AR and DU the most frequently cited item was "Clean" before "Nutritious" and "Balanced"

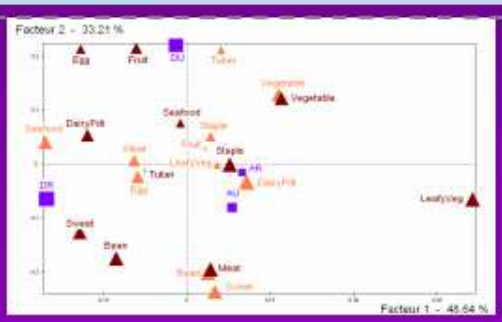

Figure 3: Correspondence analysis of categories of foods liked by children (▲) and though as nutritional by parents (▲)

Dim 1: In AU and AR leafy vegetables and staples were liked by children and perceived as nutritious by parents whereas in DU children liked most sweets and dairy products and parents perceived seafood, meat and eggs as more nutritious

Dim 2: In DU children liked more fruits and eggs but "Tubers" were viewed as more nutritious by parents.

Differences in food nutritional representations and habits were observed between the Antananarivo and Antsiranana areas. In the Antsiranana areas differences were also observed between rural and urban areas. No such difference was observed in Antananarivo areas. These results underline the necessity to take into account the geographical and social environments into educational programs to valorize neglected high nutritious foods available in Madagascar.

5th European Conference on Sensory and Consumer Research, 9-12 September 2012, Bern, Switzerland

Le but de cette étude a été d'identifier les facteurs de choix alimentaire chez la population malgache issue de quatre lieux d'étude : Antsiranana urbain (DU), Antsiranana rural (DR), Antananarivo urbain (AU) et Antananarivo rural (AR). 72 parents d'élèves scolarisés dans des écoles publiques ont été recrutés lors des groupes focus et 1000 parents d'enfants d'âge scolaire ont été enquêtés lors d'une enquête sur questionnaire.

Les résultats ont montré une différence en termes de représentations nutritionnelles entre Antananarivo et Antsiranana. Les parents venant d'Antananarivo ont plus mis en évidence les aspects en lien avec la santé par rapport à ceux venant d'Antsiranana. A Antsiranana, une différence a également été observé entre zone urbaine et zone rurale. Les parents venant d'Antsiranana urbain ont plutôt donné d'importance à la préférence de leurs enfants et la diversité des aliments, tandis que ceux d'Antsiranana rural ont raisonné en termes de disponibilité alimentaire et de pouvoir rassasiant, ainsi qu'aux habitudes alimentaires. Le terme « nutrition » a été associé aux caractéristiques « propre », «nutritif » et « équilibré » des aliments à AU, AR, DU. Mais à DR, tous les sept items ont été cités à la même fréquence. Des différences ont été également observées par rapport aux catégories d'aliments aimés par les enfants et considérés par les parents comme étant bon nutritionnellement. A AU et AR, ce sont les légumes feuilles et les aliments de base qui remplissent cette fonction, tandis qu'à DR, les enfants aiment plutôt les sucreries et les produits laitiers mais les parents considèrent les fruits de mer, les viandes et les œufs comme étant bons nutritionnellement. A DU, les enfants aiment plutôt les fruits et les œufs mais les tubercules ont été considérés par les parents comme étant bon nutritionnellement. Aucune différence n'a été observée par rapport aux représentations nutritionnelles entre zone rurale et zone urbaine à Antananarivo. Cette étude souligne la nécessité de prendre en compte les environnements géographiques et sociaux lors des programmes d'éducations afin de valoriser les aliments nutritifs encore mal valorisés à Madagascar.

IV. Conclusion

L'étude présentée dans ce chapitre a mis en évidence que pour valoriser les feuilles de MO à Madagascar, il est important de considérer les trois points suivants. Premièrement, lors de la préparation des aliments, les ménages pratiquent des cuissons longues, entraînant ainsi la diminution de taux en certains nutriments thermosensibles, tels que les vitamines A et C (Kidmose, Yang, Thilsted, Christensen, & Brandt, 2006). Or, si les feuilles de MO sont connues comme étant de bonnes sources en ces vitamines, suites à de forte température et pendant une longue durée avec une quantité importante d'eau, leur teneur en vitamine C peut diminuer jusqu'à 98,5% (Sreeramulu, Ndossi, & Mtotomwema, 1983). Lors de l'incorporation de feuilles de MO dans les aliments, il est donc important de ne pas les cuire à forte température et pendant une longue durée. Deuxièmement, l'alimentation malgache est dominée par des aliments glucidiques, dont le riz, les racines et les tubercules. Pour introduire des feuilles de MO dans l'alimentation des Malgaches, il peut donc être envisagé de les incorporer à l'un de ces aliments glucidiques les plus consommés à Madagascar. Et troisièmement, les légumes feuilles sont représentées par les parents enquêtés comme n'étant pas des aliments à valeurs nutritionnelles élevées, bien que plusieurs études aient montré le contraire. Il parait donc important d'accompagner l'introduction de MO dans le répertoire alimentaire malgache par une campagne d'information visant à développer les connaissances nutritionelles de la population concernée.

CHAPITRE 4:
FABRICATION DE GOUTERS A BASE DE MANIOC ET DE POUDRE DE FEUILLES DE MORINGA OLEIFERA

CHAPITRE 4: FABRICATION DE GOUTERS A BASE DE MANIOC ET DE POUDRE DE FEUILLES DE MORINGA OLEIFERA

I. Introduction

La finalité de cette thèse est de proposer des aliments améliorés d'un point de vue nutritionnel et incorporant les feuilles de MO. Dans le choix de ces aliments, nous avons suivi le raisonnement suivant : pour introduire un nouvel aliment, il faut préserver un sentiment de familiarité pour favoriser son acceptation, par exemple en associant ce nouvel aliment à un ingredient familier. Pour les enfants, cette notion de familiarité est très importante (Salvy, Vartanian, et al., 2008). Pour preserver ce sentiment de familiarité, nous avons choisi de fabriquer des produits à base de racines de manioc, qui est le deuxième aliment de base, très consommé à Madagascar, surtout pendant la période de pauvreté saisonnière quand le riz devient inaccessible à cause de l'augmentation de son prix.

Pour établir comment associer manioc et MO, nous avons exploré, dans une première étude, les habitudes de consommation de ces deux ingrédients et les représentations qu'ont les parents d'enfants scolarisés face à ces deux ingrédients. Ensuite, dans une seconde étude, des produits associant manioc et MO ont été formulés. Un test consommateur a ensuite été effectué pour évaluer le degré d'acceptation de ces produits par des enfants en classes élémentaires. Les nutriments apportés par les poudres de feuilles de MO ont finalement été quantifiés dans chaque portion équivalente à un goûter pour un enfant, pour les différentes formulations.

Ces deux études sont présentées dans l'**article 4** (« How to fight malnutrition in Madagascar? A study combining food representations and consumer tests »), le **poster C** (« Paradox between malnutrition and nutritional richness of foods in Madagascar: the example of *Moringa oleifera* leaves ») et le **poster D** (« Sensory acceptance of cassava snacks nutritionally enriched with *Moringa oleifera* leaf powder among children from low-income households in Madagascar"). Ce chapitre vise à vérifier l'hypothèse : « Si les feuilles de MO ne sont pas assez valorisées à Madagascar, c'est à cause de l'importance que la population malgache donne aux habitudes alimentaires et au pouvoir rassasiant des aliments.» (H3)

II. Article 4:

How to fight malnutrition in Madagascar?
A study combining food representations and consumer tests

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[Soumis à Appetite]

Abstract

The aim of this study was to understand how knowledge about consumers' habits and representation of local food products could help developing a new snack as a way to fight children malnutrition in Madagascar. Madagascar is characterized by a large variety of natural food resources among which some are rich in nutrients but not consumed by the local population, like *Moringa oleifera* (MO). The first step of the study aimed at understanding the reasons why such resources are not frequently consumed in Madagascar, whereas other resources such as cassava are largely consumed despite their low nutritional value. Results showed that while cassava roots were perceived by interviewed parents as having negative effects on health, they continued to be consumed due to their satiating power, low price, and geographical and historical availability. In contrast, MO leaves which are known for their health benefits, were not much consumed because of their low satiating power and participants' relatively low level of knowledge. The second step of the study aimed at evaluating children's liking of formulated snacks associating cassava roots and MO in four areas. These snacks contained two concentrations of MO and were either sweetened or not. The sweet snack containing the highest quantity of MO was the one children liked the most and chose to keep after the test. There was no main effect of the area on the acceptance of formulated snacks. This work is an example of valorisation of local plant ressources into malnourished population diet.

Keywords

Moringa oleifera, cassava, Madagascar, children food choice, nutritional and health beliefs, food practices

1. Introduction

Like most developing countries, Madagascar is severely affected by the problem of malnutrition, especially in rural areas (Devine, Connors, Sobal, & Bisogni, 2003; Smith, Ruel, & Ndiaye, 2005). About one out of two Malagasy children are concerned by this problem (FAO, 2005), which can cause increased mortality, or lifelong serious damages, such as reduced intellectual development, health and social problems, and reduced performance (Schroeder, 2008).

According to FAO evidence, food scarcity is the main cause of malnutrition. Scarcity may be due to two reasons: geographical inaccessibility, when food is not available, or economical inaccessibility, when food is available but too expensive for the population to buy it. However, food scarcity cannot explain malnutrition in Madagascar because this country is characterized by a large variety and quantity of natural resources, which could potentially be sufficient to feed the whole population. Yet, these resources are not accessible to poorest households. Economical factors might explains part of this inaccessibility (Smith & Haddad, 2001), but are not the only factors involved. Ramakrishnan & Huffman (2008) observed that poor households from developing countries spend a large part of their income on carbohydrate-rich staple foods, and neglect foods which bring protein and micronutrients. Thus, limited access to food may result not only in insufficient quantity of food consumed, but also in non-balanced intake and poor dietary quality.

However, in Madagascar, poverty alone cannot explain the predominance of consumption of carbohydrate-rich staple foods, because rice, for example, is not the cheapest carbohydrate staple food, but it is the most consumed food by Malagasy people whatever their economic status (from twice to three times a day according to Ramaroson Rakotosamimanana, Arvisenet, & Valentin, 2014). The principal meal is composed of a large quantity of rice, served with “laoka”, an accompaniment made of vegetables and eventually meat (Hardenbergh, 1997). During seasonal poverty, replacement of rice by cassava roots by poor rural households worsens the nutritional situation (Dostie, Haggblade, & Randriamamonjy, 2002). Cassava is the second staple food concerning consumed quantities, after rice (Ballet & Randrianalijaona, 2011). Cassava roots contain higher quantity of carbohydrates than rice but are poorer in other nutrients. They are eaten alone most of the time, even if people are aware that these roots cannot fulfill nutritional needs (Ramaroson Rakotosamimanana, Arvisenet, & Valentin, 2014). This situation is one of the major underlying causes of protein-energy malnutrition. Thus it seems that together with poverty, other determinants may explain malnutrition in Madagascar

To fight against malnutrition, micronutrient supplements are generally the practical short-term solution. But in the case of chronic malnutrition, this strategy cannot last and a better solution for improving diets of children in developing countries would be to focus not on specific nutrients, but on specific types of foods (Schroeder, 2008). In this aim, commonly consumed staple foods could be associated with affordable local plants. This association would have the advantage of increasing intake and balance of both macro- and micro-nutrients needed for growth and health. In Madagascar, several plants could be eligible to provide these nutrients. Among these plants *Moringa oleifera* (MO) seems to be a good candidate. MO is a wild plant which leaves are rich in vitamins, amino-acids, ω3 fatty acids and iron (Thurber & Fahey, 2009). This plant grows easily under Madagascar climate. It was introduced in the north, like in some coasts of Madagascar, at the beginning of the twentieth century (Foidl et al. 2001). Its growing was first a privilege of the colons. It did not spread to the center until recently, when the National Office for Nutrition (ONN) heightened population's awareness about its nutritional benefits (ONN, 2008). While MO leaves are largely eaten and valorized in other countries like India, the consumption of these leaves is rather low in Madagascar.

Among the factors underlying food choice, availability and price were reported to be the most important ones (Giskes, Van Lenthe, Brug, Mackenbach, & Turrell, 2007). For low income households particularly, food price has been shown to have precedence over all other determinants of food choice (Blaylock, Smallwood, Kassel, Variyam, & Aldrich, 1999; Glanz, Basil, Maibach, Goldberg, & Snyder, 1998). Availability and price constitute households food acquisition power that must be distinguished from households food acquisition behavior, that is, the desire to consume a particular food among multiple available and affordable foods. It has been shown in developed countries that persons of low socioeconomic status are generally less likely to consume healthy diets (Inglis, Ball, & Crawford, 2005, 2009). Financial cost of diets that comply with dietary guidelines was proposed as a reason. Another explanation could be linked to nutrition knowledge, which was shown to differ significantly between socio-demographic groups, with poorer knowledge among those of lower socioeconomic status (Butriss, 1997; Parmenter, Waller, & Wardle, 2000). Price and availability interact with past behavior or habits which are dependent on country, culture, community or family. For example, in India, where Eastern local population have a preference for rice, migrants from northwest India keep their cultural preference for wheat and continue to favor it even if it is more expensive than rice (Atkin, 2013).

Besides economical and cultural factors the sensations associated to the consumption of a food are important to explain consumers' choice to eat a specific food rather than another one. These sensations are of two orders: (i) the sensations derived from the sensory attributes of the product which are mostly related to liking and preference conducting the individual to choose a food (Clark, 1998) and (ii) the physiological sensations related to metabolic effects caused by the intrinsic properties of the product, as macro-nutrient composition and satiating power. Satiation is defined as the processes that bring a meal to an end. It is closely related to sensory and cognitive factors, as well as the sensation of "fullness". Fullness was described by participants as "feeling of food in the stomach", "stomach stretch", "satisfaction", "contentment", "energized", "focused", and "lack of the desire to eat" in the study of Murray and Vickers (2009).

The respective importance of factors underlying food choice (price, availability, habit, preference, satiating properties) depends on the environment and the population or demographic group (Scheibehenne, Miesler, & Todd, 2007). All the studies cited above were performed in developed countries. A limited number of these studies focused on low income population (e.g. Burns, Cook, & Mavoa, 2013; Dressler & Smith, 2013) but none were dedicated to understand food choices in developing countries. Yet, such knowledge could help fighting malnutrition by introducing new healthy food habits.

The goal of this study was to understand how knowledge about consumers' habits and representation of local food products could help fighting malnutrition. The first part of the study aimed at understanding the practices and beliefs about the consumption of cassava roots and MO leaves by school age children Malagasy parents in four areas (two rural and two urban areas), in which food habits were previously shown to be different (Ramaroson Rakotosamimanana, Arvisenet, & Valentin, 2014). We hypothesized that satiating properties and habits are the highest determinant of cassava and MO consumption, explaining the difference of consumption of MO leaves among the areas. The second part of the study aimed at improving the nutritional properties of cassava roots based foods by combining them with MO leaves. Food products containing these two ingredients were prepared based on food practices revealed in the first part of the study. Hedonic tests were performed on these products with school age children to evaluate the highest concentration of MO children can accept. We also hypothesized that differences in MO availability among areas would induce different levels of MO consumption and different liking of snacks containing MO by children in these different areas.

2. STUDY 1

2.1. Materials and methods

2.1.1. Localisation

The study was conducted in urban and rural areas of Antananarivo (AU and AR, respectively) and Antsiranana also known as Diégo-Suarez (DU and DR, respectively). Antananarivo, the capital of Madagascar, is located in the central part of Madagascar, and is characterized by a heterogeneous population. Antsiranana is located in the northern coast of the island and is mostly populated by two ethnic populations.

2.1.2. Participants

A total of 1000 parents of school age children from different social classes participated in the studies. Three hundred participants were recruited in AU, 300 in AR, 200 in DU and 200 in DR (Table 1). Their mean age was about 38 years old, 79.7% of them were women and 20.3% men. The difference between the Antananarivo and Antsiranana sites in the number of interviewees was related to differences in the total number of inhabitants in these two areas.

Table 1. Characteristics of interviewed parents

	Areas[a]			
	AU	AR	DU	DR
Remunerative activities				
Agriculture, farming, fishing	81	179	19	286
Manual worker, domestic work, « road » salesman, hired man	192	260	114	71
Independent	104	92	43	30
Salaried	165	86	94	49
Monthly household income				
<Ar 50 000 (<USD 22.04)	10	30	48	37
Ar 50 000 – 100 000 (USD22.04-44.09)	53	113	50	51
Ar 100 000 – 200 000 (USD 44.09-88.17)	91	94	47	56
Ar 200 000 – 300 000 (USD 88.17-132.26)	85	28	18	41
Ar 300 000 – 500 000 (USD132.26-220.43)	48	20	24	14
>Ar 500 000 (>USD220.43)	13	14	13	1

2.1.3. Questionnaire

The questionnaire used in this study is part of a larger research project aiming at understanding Malagasy school children parents' food practices and beliefs structure. First, focus groups were held with twenty-two parents of children enrolled in public primary school. Then the beliefs and practices that emerged from the focus groups were used to build a questionnaire. Only the sections of the focus groups and questionnaire related to cassava roots and MO are presented here. Other aspects of the project can be found in Ramaroson Rakotosamimanana et al. (2014).

To assess school children parents' food practices and beliefs structure about cassava and MO, the following questions were inserted in the focus groups:

- "Which foods do your children eat frequently?"
- "Do you think cassava roots have enough nutritional value?
- "Which foods do you think can be added to cassava roots to make a nutritious meal?"
- "Can you cite some examples of leafy vegetables which can be added to cassava roots?"
- "Do you have a specific reason to cite Moringa leaves?"
- "Do you think that it is possible to make a food made of cassava roots and Moringa leaves?"

The questionnaire was first elaborated in French as French was the common language among the researchers involved in the study, and then, translated by the first author into the Malagasy language. A pre-test was carried out with 40 interviewees. This first trial led to a reduction in the number of questions and to changes in the formulation of the questions. The final version of the questionnaire consisted of three parts and included 31 main questions as well as 11 socio demographic questions. The questions related to cassava roots and MO leaves are presented in Figure 1.

Ten interviewers were recruited and trained to use identical questioning techniques. To complete the questionnaire, interviewees were helped by interviewers who had to read the questions aloud to them. Each interview lasted for about 15 minutes. Interviewees were encouraged to give responses related to their own experiences and were told that there was neither right nor wrong response. To ensure even representation of each area, the questionnaires were administered in 24 neighbourhoods in AU, 18 in AR, 11 in DU and 5 in DR. Interviewees resided in the neighbourhood of the interviewing location. AR sites were located about 20 km from downtown Antananarivo, and DR sites were located about 20 to 50 km from downtown Antsiranana.

Representation of cassava roots

1: From your mind, can these foods replace rice in general and according to price, availability, nutritional value and taste?

			Price	*Availability*	*Nutritional value*	*Taste*
Maïze	□ *yes*	□ *no*	□	□	□	□
Breadfruit	□ *yes*	□ *no*	□	□	□	□
Cassava roots	□ *yes*	□ *no*	□	□	□	□
Banana plantain	□ *yes*	□ *no*	□	□	□	□
Sweet potatoes	□ *yes*	□ *no*	□	□	□	□
Taro	□ *yes*	□ *no*	□	□	□	□
Pasta	□ *yes*	□ *no*	□	□	□	□

2: From your mind, which are the 3 characteristics of cassava roots (3 responses by group of items)?

Group 1:		*Group 2*	
Bringing energy and vitamins	□	*Not tasty*	□
		Not expensive	□
Satiating	□	*Occasional meal*	□
Stomach ache	□	*Not easy to find*	□
Teeth bleeding	□	*Helping out*	□
Decalcifying	□	*Consume sugar*	□
Diversifying meal	□		

NB: The item "consume sugar" means that cassava is not eaten alone but needs to be consumed with sugar.

3: Do you plant cassava? □ *yes* □ *no*

4: Do your children like cassava roots? □ *yes* □ *no*

5: In which frequency do your children consume cassava roots? □ *never* □ *rarely* □ *frequently* □ *everyday*

6: In which part-time of the day do your children consume cassava roots?

□ *snack in the morning* □ *snack in the afternoon* □ *breakfast* □ *lunch* □ *diner*

7: From this list of ingredients, which ones do you add into your cassava roots?

	Never	*Rarely (<2 times/month)*	*Frequently (>2 times/month)*	*Every day*
Coconut	□	□	□	□
Sugar	□	□	□	□
Salt	□	□	□	□
Oil	□	□	□	□
Peanut	□	□	□	□
Leafy vegetable	□	□	□	□
Other:_____	□	□	□	□

Representation of Moringa oleifera leaves

8: Have you ever □ *heard about* □ *seen* □ *eaten* *Moringa leaves?*

If ever seen, where did you see it? □ *by the roadside* □ *in your garden* □ *in the market*

Which town? □ *Toamasina* □ *Antananarivo* □ *Antsiranana* □ *Other_____*

If you have it in your garden, □ *you planted by yourself* *or* □ *It have already grown there*

9: From your mind, what are the characteristics of Moringa leaves?

I need them for my health	□ *yes*	□ *no*
They cure	□ *yes*	□ *no*
They protect me from illness	□ *yes*	□ *no*
They bring nutrients	□ *yes*	□ *no*

They have a strong odor □ *yes* □ *no*
They should not be cooked long time □ *yes* □ *no*
They are not different from the other leafy vegetables □ *yes* □ *no*

10: Do your children like Moringa leaves? □ *yes* □ *no*

11: In which frequency do your children consume Moringa leaves? □ *never* □ *rarely* □ *frequently* □ *everyday*

12:At what time of the day do your children consume Moringa leaves?
□ *snack in the morning* □ *snack in the afternoon* □ *breakfast* □ *lunch* □ *diner*

13: From this list of ingredients, which ones do you add into Moringa leaves?

	Never	*Rarely (<2 times/month)*	*Frequently (>2 times/month)*	*Everyday*
Coconut	□	□	□	□
Sugar	□	□	□	□
Salt	□	□	□	□
Oil	□	□	□	□
Peanut	□	□	□	□
Leafy vegetable	□	□	□	□
Other:_____	□	□	□	□

Fig.1. Questionnaire related to cassava roots and MO leaves. For the second question, items were separated into two groups: health and other properties to avoid memory problems (the questionnaire was admistrated orally as many parents in rural areas have reading/illiteracy problems).

2.1.4. Data analysis

Survey data were analyzed by compiling the frequency count for each question in each interviewing area (AU, AR, DU and DR). The effect of interviewing area was then tested using adjusted chi-square (χ^2) tests with an α risk set at 0.05.

2.2. Results

2.2.1. Cassava roots: practices and beliefs

As shown in Table 2, there is a clear effect of area on respondents' practices linked to cassava plantation. Percentages of households who plant cassava in their familial field were higher in rural areas than in urban areas especially in Antsiranana areas (74.5% in DR vs. 9.5% in DU). In all areas a large part of planted cassava is consumed by households (68.4% to 96.8%). However this difference in plantation is not paralleled by a difference in consumption pattern. In all areas, cassava roots are consumed alone or accompanied by other ingredients, as shown in Fig.2. The most frequently added ingredient is sugar (more than 77% of response) followed by salt (less than 33.5%). In contrast, it is not frequent to add leafy vegetables, peanut, oil or coconut (less than 20%) to cassava roots. An effect of areas is observed for the

addition of coconut, salt and leafy vegetables which were more frequent in Antsiranana (DU and DR) than in Antananarivo (AU and AR).

In the four areas a high percentage of parents affirmed that their children liked cassava roots (82.7% in AU, 88% in AR, 78.5% in DU and 80.5% in DR) and ate them more often as a snack, especially in the afternoon (65 to 86%) than during principal meals (less than 15%). The main difference among areas concerns the frequency of consumption. The majority of children ate them "rarely" (less than two times per month) in AU and DR. In AR and DU, the consumption was balanced between "rarely" or "frequently" (more than two times per month). However, this result should be taken with precaution because it is known that cassava consumption is mostly seasonal. It was probably difficult for respondents to estimate their mean consumption of cassava.

Table 2.
Responses obtained about cassava roots and MO leaves in the four areas

		Antananarivo Urban (AU)	Antananarivo Rural (AR)	Antsiranana Urban (DU)	Antsiranana Rural (DR)
- Proportion of households planting cassava ***		31.67	51.67	9.50	74.50
- of which proportion of households consuming cassava planted ***		86.32	96.77	68.42	86.58
- Consumption of cassava by children (%) ***	- Never	2.29	6.67	4.00	1.50
	- Rarely	72.14	40.33	59.50	61.50
	- Frequently	22.14	51.33	36.50	36.50
	- Every day	3.44	1.67	0	0.50
- Interviewees having heard about, seen and eaten Moringa leaves (%)	- heard ***	82.00	70.33	98.50	100
	- seen ***	58.00	42.33	98.50	100
	- eaten ***	40.00	28.67	98.50	100
- Consumption of MO by children (%, based on interviewees that declared eating MO in previous question) ***	- Never	0.98	8.96	0	0
	- Rarely	92.16	77.61	17.50	45.00
	- Frequently	6.86	13.43	81.50	55
	- Every day	0	0	1.00	0

(***very significantly different at risk 0.001 with χ^2 test)

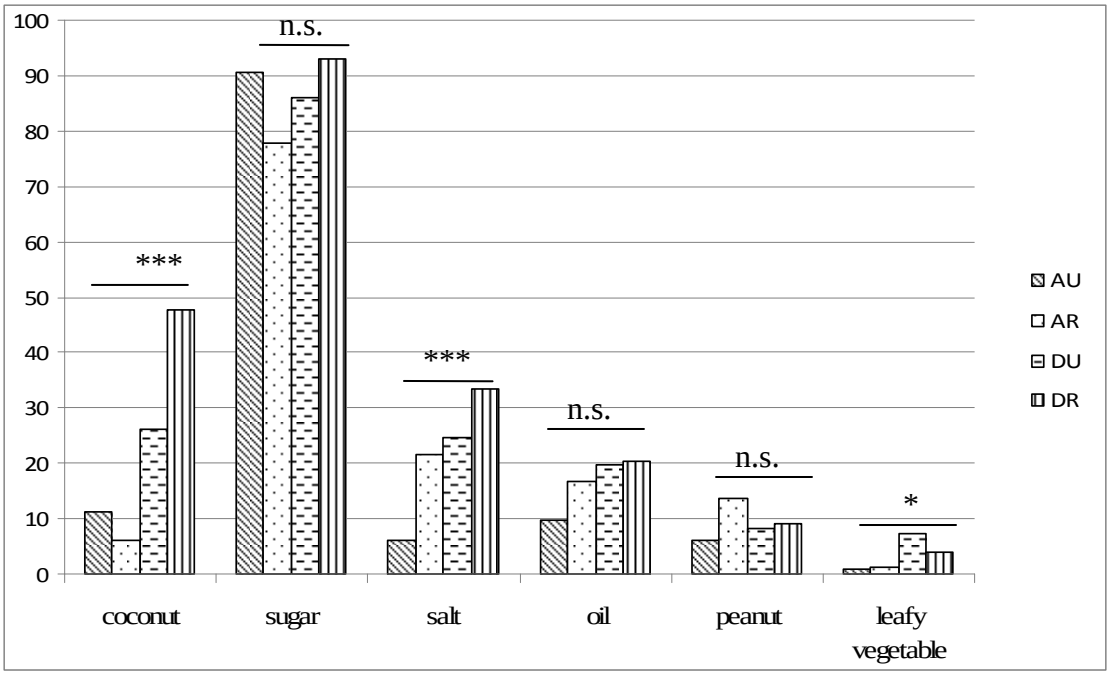
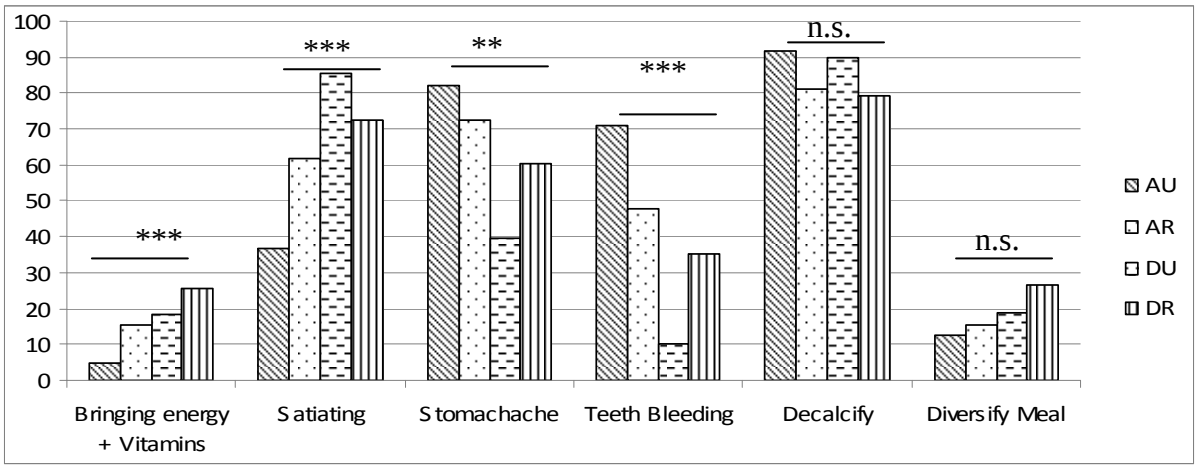


Fig.2. Ingredients added to cassava roots more than two times per month
(n.s.: not significantly different between the four areas, *: significantly different at risk 0.05, ***very significantly different at risk 0.001
AU: Antananarivo urban, AR: Antananarivo rural, DU: Antsiranana urban and DR: Antsiranana rural)

Fig. 3 shows the characteristics that parents associate to cassava roots. Among the items related to health, “decalcify” was the most cited in all locations. In Antananarivo urban (AU), the three items related to negative health characteristics were the most cited (“decalcify”, “stomachache” and “teeth bleeding”). In Antananarivo rural (AR), these three negative characteristics were also largely cited but “satiating” was in third position after “decalcify” and “stomachache”. In Antsiranana (DU and DR), the second most cited item was “satiating”. “stomachache” and “teeth bleeding” were cited less often in Antsiranana than in Antananarivo, and less often by DR than by DU respondents. The items the less often cited in all areas (less than 30%) were “bringing energy and vitamins” and “diversify meals”.

For items related to other aspects than health, cassava roots were principally considered to be a cheap and helping out food, in the four areas. In DR, “consume sugar” was most cited than in other areas. Cassava roots are more consumed occasionally in urban than in rural areas.

a



b

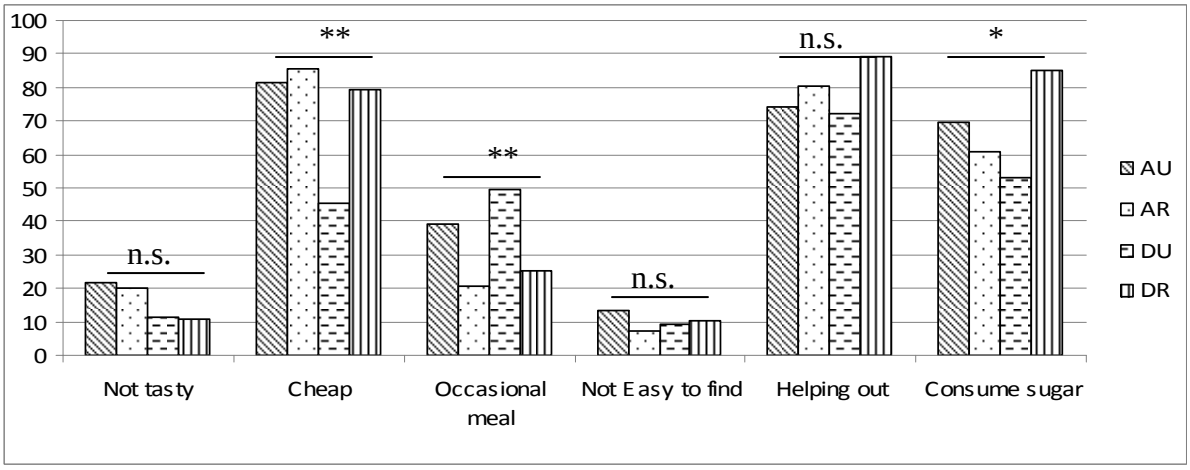


Fig.3. Percentage of citation of items to characterize cassava roots (a: characteristics related to nutrition and health, b: characteristics related to other aspects)
(n.s.: not significantly different between the four areas, *: significantly different at risk 0.05, ***very significantly different at risk 0.001 AU: Antananarivo urban, AR: Antananarivo rural, DU: Antsiranana urban and DR: Antsiranana rural)

2.2.2. MO leaves: practices and beliefs

100% of respondents from Antsiranana had already eaten MO, whereas only 40% and 29% respectively in Antananarivo urban (AU) and rural (AR) did. 18% and 30% of respondents from AU and AR respectively did not know it (Table 2). The percentages corresponding to the localization where respondents had seen these leaves are presented (Fig.4). In Antsiranana, MO often grew in respondents' garden. In DR, it was also available in the market. In AU, the leaves had been mostly seen in the market. In AR, when respondents had already seen it, it was mostly in the market. MO leaves are mostly eaten salty (Fig.5). In Antananarivo, households cook them with oil. Only about 20% of households of the four

areas ate them with other leafy vegetables. The less frequently added ingredients were coconut, sugar and peanut.

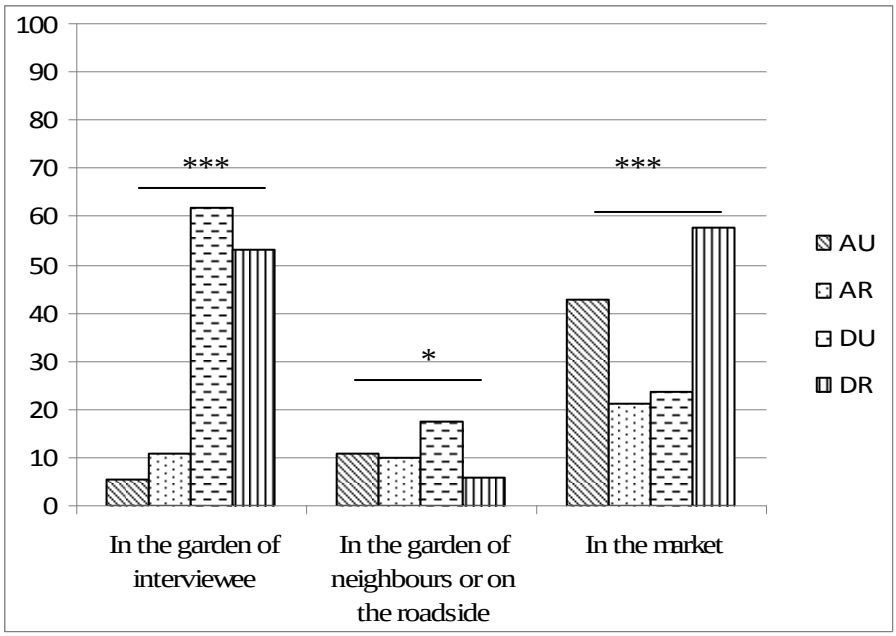


Fig.4. Locations where respondents have seen MO leaves (in percentage).
(n.s.: not significantly different between the four areas, *: significantly different at risk 0.05, ***very significantly different at risk 0.001
AU: Antananarivo urban, AR: Antananarivo rural, DU: Antsiranana urban and DR: Antsiranana rural)

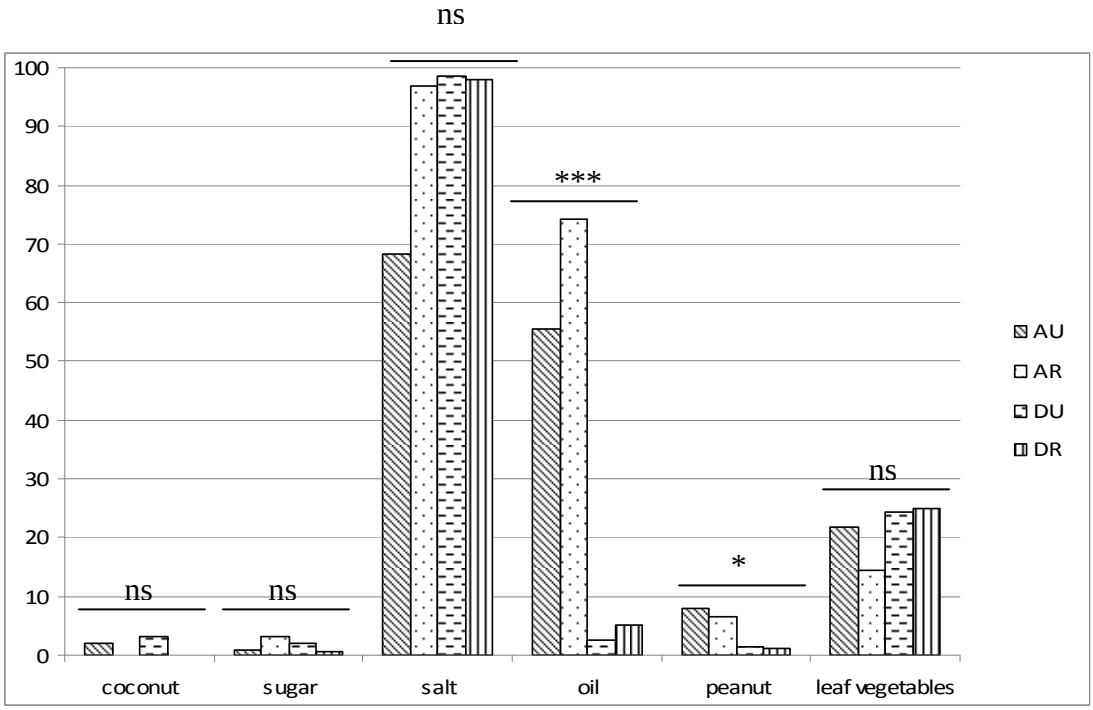


Fig.5. Ingredients frequently added to MO leaves when cooking

Most of the respondents indicated that their children consumed MO leaves more frequently at lunch. The large majority of respondents from Antananarivo declared that their children ate MO leaves rarely whereas those from Antsiranana urban ate them frequently. In AR, half of the children ate the leaves frequently and the others eat them rarely. Among children having already eaten MO leaves, 82% and 70% in AU and AR respectively liked it against 92% and 96% in DU and DR respectively.

Fig. 6 shows the characteristics parents associated with MO leaves. The characteristics "used for health", "curative" and "bring nutrients" were cited equally in the four areas. "Preventive" health characteristic was more cited by urban than rural respondents. Results related to sensory and culinary properties of MO leaves were cited mostly by respondents from Antsiranana, confirming they had more knowledge about MO leaves than those from Antananarivo. Parents from AR, the more numerous not to know MO, generally considered its leaves to be identical to other leafy vegetables.

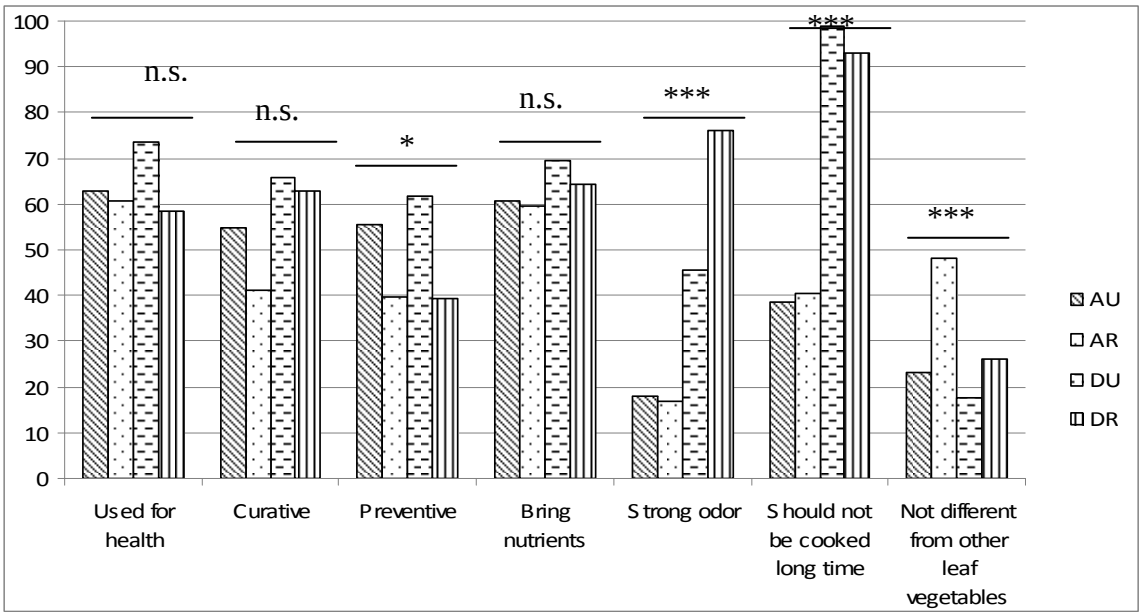


Fig.6. Percentages of items cited as characterizing MO leaves by interviewees who have already heard about MO

(n.s.: not significantly different, *: significantly different at risk 0.05, ***very significantly different at risk 0.001)

(AU: Antananarivo urban, AR: Antananarivo rural, DU: Antsiranana urban and DR: Antsiranana rural)

2.3. Discussion

On the one hand, cassava was considered by respondents to have negative impact on health, but still, was consumed in relatively large quantities. At least one respondent out of four indicated that their children consumed it "frequently" or "often", in the four studied areas.

However the mean consumption frequency declared by parents must be taken with caution, because it probably does not reflect a regular consumption. Indeed, cassava is recognized to be a food shock absorber for less advantaged households, who mostly consume it during the lean period, when rice is not affordable (Dostie, 1999). During this period, if each portion of rice was substituted by a portion of cassava, the consumption of cassava would be two or three portions a day. FAO evaluated cassava consumption in Madagascar to be between 251 and 430 g per capita (Montagnac, Davis, & Tanumihardjo, 2009). On the other hand, MO was considered by respondents to have nutritive, curative and preventive characteristics but was scarcely consumed in Antananarivo. It was consumed more frequently by Antsiranana children. This discrepancy between the large consumption of cassava despite its negative health effect and the limited consumption of MO despites its positive health effect can be explained in term of availability, price, habits, taste and satiating properties. Moreover, the importance of each factor changes from one area to another.

Availability, that is, accessibility of food in the local neighborhood, is the first condition to food acquisition. It depends either on the local growing of the food or its presence on the local market. Respondents consumed cassava at a similar frequency in the four studied areas. Growing of cassava in gardens was largely spread in the two rural areas, where the availability of varied food on markets could be more limited than in urban areas, showing that cassava was easily available for all the population studied. This is in accordance with the large availability of cassava observed in Madagascar: 2366250 tones in 2002 from data of Agricultural ministry of Madagascar (MAEP, 2004). This criterion could favor the wide consumption of cassava despite its nutritional poorness: 157g per person per day in Antananarivo and 48g per person per day in Antsiranana (Dostie, Randriamamonjy, & Rabesolo, 1999). Concerning MO, the situation was quite different. As expected it was not only more consumed but also better known in the north part of the country (DU and DR), compared to the center part. In DU it could be found in markets. It was also available in markets in AU where respondents did not grow it. Of course, availability of a product is the first condition to its consumption, but our results show that the reverse is not always true: an available product can be neglected as a food. It is observed for MO which is available at AU but not much consumed. The historical availability of MO seems to influence its consumption more than its present availability.

Price is probably another explanation of the attractiveness of cassava for poor households. It is one of the cheapest staple foods consumed in Madagascar. Our study shows that in rural areas, at least half the households plant cassava, and thus make it even more

affordable than in the market. One kilogram of these roots cost MGA1000 (~USD0.45) in the market in 2013, and can feed a family of four or five persons at lunch. MO is also planted by half the households in Antsiranana area (DR and DU). Its price is higher in the markets of Antananarivo than in those of Antsiranana, probably due to its higher availability in Antsiranana. Yet, even if the role of price is of major importance, it cannot explain the limited consumption of MO in Antananarivo. According to Malagasy households' practice, leafy vegetables are eaten in small portion and usually accompany rice (Randrianatoandro, Avallone, Picq, Ralison, & Trèche, 2010). The proportion between leafy vegetables and rice in "laoka" is estimated to 1/4 to 1/10 according to households' practices (Chan Tat Chuen, 2010; Randrianatoandro et al., 2010). When rice is not affordable, poor Malagasy households often replace it by cassava but without accompanying it with leafy vegetables, as showed by our results. Though, the association of cassava with MO would put the meal at the same cost or even cheaper than an equivalent quantity of rice alone: about MGA2000 per kilogram during high season (0.9 USD).

Our results show that the knowledge of the positive properties of MO on health has reached the population of the center, but its consumption has not spread among all the population. On the contrary, cassava is largely consumed, despite awareness of consumers about its low nutritional interest. These results confirm statements previously made in developed countries, that knowledge of nutritional and health properties of a food do not systematically increase its consumption (Ginon, Lohéac, Martin, Combris, & Issanchou, 2009). To our knowledge, there is no information in the litterature about the weight of nutritional information on food choices in developing countries. Nutritional knowledge and priorities in terms of nutrition and health are so different in developed and developing countries that it would be tricky to compare our results with results obtained in developed countries. Yet, one study could bring us elements to understand our results. This study focused on the hierarchy of determinants of choice for low income consumers of developed countries (Burns, Cook, & Mavoa, 2013). It showed that low-income consumers who have experienced food insecurity weight up the attributes of a food in relation to its price. Satiating hunger is the primary consideration in food purchase, before other needs and sometimes at the expense of perceived healthiness of a food. It seems that it was also the behavior of the respondents in our study. "Satiating" was among the most cited items associated with cassava by the respondents. The weakness of cassava in terms of nutrient composition is probably considered as a minor consideration compared to this satiating hunger perceived property. Satiety sensation of cassava and staple food in general is very important related to their price,

and this factor may be an important element of food choice, as demonstrated in Burns et al's study (Burns, Cook, & Mavoa, 2013). Satiating power of leafy vegetables was not mentioned by parents during focus group discussions when talking about characteristics of leafy vegetables. These products are probably considered as not enough satiating for their price and for this reason, not consumed in as much quantity as staple foods.

Additional factors could intervene, like *fady* (cultural dietary taboos) which are often mentioned to explain food behavior in Madagascar. *Fady* are linked to ancestral beliefs. They are decreed by the village elder. They are specific to a village or tribe and can vary a lot between different tribes. *Fady* can concern all types of food. One example of *fady* concerns noble people from Antsirabe region who should not consume *Bidens pilosa* leaves, which are perceived as inflating knee (François, 1968; Graeber, 2007). However the importance of *fady* should not be overemphasized, since they almost disappeared in large cities like Antananarivo and we failed to find any evidence of fady able to explain our results. More generally, vegetables in Madagascar are not really considered as food but mostly as accompaniments, which is probably the reason for their limited consumption compared to carbohydrate rich staple food (Razafimanantsoa et al., 2013).

The last factor influencing food choices is organoleptic property. Cassava is appreciated by children and children who already tasted MO did not seem to reject it. This allows us to envisage the formulation of a product associating cassava and MO to increase the consumption of MO in Madagascar. The formulation should take into account the practices of Malagasy people concerning the two products. Respondent declared to consume Cassava mostly with sweet products, while MO was consumed added with salt and oil in Antananarivo. This last practice corresponds to the most usual way to consume leafy vegetables, which is to fry it first and to add it with water to prepare a stock which serves to humidify rice during its cooking and is served with rice (Chan Tat Chuen, 2010). Respondents from Antsiranana, who know MO well, underlined its strong odor as a limiting factor. This factor should be taken into account when proposing MO to children. A solution could be to propose sweet products, first to increase their palatability for children, who are known to like sweet products, and secondly to correspond to the way of consumption of cassava and introduce a new way to consume MO. If this product is liked by children, it could be a way to improve the nutritional quality of cassava by associating it with MO.

3. STUDY 2

The purpose of this study was to evaluate children's liking of snacks made of cassava and MO in four areas in Madagascar.

3.1. Material and method

3.1.1. Assessors and localisation:

A total of 424 children between 6 and 13 years old participated in the hedonic tests (respectively 119, 100, 101 and 103 in AU, AR, DU and DR). Sessions were realized in four public schools located in four neighbourhoods. The ratio between boys and girls was respectively 1.3, 1.6, 1.1 and 1.4 in AU, AR, DU and DR. Depending on the locations, 0% to 2% of the children were under the age of 7, 13% to 19% were 7 and 8 years old, 27% to 38% were 9 and 10 years old, 27% to 39% were 11 and 12 years old, and 10% to 17% were older than 12 years.

3.1.2. Products

Four products, made of cassava roots, MO leaf powder and sugar in different proportions (Table 3) were formulated. Fresh cassava roots were purchased at the local market. They were grated and mixed with the other ingredients. MO leaves were from Antananarivo. They were sun-dried, then grinded to powder by using a domestic blender. The powder form was chosen for practical reason (powder is easier to store than fresh leaves). The mixture was cooked in steam bath for 45 minutes, also for practical reason. The mixture was cooled at ambient temperature and samples of about 25 g were distributed in glasses. Tests took place less than three hours after samples cooking.

Table 3
Ingredients in different formulations (in percentages w/w)

Product	Grated cassava roots	*Moringa oleifera* leaf powder	Sugar
C	100	0	0
C+M1	99,4	0,6	0
C+M1+S	89,4	0,6	10
C+M2+S	88,8	1,2	10

C: cassava roots; M: *Moringa oleifera* leaf powder; S: sugar

3.1.3. Procedure of hedonic tests

Each child participated in one session and tasted the four samples which were presented in a sequential monadic design according to a Williams Latin square. No information about the

products to be tasted was communicated to children before and during the test. Children were assisted by animators for scoring the overall liking on 7-point pictorial scales (Fig.7). The answers given by children were transformed into scores to treat the results (extremely disliked: picture on the left = 1, extremely liked: picture on the right = 7). Animators also filled out the second part of the form regarding age, gender and education level of children. At the end of the test, children chose one of the products as a reward for their participation to the test. To ensure they did not choose it on the basis of the remaining quantity of each sample, they were given takeaway samples specially prepared, and not the samples used for the test. The code of the chosen product was recorded into the form by the animator. The test was performed in the native language of each location.

The tests were performed during snack time (from ten to twelve o'clock), before lunch. Children did not eat at least two hours before the test.

Fig.7. 7-Pictorial scale used in the hedonic test

3.1.4. Data analysis

Hedonic scores from the four panels were submitted to a two-way ANOVA with the following mixed model: Score = assessor area + product + product x area + error. When a significant effect of product was found a Neuman-Keuls (SNK) multiple comparison test was performed to reveal significant differences among the four products. XLStat 2013 (Addinsoft, Paris) was used for data analysis.

The choice data were analyzed by recording the number of children who chose each product as a gift at the end of the test in each area. A χ^2 test was performed to check for area effects.

3.2. Results

3.2.1. Acceptance of foods made of cassava roots and MO leaves

The ANOVA showed:

- a main effect of product (F = 102.5; $p < 0.0001$). The presence of sugar influenced the hedonic ratings. The SNK test indicates that sweet products

(C+M1+S and C+M2+S) received higher scores (higher than 5 out of 7) than the other products (scores between 3.5 and 4.4).

- no main effect of area (F = 0.42; p = 0.73).
- a significant interaction between area and product (F = 2.87; p < 0.002). A subdesign analysis carried out by area showed that the effect of product was significant in all areas (F between 9.55 and 37.78, p<0.001). SNK test carried out by area indicates that there was no difference of liking between C+M1+S and C+M2+S, whatever the area, nor between C and C+M1, except in AU where C+M1 was the least liked product (Fig.8).

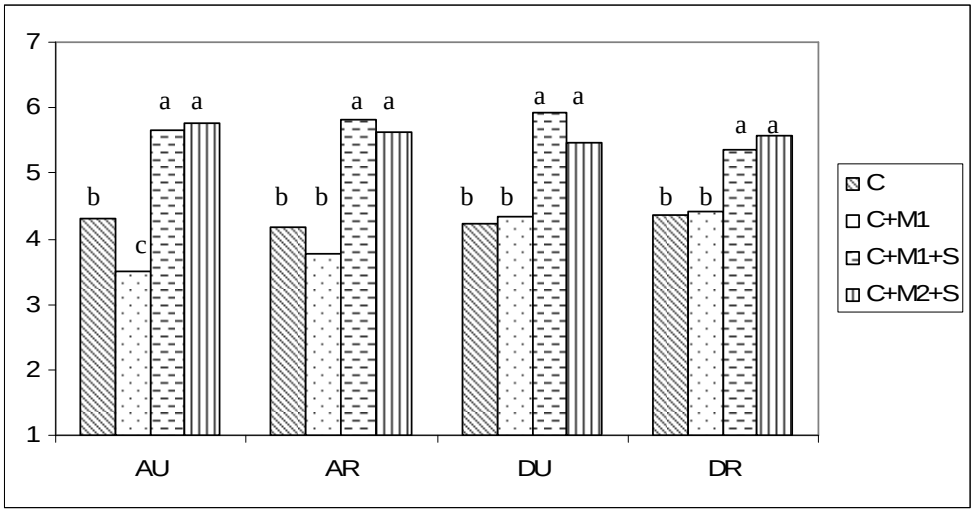


Fig.8. Scores given to the tested products in acceptance tests
(In each area, means taking the same letter were not significantly different from SNK tests at α=0.05)
(AU: Antananarivo urban, AR: Antananarivo rural, DU: Antsiranana urban and DR: Antsiranana rural)
(C: cassava roots; M: *Moringa oleifera* leaf powder; S: sugar)

3.2.2. Product chosen by children

At the end of the test, children had to choose one product among the four products of the test, as a reward for their participation. The frequency at which each product was chosen by children was first computed for all areas taken together. A significant difference was observed between the four products (χ^2 = 98.05 at α=0.05). C+M2+S was chosen the most often (41.98%) followed by C+M1+S and C (28.54% and 20.52% of children respectively). C+M1 was the least chosen (8.96%).

Then, to evaluate the effect of area on children choice, the frequency at which each product was chosen was computed for each area (Fig.). In AU, DU and DR, C+M1+S and C+M2+S were the most chosen, at similar frequencies (χ^2 between 0 and 3.2 at α=0.05), whereas in AR,

C+M2+S was chosen the most. C+M1 was chosen the least in urban areas, whereas the three first products (C, C+M1 and C+M1+S) were chosen the least in rural areas. A significant effect of area on product choice was found only for C+M1+S ($\chi^2 = 10.93$ at $\alpha = 0.05$).

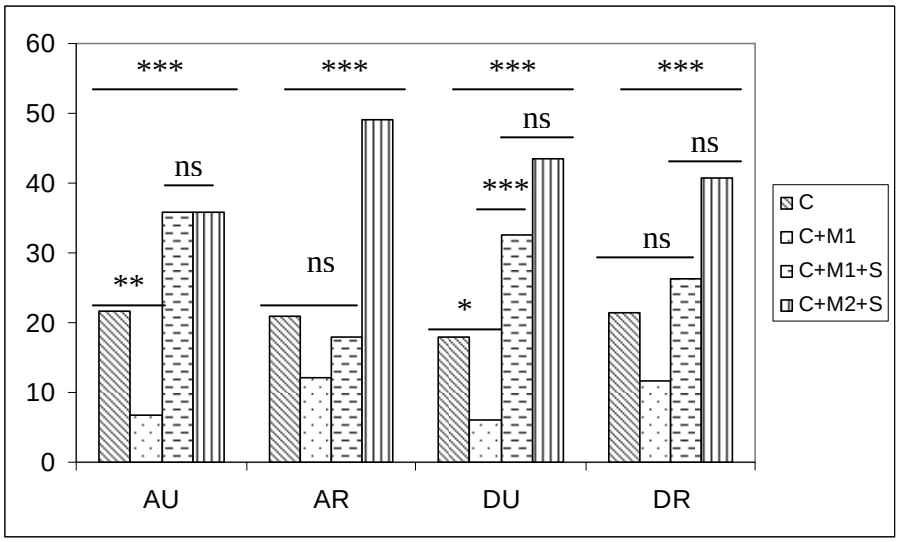


Fig.9. Products chosen by children as remuneration (%)
(AU: Antananarivo urban, AR: Antananarivo rural, DU: Antsiranana urban and DR: Antsiranana rural)
(C: cassava roots; M: *Moringa oleifera* leaf powder; S: sugar)
(ns: no significant difference, *: significant difference with khi-square test at $\alpha = 0.05$, **: significant difference with khi-square test at $\alpha = 0.01$, ***: very significant difference with khi-square test at $\alpha = 0.001$)

3.3. Discussion

The addition of MO leaf powder did not decrease the liking of product based on cassava roots, except in AU where the product containing leaf powder without sugar was slightly disliked. Moreover the products containing MO were chosen by a majority of children in the four areas. Thus liking of MO did not depend on its consumption frequency by children. Indeed, the first part of our result showed that in AU and AR, respectively 3 and 4 % consumed MO frequently or more, versus 83% and 55% in DU and DR. The result obtained from AR is noteworthy because the percentage of children who had chosen the product with a double amount of MO powder (C+M2+S) is high compared to the three other products. In this area, population consumed more frequently green leafy vegetables, compared to the three other areas (Rakotonirainy, Razafindratovo, Sarter, Andrianarisoa, Dabat, Ralison et al., 2012). As leafy vegetables are more largely available in AR fields (Rakotonirainy, Razafindratovo,

Sarter, Andrianarisoa, Dabat, Ralison et al., 2012), perhaps familiarity to green leafy vegetables may have guided them to choose the C+M2+S over the other products.

The presence of sugar enhances the liking of the products by children. Sweet products were rated higher and were more often chosen by children at the end of the test. These results are in agreement with the notion of innate liking of sweet products by children. This predisposition to prefer a sweet taste is modified by experience with food (Birch, 1999). In a study of Desor & Beauchamps (1987), half of the 11-15 years participants selected the highest concentration of sucrose as their most preferred. Few years later, only 32% of these same participants selected the highest sucrose concentrations.

The addition of sucrose could be questionable in a developed country, but it is not against dietary recommendations in a country such as Madagascar, where caloric intake is often low. Moreover, our results showed that the presence of sugar really increase the liking of products containing MO leaf powder. Thus children can be expected to consume sweet product more than product containing only cassava and MO. Presence of sucrose could thus promote a higher consumption of micro-nutrients, ω3 fatty acids and amino acids by children.

The prices of the four formulations were calculated by considering that all ingredients were bought in local market. Each sample of 100 g costs MGA102 (~USD0.04), MGA222 (~USD0.12), MGA239 (~USD0.12) and MGA359 (~USD0.12) for C, C+M1, C+M1+S and C+M2+S respectively. A solution to make a cheapest product could be to promote the plantation of MO in local family fields for example.

4. Conclusion

The most important factors found on this study to explain cassava large consumption was satiating power. Habits can also explain why cassava roots take the place of second staple after rice. The situation was different concerning MO. Its consumption mostly depends on its knowledge by people, and culture to consume it in a geographic area. MO was considered to have positive properties and was appreciated by people who consumed it. But it is difficult to imagine to integrate MO leaves in Malagasy repertory food at the same place as staple food, because people would probably not consider them as satiating enough. A better alternative is to propose a food containing cassava and MO. It was well accepted by children and could be suggested to parents as a snack both satiating and providing to their children micro and macro-nutrients such as proteins and ω3. In parallel, an education program about the nutritional properties of MO leaves could be used to encourage households to grow MO.

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III. Poster C :

Paradox between malnutrition and nutritional richness of foods in Madagascar: the example of *Moringa oleifera* leaves

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Introduction

In Madagascar food insecurity exists despite rich natural resources.
In other countries, *Moringa oleifera (MO)* was proposed as a potential solution to malnutrition due to its high nutritional properties.
The aims of this study were to understand:

- if *MO* is known and how it is perceived by Malagasy population
- what are the nutritional properties of *MO* leaves from Madagascar

20 to 35% of population suffer from malnutrition
5 to 19% of population suffer from malnutrition
Countries where MO can be found

Materials and methods

Representation of MO leaves

Aim: - Knowledge and consumption of MO
- Characteristics attributed to MO leaves

Focus groups : 72 parents of scholar age children
67 ♀ and 5 ♂, 19 – 62 years old

Questionnaire: 1000 parents of children
797 ♀ and 203 ♂, 18 – 59 years old

Determination of nutritional composition of *MO* leaves

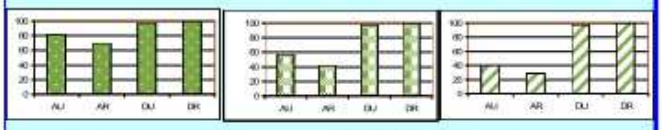
Product: *MO* harvested in Antananarivo, sun-dried and milled into powder

Analyses:

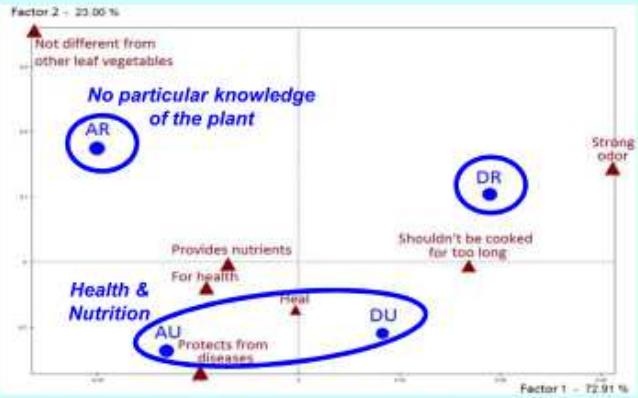
- **Crude protein**: Dumas Nitrogen Analyzer. Conversion factor from nitrogen to crude protein: 4.4
- **Crude fat**: Randall Extractor. Acid hydrolysis: 1h; drying of samples before extraction. Extraction solvent: petroleum ether
- **Minerals:** atomic absorption spectrometry

Results

Have you already heard about MO ? | *Have you already seen MO ?* | *Have you already eaten MO leaves ?*



⇒*MO* is less known and consumed in Antananarivo than in Diego
⇒No difference between rural ans urban areas was observed



Correspondence analysis of properties attributed to MO leaves in the four areas

Nutritional value of *MO* dried leave powders

Crude proteins (g/100g)	26.5
Crude fat (g/100 g)	5.1
Total carbohydrates (g/100g)	45.1
Ca (g/100g)	2.5
Mg (mg/100g)	270.2
Fe (mg/100g)	5.8

Values were averaged over three or four replicates. Total carbohydrates value is obtained by difference.

Dried *MO* powder =

2 x Twice the protein content of eggs
3 x Three times more calcium than Swiss cheese
1 x The same iron content than crude lentils
1 x The same magnesium content than almonds

Conclusion

Main results

- There is nutritional interest to add *Moringa oleifera* into Malagasy food repertory.
- *MO* leaves were not equally known depending on the area: participants in urban areas were aware of nutritional properties whereas participants from Diego rural know how to cook it. In Antananarivo rural, participants did not have specific knowledge about *MO*.

Perspectives:

- To find a way to introduce *MO* leaves in Malagasy food repertory, by combining it with satiating foods, such as cassava or rice.
- To inform population about *MO* properties: sensory and culinary aspects should by highlighted in urban areas, and nutritional properties in rural areas.

Si, à Madagascar, la malnutrition touche encore une grande proportion de la population, certaines ressources alimentaire à fort potentiel nutritionnel restent encore mal valorisées, telles que les feuilles de MO. Cette étude vise, d'une part, à comprendre le niveau de connaissance et de perception de MO par les parents malgache issus de quatre lieux d'étude (AU : Antananarivo urbain, AR : Antananarivo rural, DU : Antsiranana urbain et DR : Antsiranana rural), et d'autre part, à connaître les propriétés nutritionnelles des feuilles de MO venant d'Antananarivo. Cette étude combine une étude de représentation des feuilles de MO, à travers des groupes focus et un questionnaire, et de leurs analyses nutritionnelles (protéine, lipide et minéraux).

A Antananarivo, les feuilles de MO sont moins connues et moins consommées qu'à Antsiranana où 100% de la population les ont déjà consommées. Aucune différence de niveau de connaissance et de consommation n'a été observée entre zones rurales et zones urbaines. Les parents venant des zones urbaines (AU et DU) ont associé plutôt MO à un aliment bon pour la santé et nutritif. Ceux de DR ont plus des connaissances liées aux aspects olfactifs et culinaires des feuilles, tandis que ceux d'AR ont considéré les feuilles de MO identiques à toutes les légumes feuilles, traduisant un manque de connaissance de cette plante dans ce lieu. Du point de vue nutritionnelle, les poudres de feuilles de MO contiennent deux fois plus de protéine que les œufs, trois fois plus de calcium que les fromages à pâte dure, la même quantité de fer que les lentilles et la même quantité de magnésium que les amandes. Cette étude a montré l'intérêt nutritionnel d'introduire les feuilles de MO dans le repertoire alimentaire malgache. Il est envisageable de faciliter cette introduction en combinant les feuilles de MO aux aliments considérés comme étant rassasiants, tels que les racines de manioc ou le riz. Les propriétés de MO doivent être communiquées à la population afin de lui apporter des connaissances sur leurs feuilles : connaissances sensorielles et culinaires pour les ménages en zones urbaines et connaissances nutritionnelles pour ceux en zone rurales.

IV. Poster D :

Sensory acceptability of cassava snacks nutritionally enriched on Moringa oleifera leaf powder among children from low-income households in Madagascar

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Introduction

48% of malagasy children under the age of five have stunting problem due to poverty. In contrast, Madagascar possesses a huge number of nutritious and edible plants, like *Moringa oleifera* (*M.o.*). These natural food resources can be utilized to improve dietary quality in children, helping to prevent malnutrition. In this study, *M.o.* leaf powder was added to cassava roots to nutritionally improve cassava based foods.

Cassava roots

-"Security food" for low-income households in Madagascar

-Satieting food but deficient in protein, minerals …

***Moringa oleifera* leaf powder**

-Used to combat malnutrition in other countries

-Though cheap and available, underutilized in Madagascar

+

Objective: To make nutritionally improved products from available foods (cassava roots enriched with *Moringa oleifera* leaf powder) for malnourished malagasy children

Aim: To determine if children would accept the new formulated products and analyze the nutritional composition of *Moringa oleifera* leaf powder in these products

Materials and methods

Hedonic test

Assessors: 424 children between 7 and 12 years old
Locations: four public schools from two regions :
- Antananarivo (center) – population not consuming *M.o.*
- Antsiranana (north) – population consuming *M.o.*

both in urban (AU and DU respectively) and rural areas (AR and DR respectively).

Acceptance test

Hedonic measures by using pictural structured scale:

Choice test

Each child chose one among the four products as a remuneration after acceptance test

Formulation of the products :

Product cooked with steam	Grated cassava roots	*M.o.* leaf powder	Sugar
C	100	0	0
C+M1	99,4	0,6	0
C+M1+S	89,4	0,6	10
C+M2+S	88,8	1,2	10

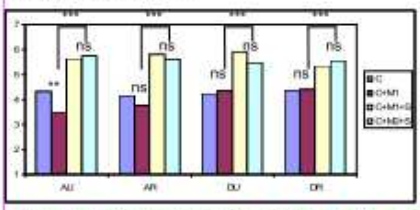
Nutritional composition of M.o. leaf powders:

- Protein – Dumas method
- Minerals (Ca, Mg and Fe) – Flame atomic absorption spectrophotometry
- Fatty acids – Gas chromatography

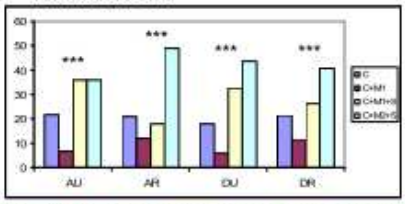
Measures in triplicate

Results

Scores given to the tested products in acceptance tests :



Products chosen by children (%) as remuneration :



The level of acceptability of *M.o.* by the children depended on region: C+M1 was more accepted in Antsiranana (rural and urban) than in Antananarivo (rural and urban), where it was disliked slightly. → People from Antsiranana were familiar to *M.o.*, unlike those from Antananarivo.

The level of acceptability of formulated products increased when sugar was added, regardless of the proportion of *M.o.* incorporated. The sweet product with the highest quantity of *M.o.* (C+M2+S) was chosen most often in the four areas, whereas the one without sucrose with *M.o.* (C+M1) was chosen least. →The sweetness facilitates the introduction of *M.o.* for children.

		Protein	Ca	Mg	Fe	linoleic ac.	α-linolenic ac.
Nutritional composition of *M.o.* leaf powder*		26.49% DM	2530 mg/100g DM	270.2 mg/100g DM	5.83 mg/100gDM	1.7 mg/g HM	7.94 mg/g HM
quantity of nutrients into 200g of product :	**1.2%** of *M.o.* leaf powder	0.63 g	60.72 mg	6.48 mg	0.07 mg	0.04 mg	0.19 mg
	5% of *M.o.* leaf powder **	1.9 g	182.16 mg	19.45 mg	0.42 mg	0.12 mg	0.57 mg
Participation of 5% of M.o. according to **dietary reference intakes** (DRI) for a children of 4-5 y.o		12.96% of DRI	22.77% of DRI	14.96% of DRI	6% of DRI	1.2% of DRI	63.52% of DRI

* DM (dry matter), HM (humid matter); ** 3 times of quantity of *M.o.* than those in C+M2+S

Conclusion

Knowing that the snacks enriched on *M.o.* were accepted and liked by the children, and that they increased the protein and oligo elements intake, this study can help to formulate products with higher concentration of *M.o.*, in order to improve the nutritional status of Malagasy children from low-income households.

The sensory study was founded by French Embassy in Madagascar (Parrur project)

Si les racines de manioc constituent l'aliment de sécurité chez les ménages à faible pouvoir d'achat malgache et sont considérées comme étant un aliment rassasiant mais pauvre en proétine et minéraux, les poudres de feuilles de MO sont utilisées pour lutter contre la malnutrition dans d'autres pays et sont un aliment pas cher et disponible mais sous valorisé à Madagascar. Comme ces deux aliments se complètent nutritionnellement, les feuilles de MO ont été ajoutées aux racines de manioc dans le but d'enrichir nutritionnellement ces racines. Le but de cette étude est d'évaluer le niveau d'acceptabilité des produits formulés et d'analyser la composition nutritionnelle des poudres de feuilles de MO.

Quatre formulations ont été fabriquées : C (100% racines de manioc), C+M1 (racine de manioc + 0,6% de poudre de feuilles de MO), C+M1+S (racine de manioc + 0,6% de poudre de feuilles de MO + 10% de sucre) et C+M2+S (racine de manioc + 1,2% de poudre de feuilles de MO+ 10% de sucre). Ces produits ont été évalués auprès de 424 enfants scolarisés dans des écoles publiques de quatre lieux d'étude (AU : Antananarivo urbain, AR : Antananarivo rural, DU : Antsiranana urbain et DR : Antsiranana rural). Les tests hédoniques comportent deux étapes : test d'acceptabilité utilisant une échelle picturale à 7 points et un test de choix où chaque enfant devrait choisir un parmi les quatre produits proposés comme rémunération. Ensuite, les apports nutritionnels apportés par 1,2% et5% de poudres de MO dans les formulations ont été calculés : protéine, minéraux (Ca, Mg, Fe) et acides gras essentiels (acide linoléique et acide α-linolénique).

Le niveau d'acceptabilité de C+M1 dépend des régions : il est plus accepté à Antsiranana qu'à Antananarivo. Ceci peut être expliqué en termes de familiarité de cette plante par les gens d'Antsiranana. Les produits sucrés (C+M1+S et C+M2+S) ont été les plus acceptés et le C+M2+S a été le plus choisi dans les quatre lieux, tandis que C+M1 a été le moins choisi. La présence de sucre a donc facilité l'introduction de MO chez les enfants. Une formulation incorporant 5% de MO participe à environ 13%, 22,8%, 15%, 6%, 1,2% et 63,5% par rapport à la consommation recommandée en protéine, calcium, magnésium, fer, acide linoléïque et acide α-linolénique respectivement chez un enfant de 4 ou 5 ans. Il peut donc être envisagé d'augmenter la proportion en MO ajouté dans le cadre d'améliorer l'état nutritionnel des enfants malgaches issus des ménages à faible pouvoir d'achat.

V. Conclusion

Cette étude a montré qu'il est possible pour la population malgache de fabriquer facilement et à moindre coût des aliments qui contiennent des quatités intéressantes de protéines, acides gras essentiels et micronutriments et qui sont également rassasiants et appréciés. Toutefois, même si les goûters proposés ont été appréciés, pour pouvoir aller vers la phase d'appropriation de tels goûters par les ménages pauvres malgaches, il faudrait proposer un mode de cuisson adapté à ces ménages. En effet dans ce projet, les gouters ont été cuits à la vapeur, un mode de cuisson ayant l'avantage de minimiser la destruction des nutriments thermosensibles présents dans le MO mais qui ne fait pas partie des modes de cuisson coutumiers à Madagascar. Un travail d'optimisation des conditions de cuisson devra donc être réalisé dans le futur avec une double contrainte : développer un procédé accessible à tous les ménages et ne dégradant pas les propriétés nutritionnelles des produits. Les feuilles de MO étant consommables à l'état frais ou en poudre sans être cuites, une solution envisageable évitant la dégradation des propriétés nutritionnelles serait de pratiquer la cuisson de l'aliment support indépendamment de l'ajout de MO. En effet, le MO peut être ajouté après la cuisson de cet aliment support. De plus, la suppression de la cuisson des feuilles de MO pourrait éviter la présence de forte odeur décrite comme un frein à la consommation de MO par les personnes enquêtées à Antsiranana rural notamment.

DISCUSSION GENERALE

DISCUSSION GENERALE

L'objectif général de cette thèse était de comprendre pourquoi une grande partie de la population malgache souffre de malnutrition alors que Madagascar est connu pour ses richesses en ressources naturelles. Nos travaux se sont focalisés sur les feuilles de MO. Trois approches ont été utilisées: l'approche chimique à travers les analyses nutritionnelles, l'approche sensorielle à travers les tests descriptifs et hédonique et l'approche psychologique axée sur les études des pratiques et croyances alimentaires.

1) Causes de la malnutrition à Madagascar

a) Importance des habitudes et des structures des croyances alimentaires de la population malgache, au détriment du contenu nutritionnel des aliments

Cette thèse a permis de comprendre que les structures des croyances alimentaires de la population malgache expliquent certaines origines de la malnutrition à Madagascar, tel que montré à travers les études de representations autour des feuilles de MO et des racines de manioc. En effet, il a été montré que la population malgache privilégie les aliments glucidiques car ils sont considérés comme étant les plus rassasiants. Les produits céréaliers, les racines et les tubercules sont considérés comme ayant ce caractère. Contrairement à cela, les aliments riches en d'autres nutriments, tels que les aliments sources de protéines et de micro-nutriments, ne sont pas autant consommés car ils ne sont pas considérés comme ayant le même caractère que les aliments glucidiques. La faible consommation de certains aliments à fort potentiel nutritif et la consommation importante d'aliments peu nutritifs résultent donc des structures de croyances alimentaires développées dans différentes régions de Madagascar (Hypothèse 2).

En plus des croyances, les pratiques alimentaires malgaches sont aussi responsables du problème de malnutrition à Madagascar. Ces pratiques sont étroitement liées aux habitudes bien ancrées de génération en génération. La première pratique qui ressort de notre étude est la surconsommation des aliments glucidiques, telle que déjà mentionnée ci-dessus. L'exemple le plus concret est la forte consommation de riz, qui est héritée de la culture alimentaire asiatique, puisque les premiers habitants de Madagascar, les Austro mélanésiens, venaient d'Asie (Randriamandimby, 1981; Serva, 2012). Le riz représente entre 3/4 et 9/10 dans un

repas malgache (Chan Tat Chuan, 2010). Le reste du repas (entre 1/9 et 1/4) constitue le « laoka », l'accompagnement qui est sensé apporter les protéines, les matières grasses, les minéraux et les vitamines dans une ration alimentaire. Cette faible proportion de « laoka » explique la présence de carences en nutriments observés chez une grande proportion de la population malgache.

L'observation de ces croyances et pratiques nous permet de déduire que si les feuilles de MO ne sont pas assez valorisées à Madagascar, c'est à la fois parce qu'elles ne font pas partie des habitudes alimentaires et parce qu'elles sont considérées comme peu rassasiantes (hypothèse 3).

La deuxième pratique mise en évidence dans ce travail est en lien avec le mode de cuisson des aliments pendant une longue période. Une des raisons d'une telle pratique est le fait de pouvoir détruire tous les organismes pathogènes éventuellement présents dans les aliments non cuits ou lors de leurs manutentions, puisque Madagascar est parmi les pays dont la prévalence de mortalité liée au problème sanitaire est élevée (WHO, 2006). Or, l'effet dégradant de certains nutriments dans les aliments suite à la cuisson pendant une longue durée est bien connu. Afin de minimiser un tel effet, d'autres procédés de cuisson dégradant moins les nutriments peuvent être proposés à la population, avec des matériels facilement accessibles et pratiques.

b) Accessibilité des aliments

Le fait de privilégier le type d'aliments glucidiques peut être considéré comme un « comportement de survie » chez la population malgache à faible pouvoir d'achat, puisque ces aliments restent le groupe d'aliments accessible pour elle (Ramakrishnan & Huffman, 2008). L'accessibilité englobe le prix et la disponibilité des aliments dans l'environnement considéré. Par exemple, pendant chaque « période de soudure », c'est-à-dire période de pauvreté saisonnière entre deux récoltes, le riz devient moins disponible et plus cher à Madagascar. Cette situation entraine le groupe de population pauvre à substituer le riz par d'autres aliments encore plus glucidiques, tels que les tubercules et les racines, qui sont accessibles toute l'année (Dostie, Haggblade, & Randriamamonjy, 2002). Or, non seulement ces dernières sont déficientes en d'autres nutriments (FAO, 1990), mais elles sont aussi souvent consommées seules sans accompagnement, contrairement au riz, comme observé dans nos résultats. Ceci engendre par la suite des états de carences nutritionnelles chez ce groupe de population.

c) Connaissances nutritionnelles et sanitaires vs connaissances culinaires et sensorielle

Il a été également montré dans cette thèse que si les feuilles de MO sont moins valorisées, ce n'est pas par manque de connaissances nutritionnelles ou sanitaires---entre 59 et 70% des participants ont caractérisé ces feuilles comme étant nutritives et entre 60 et 75% pensent qu'ils en ont besoin pour leur santé---mais plutôt par manque d'appropriation de ces connaissances. Ce manque d'appropriation se manifeste par l'incapacité de la population à associer les connaissances reçues à un changement de comportement.

D'après SunWoong, ChungJa, AeJung, & Mihyun (2000), il existe une association entre connaissances, attitudes et comportement alimentaires. A Antananarivo et Antsiranana, cette association s'observe uniquement à patir des connaissances culinaire et sensorielle. En effet, en comparant les résultats d'enquête entre Antananarivo et Antsiranana, plus de participants caractérisent les feuilles de MO par rapport à leurs connaissances culinaire et sensorielle à Antsiranana qu'à Antananarivo, ce qui est à mettre en lien avec sa consommation plus importante à Antsiranana qu'à Antananarivo. Les connaissances culinaire et sensorielle sont basées sur une exposition et une manipulation du produit, contrairement aux connaissances nutritionnelles et sanitaires que les parents ont des feuilles de MO, qui peuvent être non robustes face aux expériences alimentaires. Les connaissances nutritionnelle et sanitaire sont souvent basées uniquement sur des informations indirectes, telles que le « bouche à l'oreille ». Enfin, dans une société de survie, le comportement alimentaire est plutôt basé sur les apports ressentis immédiatement que sur les apports à long terme.

2) <u>Stratégies d'introduction de MO dans le répertoire alimentaire malgache</u>

Nos résultats ont montré que les feuilles de MO d'origine malgache constituent une source intéressante de divers nutriments (protéines, acides aminés essentiels, acides gras essentiels, minéraux…) et permettent de contribuer à la lutte contre la malnutrition à Madagascar. Or il a été montré que les compositions nutritionnelles de feuilles de MO varient selon leur lieu d'origine (Hypothèse 1). Dans l'objectif d'introduire les feuilles de MO dans le répertoire alimentaire de la population malnutrie malgache, plusieurs stratégies complémentaires pourraient être proposées.

a) Optimisation de la valeur nutritionnelle de MO d'origine malgache

L'étude portant sur les caractéristiques nutritionnelles des poudres de feuilles de MO a montré des variabilités par rapport aux zones de plantation. Comme pour toutes les plantes, la

variabilité de la composition nutritionnelle peut être due à plusieurs facteurs tels que le climat (Iqbal, 2006), la composition du sol (Anjorin, Ikokoh, & Okolo et al., 2010; Jongrungruangchok, Bunrathep, & Songsak, 2010), l'état de maturité des feuilles (Bamishaiye, Olayemi, Awagu, & Bamshaiye, 2011), les variétés génétiques (Pandey, Pradheep, Gupta, Nayar, & Bhandari, 2010). Il serait donc intéressant de contrôler ces paramètres pour pouvoir optimiser les compositions nutritionnelles des feuilles à récolter et identifier la période optimale de récolte. Pendant une saison de pluie et chaude, le développement des feuilles est plus rapide. MO préfère les zones chaudes et humides pour un développement optimal, telles que dans les régions côtières (Toamasina, Antsiranana et Mahajanga). Par ailleurs, il a été montré par Shih, Chang, Kang, & Tsai (2011) qu'aucune variation n'a été observée par rapport aux taux de protéines, de matières grasses dans les feuilles récoltées en hiver et en été. Néansmoins, les feuilles récoltées en hiver sont plus riches en calcium et en cendre. La période d'hiver se situe entre juin et août pour Madagascar. Concernant les compositions du sol, l'ajout de fertilisant influence considérablement la composition nutritionnelle de la plante. Les biofertilisants microbiologiques ont été responsable de l'augmentation des taux en protéines, manganèse, fer, magnésium, potassium, phosphore, cuivre et vitamine C (Zayed, 2012). Les feuilles dites « vieilles » (20ème semaine après la taille de la plante) contiennent le maximum de taux en protéine, fibre, cendre, matières grasses (Bamishaiye, Olayemi, Awagu, & Bamshaiye, 2011).

En complément à cette stratégie d'optimisation de la valeur nutritionnelle de MO, la population cible devrait être encouragée à transformer les feuilles en poudre pour une meilleure concentration en nutriments. Pour un meilleur résultat, le mode de séchage idéal est le séchage à l'ombre car les rayons solaires déteriorent certaines vitamines (Bechoff, Dufour, et al., 2009). La transformation des feuilles en poudre permettrait également l'augmentation de la disponibilité toute l'année et aussi une meilleure conservation.

b) Facilitation de l'appropriation des connaissances nutritionnelles

Il a été observé que la plupart des participants enquêtés dans notre étude ont des connaissances nutritionnelle et sanitaire du MO. Par contre, il semble que l'éducation nutritionnelle et sanitaire qu'ils ont reçue n'a pas réussi à modifier leur comportement vis-à-vis de la valorisation des feuilles de MO. Des mesures d'appropriation de telles connaissances sont nécessaires en complément. Afin de cibler les enfants, ces mesures d'appropriation doivent considérer certains contextes :

- S’adresser aux parents, notamment aux mères, afin de rendre le programme d’éducation nutritionnelle beaucoup plus efficace dans les ménages (Sheikholeslam, 2004).
- Favoriser les interactions entre les enfants de même âge à l’école ou avec les personnes ayant une influence sociale au cours de la consommation de ces aliments (Hendy & Raudenbush, 2000; Olsen, Ritz, Kraaij, & Møller, 2012). Des collaborations avec les écoles pourraient être poursuivies dans ce sens.
- Multiplier les contextes dans lesquelles les aliments enrichis en MO sont visibles pour les enfants. Il s’agit de la notion de simple exposition telle que développées par Zajonc, & Robert (1968). Ces contextes d’exposition peuvent être multiples : dans les écoles (cantines scolaires, vendeurs d’aliments cuits ou à la maison). La présentation sous forme de goûters peut s’averer plus efficace, dans ce cas, pour les enfants malgaches. Toutefois, il faut faire attention de ne pas entraîner la lassitude avec des expositions trop répetées (Olsen, Ritz, Kraaij, & Møller, 2012).
- Créer plus d’occasions de consommation de ces aliments, par exemple en utilisant les moments de récréation le matin, correspondant aux moments de faim entre deux repas (Williams, Paul, Pizzo, & Riegel, 2008)

c) Augmentation de la disponibilité de MO au niveau des ménages

Il serait judicieux d’augmenter la disponibilité de cette plante au niveau des ménages. Des ONG présentes à Madagascar, telles que Sun For Life, se sont impliquées dans la promotion de la plantation de MO dans les champs familiaux, notamment en milieu rural où la population est beaucoup plus pauvre. Leur but était de rendre les feuilles de MO facilement accessibles au même titre que les autres légumes feuilles et les autres ressources alimentaires destinées à l’auto-consommation. Cependant ces actions n’ont pas eu les résultats escomptés et et n’ont pas débouchées sur la plantation de MO. Nos résultats fournissent une explication possible de cet echec. La population rurale malgache, surtout pauvre, a tendance à prioriser plutôt la plantation d’aliments qu’elle juge comme étant rassasiants.

Afin de pouvoir réussir toute action promouvant la plantation de ressources alimentaires à fort potentiel nutritionnel, tel que le MO, il peut être, par exemple, proposé à ces ONG d’inclure dans leur programme une action de commercialisation des produits dérivés des autres parties de la plante. Par exemple, dans d’autres pays, plusieurs acteurs se sont lancés dans la fabrication des huiles de graines de MO (Tsaknis & Lalas, 2002). En effet, le

fait d'inclure un aspect commercial et une source de revenus potentiels est probablement plus motivant pour une population pauvre.

d) Association des feuilles de MO à un aliment de base habituel

Pour faciliter l'introduction des poudres de MO dans le répertoire alimentaire des Malgaches, elles doivent être mélangées à des aliments familiers, peu chers, disponibles, appréciés et rassasiants. Les aliments possédant ces critères peuvent être différents selon les régions considérées. Par exemple, pour le cas d'Antsiranana, les bananes plantains sont les plus consommées après le riz, d'après les données issues des groupes focus et d'enquête. Pour Antananarivo, les racines de manioc respectent ces critères. Les patates douces, le taro, le maïs… peuvent être aussi utilisés selon le lieu.

CONCLUSION GENERALE ET PERSPECTIVES

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Cette thèse a montré que la prévalence de la malnutrition à Madagascar peut diminuer si toutes les ressources alimentaires potentiellement nutritives, telles que les feuilles de MO, sont valorisées. Toutefois, pour que l'introduction de tels aliments dans le repertoire alimentaire de la population cible soit efficace, ceux-ci doivent être acceptés du point de vue sensoriel. Des optimisations de formulations sont nécessaires afin de pouvoir améliorer les qualités organoleptiques des produits formulés. Les optimisations au niveau de la flaveur ou de la texture peuvent être opérées, en ajoutant par exemple d'autres ingrédients dans la formulation. D'autres types de formulation destinée au commerce local, telles que les produits de biscuiterie ou de patisserie, comme dans les essais de Dachana, Jyotsna Rajiv, Indrani, & Prakash (2010) et de Owusu, Oduro, & Ellis (2011), sont aussi envisageables. Des proportions en MO plus élevées peuvent encore être testées afin d'obtenir un produit s'approchant davantage des apports nutritionnels recommandés. D'après nos calculs, si on incorpore 5% (m/m) de poudre de feuilles de MO dans un goûter de 200 g, cela participera environ à 13%, 23%, 15% et 6% des apports recommandés journaliers en protéines, calcium, magnésium et fer, respectivement, chez un enfant de 4-5 ans.

Actuellement, plusieurs ONG oeuvrent dans la promotion des feuilles de MO dans le cadre de l'aide nutritionnelle. Comme exemple d'ONG, on peut citer « Bel Avenir » (Toliara et Fianarantsoa), Sun For Life (Antsiranana). En termes de perspectives, il est envisageable de mettre en pratique les stratégies d'introduction du MO dans le repertoire alimentaire de la population afin de valoriser toutes les ressources alimentaires intéressantes du point de vue nutritionnel et disponibles à Madagascar. La même démarche est applicable dans d'autres pays touchés par le problème de la malnutrition.

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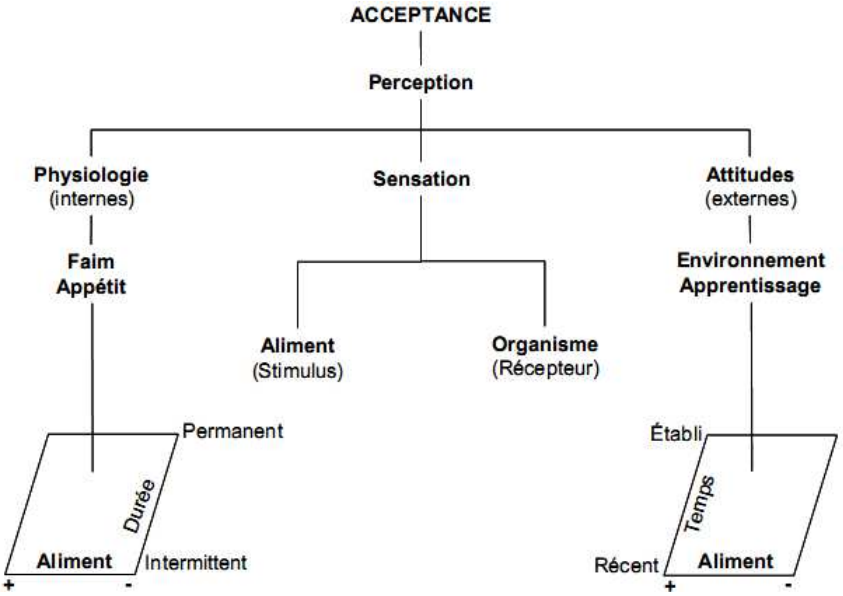
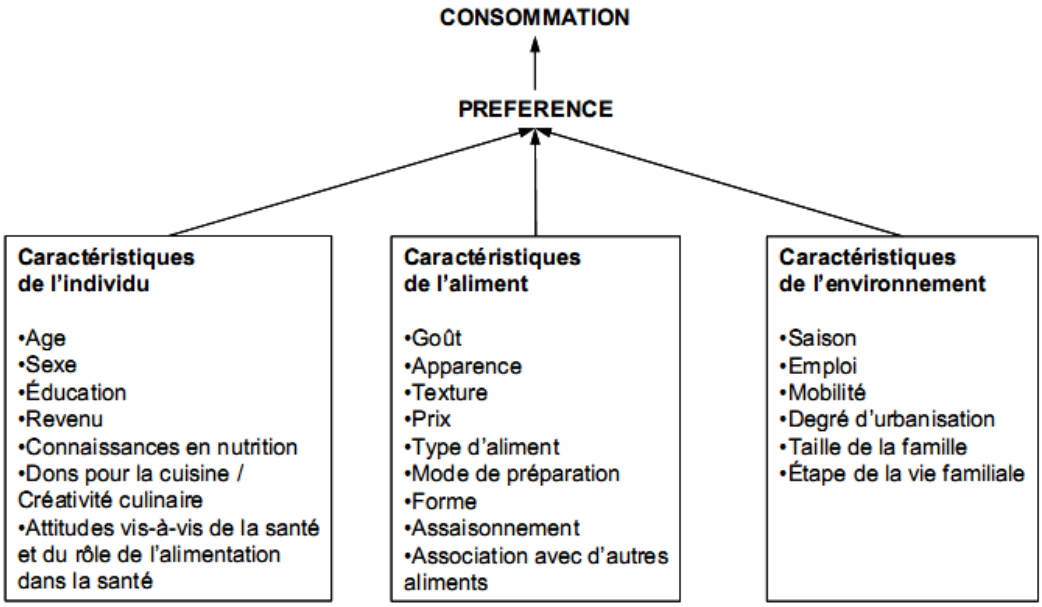
ANNEXES

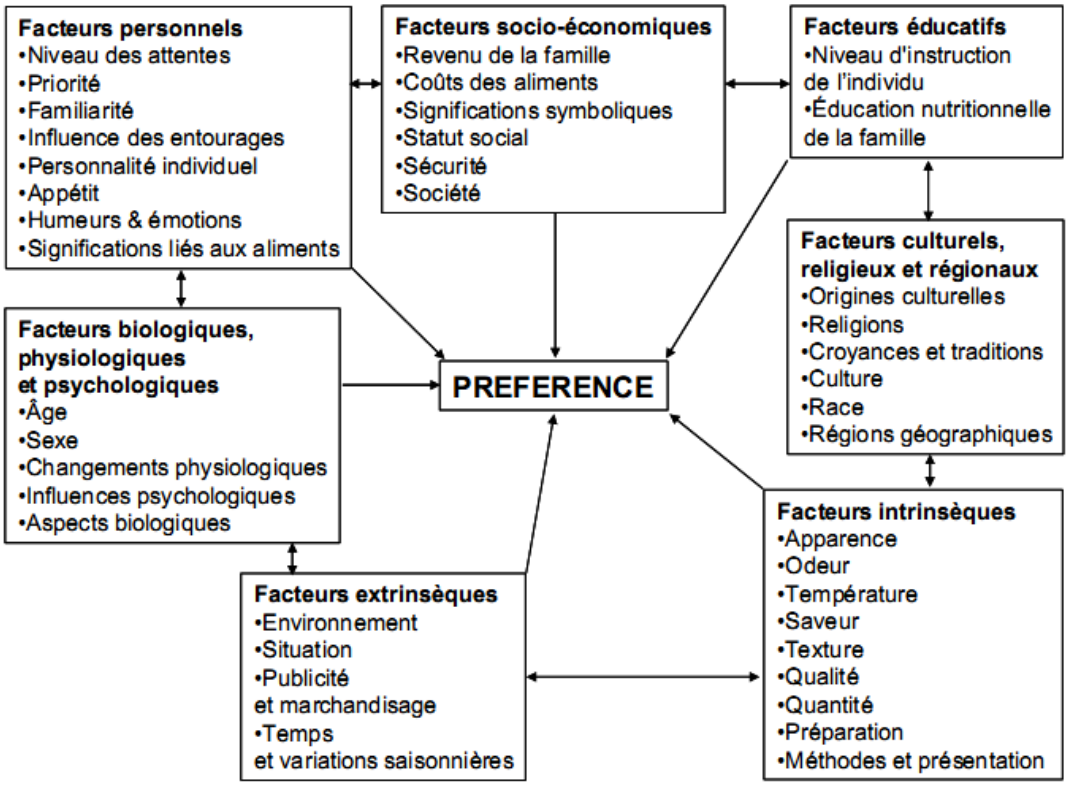
Annexe 1. Modèle de Pilgrim (1957)



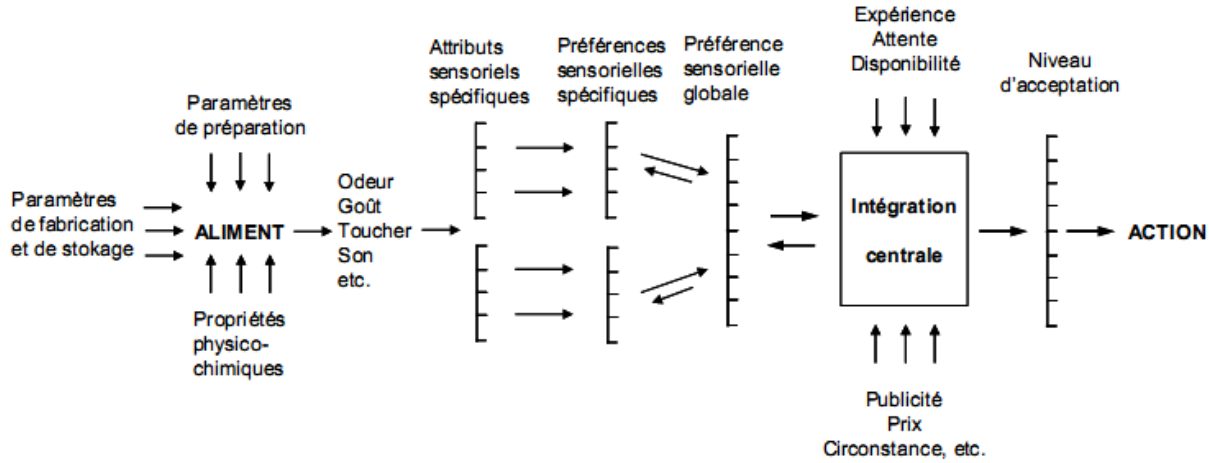
Annexe 2. Modèle de Randall et Sanjur (1981)



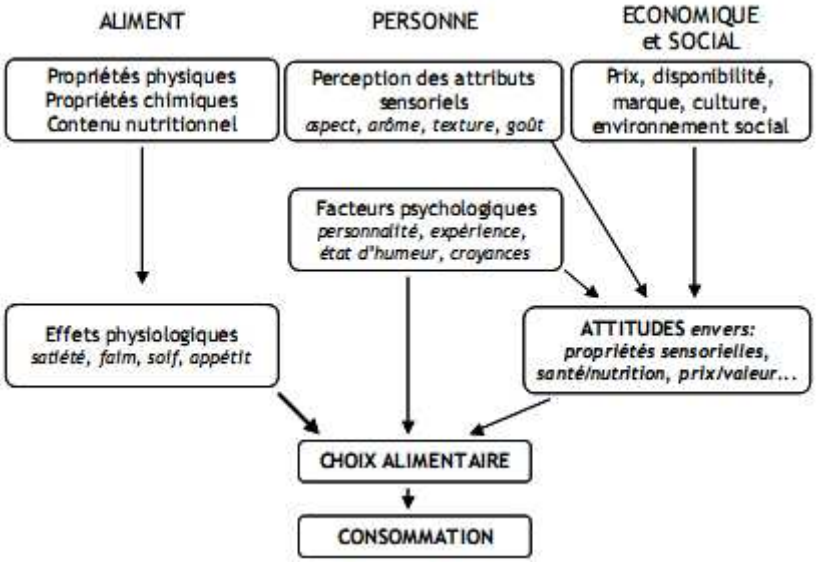
Annexe 3. Modèle de Khan (1981)



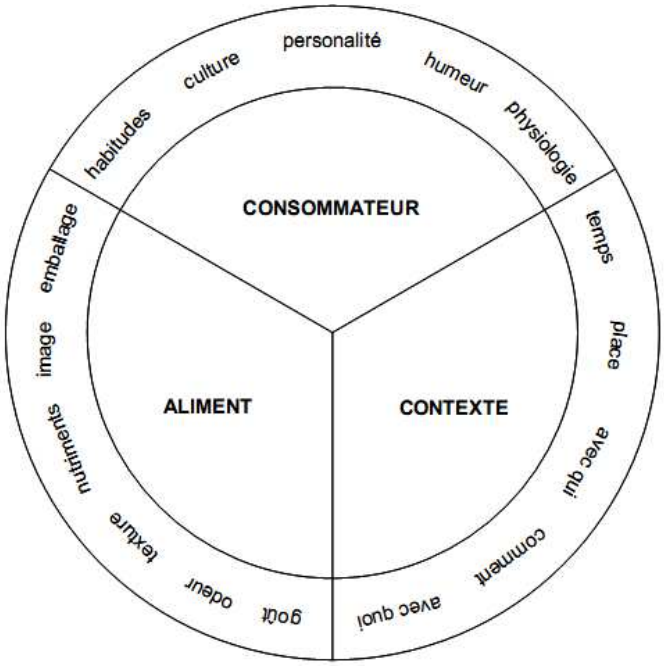
Annexe 4. Modèle de Land (1983)



Annexe 5. Modèle de Shepherd (1985)



Annexe 6. Modèle de Gains (1994)



Annexe 7. Résumé en anglais du poster A : "Bilingual panels: a tool to evaluate the role of language in descriptive tasks"

Cross cultural studies relating sensory profiles established in different countries suggest that part of the observed cultural differences might be due to language. Indeed, participants in cross cultural studies often have different food experiences as well as different languages and so the effects of language and cultures cannot be easily separated. A way to separate these effects is to work with bilingual assessors. Madagascar is a good candidate to perform such a study as two languages coexist in this country: Malagasy and French. Four flash profiles were performed to evaluate six samples of *Moringa oleifera* leaf powders: two in French and two in Malagasy. The descriptors generated by the four panels were classified in six categories: appearance, touch, odor, flavour, texture and sound; the frequencies of terms of each category were computed for each language condition. Chi-square tests failed to show any difference between the French and Malagasy groups. In both languages the appearance and taste terms were more frequent than the other terms, followed by odor, touch, texture and sound terms. However a qualitative analysis showed that the preciseness of the terms in a given category depended upon the language. Malagasy terminology was richer than the French one for several categories. Multiple factor analyses were then carried out to evaluate whether these qualitative differences in language led to different product maps. Higher between (0.85) than within language RV coefficients (0.78) were observed for the taste / odor descriptors categories. For the other descriptors no effect of language was observed on the positioning of the powders. This effect of language on the odor/taste category can be put in perspective with previous results showing a strong effect of culture on aroma descriptors (e.g. Tu el al., 2010) and suggest that such an influence might be due to language availability effects.

Annexe 8. Résumé en anglais du poster B : "Food choice factors in developing countries: The case of Madagascar"

Madagascar, a developing country, suffers from seasonal poverty. Although some natural resources exist, malnutrition problems continue to affect a large proportion of the population especially in rural areas. The main purpose of the study was to evaluate the effect of geographical and economical environments on food choice determinants in Madagascar. Focus group discussions and questionnaire surveys were carried out to investigate the representations of the concepts of eating and nutrition in four areas in Madagascar: Antananarivo urban (AU) and rural (AR), in the centre part of Madagascar, and Antsiranana urban (DU) and rural (DR), in the northern coast. In all areas 72 parents of schooled children participated in the focus groups and 1000 in the questionnaire surveys. Focus groups were conducted using a semi structured interview guide. Audio recordings of the groups were transcribed verbatim. Major themes and subthemes were identified, and representative quotes were selected. Questionnaires were analysed using chi square tests and correspondence analysis to emphasize the similarities or differences between areas. Price, diversity and health were the most important factors in overall households' food choice. Parents in AU and AR were more concerned by health, nutrients contents and cleanliness of foods, whereas children's liking was emphasized in DU, and in DR parents took more into account satiation, availability and habit. Differences between rural and urban areas were visible in Antsiranana but not in Antananarivo. These results underline the necessity to take into account the geographical and social environments into educational programs to valorise neglected high nutritious foods available in Madagascar.

Annexe 9. Résumé en anglais du poster C : " Paradox between malnutrition and nutritional richness of foods in Madagascar: the example of *Moringa oleifera* leaves"

Madagascar has two faces: a developing country with a high percentage of population under poverty scale, and a country rich in natural resources. Only few studies examined this paradox between malnutrition prevalence and food availability. In other developing countries *Moringa oleifera* (MO) was proposed as a potential solution for its high nutritional value. In Madagascar this plant grows in the wild.

The present research investigated why MO leaves are not part of Malagasy diet and how it could be introduce as daily food. A first study examined the actual nutritional composition of Malagasy MO leaves, and a second one the perceived nutritional value of these leaves by Malagasy people.

Results showed that the dried leaves are very rich on crude protein, essential fatty acids, calcium, magnesium and iron. In contrast, the consumption of MO leaves is scarce and their nutritional properties not known by the population. Differences were observed between population from Antsiranana (north) and Antananarivo (center). If, in Antananarivo, only 30% of the respondents consume these leaves, they associated them to a healthy food. But in the Antsiranana, where this plant is more available and 100% of the respondents have consumed it at least once, no spontaneous association with nutrition was observed. Moreover, the representation the respondents had of these leaves differed in rural and urban Antsiranana areas. In rural areas knowledge about the sensory properties of MO leaves and their cooking specificities were observed, whereas in urban areas MO leaves were not distinguished from other Malagasy leaves. This research showed that Malagasy people are not well informed about foods which are good nutritionally and easily available. The next step will be to find a way to introduce foods containing MO leaves in Malagasy food repertory and to convey a clear message on the nutritional properties of these leaves.

Annexe 10. Résumé en anglais du poster D : "Sensory acceptability of cassava snacks nutritionally enriched on *Moringa oleifera* leaf powder among children from low income households in Madagascar"

Ninety two percent of Malagasy population lives with less than two dollars per day. This situation contributes to undernourishment, particularly among children from low-income households: 48% of children under the age of five have stunting problem. Yet, Madagascar possesses natural food resources with high nutritional value, like leaves of *Moringa oleifera* (*M.o.*), rich on protein and different oligoelements. These natural food resources should be valorised by incorporating them into children diet, in order to help improving the balance of the diet and thus fight against malnutrition. In this study, *M.o.* leaf powder was added to cassava roots, which are consumed as a "security food", during lean period, when the harvests are exhausted and the price of food products increase. The obtained product was a snack targeted to schooled children. The objective was to determine if children would accept this new product. Four formulations were made: cassava alone, cassava with 0.6% of *M.o.*, cassava with 0.6% of *M.o.* and 10% of sugar, and cassava with 1.2% of *M.o.* and 10% of sugar. Two hundreds and twenty four schooled children, balanced over four locations (urban and rural areas of two regions: Antananarivo, where *M.o.* is not known by the population, and Antsiranana, where *M.o.* is known and consumed by the population), measured the acceptability of the snacks. The measure was made by using facial 7-points scale (1: disliked extremely, 4: nor disliked nor liked, 7: liked extremely). Results showed that the level of acceptability of *M.o.* by the children depended on region: cassava enriched by *M.o.* was better accepted in both Antsiranana rural and urban (acceptance score = 4.24-6.64), than in Antananarivo, where it was slightly disliked (acceptance score = 3.5 and 3.77 respectively in urban and rural area) when no sugar was added. Knowing that the snacks enriched on *M.o.* were accepted and liked by the children, and that they increased the protein and oligoelements intake, this study can help to formulate products with higher concentration of *M.o.*, in order to improve the nutritional status of Malagasy children from low-income households.

Annexe 11. Questions posées lors des discussions avec les groupes focus

Concept de la "Nutrition"et du goût

- ✓ *Si je vous dis « nutrition » qu'est-ce qui vient spontanément dans votre esprit?*
- ✓ *Et si je vous dit "goût"?*

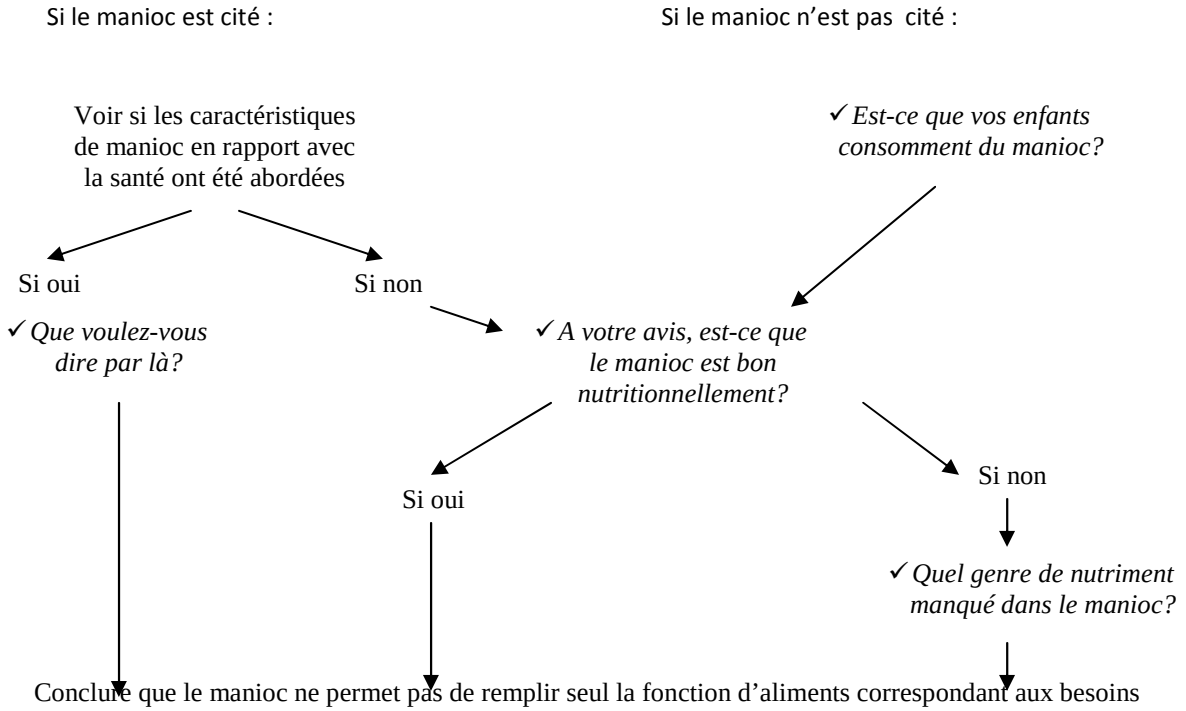
Critères de choix et habitude alimentaire

- ✓ *Si vous penser à votre alimentation, qu'est-ce qui est le plus important pour vous, le côté parce que votre corps en a besoin ou le côté parce que c'est bon en goût? donnez des exemples.*
- ✓ *Qu'est-ce qui est le plus important pour votre enfant? donnez des exemples.*
- ✓ *Quel genre d'aliments avez-vous l'habitude de manger?*
- ✓ *A quelle fréquence cet ou ces aliment(s) est/sont cuisiné(s) à la maison (dans la semaine ou dans un mois)?*
- ✓ *Quels critères sont pris en compte par la personne qui s'occupe de la préparation des aliments quand elle choisit les aliments à cuisiner ? donnez des exemples.*

Préference alimentaire des enfants et aliments recommandés

- ✓ *Parmi les aliments montrés dans les photos, lesquels sont les aliments habituellement consommés par vos enfants?*
- ✓ *Pour quelles raisons vont-ils choisir tel ou tel aliment ?*
- ✓ *Parmi ces aliments dans les photos, y a-t-il d'aliments que vous trouvez que vos enfants devraient privilégier alors que vous ne leur en donnez pas souvent ?*

Manioc



- ✓ *A votre avis, quels genres d'aliments peuvent être melangés au manioc pour former un aliment complet ou riche nutritionnellement?*

Manioc et Moringa ensemble

Si le Moringa est cité :

- ✓ *Pouvez-vous expliquer mieux pourquoi avez-vous citer Moringa ?*

Si le Moringa n'est pas cité, montrer la photo de Moringa et parler de la richesse des feuilles en nutriments :

- ✓ Pour vous, est-ce que ça vous direz de mélanger du manioc aux feuilles de Moringa ?

- ✓ *Imaginez-vous dans une situation où vous n'avez pas d'argent et qu'il n'y a rien d'autres à manger que du manioc et du Moringa. Vous êtes obligé de préparer un aliment nutritif pour vos enfants à partir de ces deux ingrédients. Comment allez-vous les cuisiner ?(rappelez-vous que cet aliment sera destiné à votre enfant).*
- ✓ *Selon la recette que vous avez pu créer, est-elle plutôt adaptée en tant que repas principal ou en tant que goûter ?*

Annexe 12. Questionnaire lors des enquêtes

Codes enquêteurs :_____Date de l'enquête :_____ N°questionnaire : ____ Lieu :_____ _____ 1

I. Connaissance des parents de la « nutrition » et du « goût »

Q1 : Pour vous, quels sont parmi ces adjectifs les 3 qui permettent de définir le mot « nutrition » ?

□ Cher □ Nutritif
□ Propre □ Bien cuit
□ Equilibré □ Délicieux
□ Rassasiant □ Autre : _____

Q2: Citez 3 aliments avec une bonne valeur nutritionnelle :

_____ _____ _____

Q3: D'après vous, quand vous faites les courses, quels sont les 3 critères les plus importants ?

□ Diversité □ Budget □ Disponibilité □ Ce que les enfants aiment
□ Ce qu'on a l'habitude d'acheter □ Santé

Q4 : Quand vous faites à manger aux enfants, quels sont les 3 critères les plus importants ?

□ Propreté □ Richesse en vitamines et calcium □ Rassasiement
□ Diversité □ Ce que les enfants aiment □ Apport d'energie

Q5: D'après vous, est-ce que ces aliments peuvent remplacer le riz en général?

		Prix	Disponibilité	Valeur nutritionnelle	Goût	Hafa
Maïs	□ oui □ non	□	□	□	□	
Fruit à pain	□ oui □ non	□	□	□	□	
Manioc	□ oui □ non	□	□	□	□	
Banane plantain	□ oui □ non	□	□	□	□	
Patate douce	□ oui □ non	□	□	□	□	
Taro	□ oui □ non	□	□	□	□	
Pâte	□ oui □ non	□	□	□	□	

Q6: Quelles sont, selon vous, les 3 caractéristiques du manioc ?

Apportant d'énergies et de vitamines	□
Rassasiant	□
Maux d'estomac	□
Saignement des dents	□
Décalcifiant	□
Diversifie le repas	□

Même question :

Pas bon goût	□
Pas cher	□
Plat occasionnel	□
Pas facile à trouver	□
Dépannant	□
Consomme du sucre	□

Q7: Plantez-vous du manioc ? □ oui □ non
Si oui, le mangez-vous? □ oui □ non

Q8: Avez-vous déjà: □ entendu parler de □ vu du □ mangé du *Moringa?*
Où l'avez-vous vu, si vous l'avez déjà vu ? □ bord des routes □ votre cour □ au marché
Quelle ville? □ Tamatave □ Antananarivo □ Diégo Suarez □ autre:_____
Si vous l'avez dans votre cours, □ *vous l'avez planté vous-même* □ ou il a déjà poussé tout seul?

Q9: Avez-vous déjà fabriqué de la poudre de Moringa ? □ oui □ non

Q10: Avez-vous déjà mangé la poudre de Moringa? □ oui □ non
Si oui, parmi ces ingrédients, quels sont les ingrédients que vous mélangez à la poudre de Moringa ?
□ *Riz* □ *Viande* □ *Brède* □ *Poisson* □ *Manioc*

Q11: Quelles sont, selon vous, les caractéristiques des feuilles de Moringa?

J'en ai besoin pour ma santé	□ oui □ non
Elles guérissent	□ oui □ non
Elles protègent des maladies	□ oui □ non
Elles apportent de nutriments	□ oui □ non
Elles ont une odeur forte	□ oui □ non
Elles ne doivent pas être cuites longtemps	
Elles ne sont pas différentes des autres brèdes	

1

Codes enquêteurs :_____Date de l'enquête :_____ N°questionnaire : ____ Lieu :_____ _____ 1

II. Pratique alimentaire des enfants :

Q12: Faites vous les plats de façon spéciale pour vos enfants ? □ oui □ non

Q13: Quels sont les 3 aliments préférés de vos enfants

_____ □ oui □ non
_____ □ oui □ non
_____ □ oui □ non

Q14: Est-ce ces aliments ont une bonne valeur nutritionnelle ?

II.1. Structure des repas

Petit-déjeuner

Q15 : Quels aliments sont consommés au petit déjeuner ?

	Jamais	Rarement (<2f/mois)	Souvent (>2f/mois)	Tous les jours
riz	□	□	□	□
brède	□	□	□	□
viande	□	□	□	□
poisson	□	□	□	□
beignet	□	□	□	□
lait	□	□	□	□
thé	□	□	□	□
café	□	□	□	□
pain	□	□	□	□
Tubercules/racines	□	□	□	□
autre :_____	□	□	□	□

Déjeuner

Q16: Contexte de la prise : □ A la maison □ à la cantine □ autre : _____

Q17: Quels aliments sont consommés au déjeuner ?

	Jamais	Rarement (<2f/mois)	Souvent (>2f/mois)	Tous les jours
riz	□	□	□	□
brède	□	□	□	□
viande	□	□	□	□
poisson	□	□	□	□
beignet	□	□	□	□
pain	□	□	□	□
Tubercules/racines	□	□	□	□
autre :_____	□	□	□	□

Goûter :

Q18: Fréquence de prise de goûter :

Matin				Après-midi			
Jamais	Rarement (<2f/mois)	Souvent (>2f/mois)	Tous les jours	Jamais	Rarement (<2f/mois)	Souvent (>2f/mois)	Tous les jours
□	□	□	□	□	□	□	□

Q19: D'où provient le goûter :

Matin			Apres-midi		
Parent	De la cantine	Enfant achète	Parent	De la cantine	Enfant achète

Q20: Quels aliments sont consommés en goûter?

	Jamais	Rarement (<2f/mois)	Souvent (>2f/mois)	Tous les jours

2

maïs	□	□	□	□
taro	□	□	□	□
beignet	□	□	□	□
« ramanonaka », « mofogasy »	□	□	□	□
pain	□	□	□	□
biscuit	□	□	□	□
Patate douce	□	□	□	□
manioc	□	□	□	□
autre :_____	□	□	□	□

Dîner :

Q21 : Quels aliments sont consommés au dîner ?

	Jamais	Rarement (<2f/mois)	Souvent (>2f/mois)	Tous les jours
riz	□	□	□	□
brède	□	□	□	□
viande	□	□	□	□
poisson	□	□	□	□
Tubercules/racines	□	□	□	□
autre :_____	□	□	□	□

II.2. Manioc

Q22 : Est-ce que vos enfants aiment le manioc? □ oui □ non

Q23: Fréquence de consommation? □ Jamais □ Rarement □ Souvent □ Tous les jours

Q24: A *quel moment dans la journée vos enfants consomment-ils le manioc le plus fréquemment?*
□ Goûter le matin □ Goûter dans l'après-midi □ Petit déjeuner □ Repas du midi □ Dîner

Q25: Parmi ces ingrédients, lesquels ajoutez-vous au manioc ?

	Jamais	Rarement (<2f/mois)	Souvent (>2f/mois)	Tous les jours
coco	□	□	□	□
sucre	□	□	□	□
sel	□	□	□	□
huile	□	□	□	□
cacahuette	□	□	□	□
brède	□	□	□	□
autre:_____	□	□	□	□

II.3. feuilles de Moringa

Q26: Est-ce que vos enfants aiment les feuilles de Moringa? □ oui □ non

Q27: Fréquence de consommation? □ Jamais □ Rarement □ Souvent □ Tous les jours

Q28: *A quel moment de la journée vos enfants consomment-ils les feuilles de Moringa le plus fréquemment?*
□ Goûter le matin □ Goûter dans l'après-midi □ Petit déjeuner □ Repas du midi □ Diner

Q29: Parmi ces ingrédients, lesquels ajoutez-vous aux feuilles de Moringa?

	Jamais	Rarement (<2f/mois)	Souvent (>2f/mois)	Tous les jours
coco	□	□	□	□
sucre	□	□	□	□
sel	□	□	□	□
huile	□	□	□	□
cacahuette	□	□	□	□
brède	□	□	□	□
autre:_____	□	□	□	□

Q30 : Vos enfants acceptent-ils facilement les nouveaux aliments ? □ oui □ non

Codes enquêteurs :_____Date de l'enquête :_____ N°questionnaire : ____ Lieu :_____ _____ 1

Q31 : *A votre avis pour faire apprendre à un enfant un aliment nouveau ?*
- □ Faire goûter plusieurs fois cet aliment
- □ Apprendre à l'école les bienfaits apportés par l'aliment nouveau
- □ Ajouter d'achard/rougaille à côté de l'aliment
- □ Donner les aliments à la cantine

III. Informations socio-démographiques:

Q32 : Sexe: □ homme □ femme

*Q33: Quartier de résidence :*_____

*Q34: Depuis combien d'années vous habitez là ?*_____ *Votre conjoint*_____

Q35: Où habitiez-vous avant ? _____ *Votre conjoint*_____

*Q36: Combien d'enfants sont en classe primaire sous la charge des parents ?*_____.

Q37: Votre niveau de scolarisation: □ niveau primaire □ niveau BEPC □ niveau BAC □ université

Q38: Nombre d'enfant dans le foyer ? _____

Q39: Vont-ils à l'école : □ publique □ privé ?

Q40: Quelles sont les activités du foyer ?
□ Agriculture □ Elevage □ Pêche □ Ouvrier □ Employé de maison □ Commerce de rue
□ Indépendant □ Salarié □ Cadre □ Activité saisonnier □ Autre :.....

Q41:Votre âge : □ moins de 25 ans □ 25 – 40 ans □ 41 – 55 ans □ 56 ans et plus

Q42: Revenue mensuelle du foyer:
□ Moins de Ar 50000 □ Ar 50000 – 100000 □Ar 100000 – 200000
□ Ar 200000 – 300000 □ Ar 300 000 – Ar 500 000 □ Plus de 500000

Annexe 13. Questionnaire lors du test hédonique

Date : …….. N° quest : …….
Lieu : …… Animateur : ……..

1/Test d'acceptabilité

Ech 1 ☐

Moins aimé Très aimé

(Boire de l'eau entre 2 échantillons)

Ech 2 ☐

Moins aimé Très aimé

(Boire de l'eau entre 2 échantillons)

Ech 3 ☐

Moins aimé Très aimé

(Boire de l'eau entre 2 échantillons)

Ech 4 ☐

Moins aimé Très aimé

2/ Informations socio-démographiques : entourer la réponse

Âge : ☐ < 7 ans ☐ 7-8 ans ☐ 9-10 ans ☐ 11-12 ans ☐ >12 ans

Sexe : garçon fille

Classe : ☐ <CP2 ☐ CP2 ☐CE ☐ CM1 ☐ CM2 ☐ Autre

3/ Test du choix : Ecrire le code de l'échantillon choisi : ☐

Annexe 14. Composition en macronutriments et en vitamines de feuilles de *Moringa oléifera* issues de différentes origines d'après la littérature (MS : Matière Sèche)

Auteur(s) et année	Type de feuilles analysées	Origine des Feuilles	Humidité (%)	Protéines totales (% de MS)	Lipides totaux (% de MS)	Glucides totaux (% de MS)	Cendres brutes ou minéraux (% de MS)	Vitamine A	Vitamine C (mg/ 100g de MS)
(Broin 2006)	Feuilles fraiches	*synthèse de plusieurs origines*		29 +/- 6	8± 2,5	38± 7 (dont fibre: 10± 3)	11± 2,2	15620± 6475 IU	773± 91
(Makkar and Becker 1997)	Feuilles fraiches	Nicaragua		26,4			8,87		
(Makkar and Becker 1996)	Feuilles sèches	Nicaragua		25,1					
(Sanchez 2006)	Feuilles fraiches	Nicaragua	83,6	17,8			10,76		
(Sánchez-Machado, Núñez-Gastélum et al. 2010)	Feuilles séchées à l'étuve	Mexique		22,42	4,96	27,05	14,6		
(Mohammed, Sarmiento-Franco et al. 2012)	Feuilles fraiches	Mexique	75	22,73					
(Zayed 2012)	Feuilles fraiches ou sèches	Egypte		entre 20 et 41					

	(paramètres: engrais bio)							
(Ndong, Wade et al. 2007)	Feuilles fraiches	Sénégale	73,57		4,95	28,60	2,42	
	Poudres de feuilles		4,53		7,85	35,33	11,39	
(Richter 2003)	Feuilles fraiches	Niger	93,8	25	10,6		8,4	
(Sena, VanderJagt et al. 1998)	Feuilles séchées au soleil	Niger		22,9				
(Amaglo, Bennett et al. 2010)	Feuilles	Ghana		28,1 et 29,4	5,04 et 7,21			
(Moyo, Masika et al. 2011)	Poudres de feuilles	South Africa	9,53	30,29	6,5		7,64	
(Shih, Chang et al. 2011)	Feuilles (d'hiver et d'été)	Taiwan		25,29 et 24,42	5,75 et 5,37		8,53 et 11	
(Kidmose, Yang et al. 2006)	Feuilles fraiches	Taiwan						B-carotène: 6630 µg/100g
(Ruby, Nathan et al. 2000)	Poudres de feuilles contaminées par *Cynopterus sphinx*	Inde		14,04	3	12,07		

Annexe 15. Composition en minéraux (en mg/g par rapport à la matière sèche) des feuilles de *Moringa oleifera* issues de différentes origines d'après la litterature

	(Broin 2006)	(Zayed 2012)	(Ndong, Wade et al. 2007)		(Anjorin, Ikokoh et al. 2010)	Becker & Makkar [non publié]			(Moyo, Masika et al. 2011)	(Shih, Chang et al. 2011)	(Barminas 1998)
Origine		Egypte	Sénégal		Nigeria	Nicaragua	India	Niger	Afrique du Sud	Taiwan	Nigéria
Type de feuilles		Feuilles fraiches ou sèches	Feuilles fraîche	Poudre de feuilles	(2 régions différentes)				Poudre de feuilles	Feuilles (d'hiver et d'été)	Feuilles séchées
Ca	1924± 288		423,19	1526,74	346,3 et 382,7	1750	2640	1390	3650	870 et 1862	2040,6
Mg	422± 52	3.112	97, 27	428,87	72,5 et 80,56	11	11	11	500		450,6
Fe	28± 6	0,8	21,72	18,86	4,1 et 7,88	58,2	17,5	34,7			28,7
P	267± 49	~25				1160	1360	1220	300		896,7
K	1384± 420	≤ 12	254,44	888,5		1910	2170	1840	1500		
Na			70,87	77,17		1160	2730	2610	164		
Cu	1± 0,2	0,003			4,4 et 4,3	1,12	0,71	1,06	0,81		1,3
Mn	8,4± 2,4	≤ 0,09				4,71	5,18	11,39	8,68		7,7
Zn	2,5± 0,6	≤ 0.078	1,13	2,13		1,35	1,37	2,42	3,1		25,5
S									630		

Annexe 16. Composition en acides aminés (en mg/g par rapport à la matière sèche) dans les feuilles de *Moringa oleifera* d'après la litterature

	(Makkar and Becker 1996)	(Sánchez-Machado, Núñez-Gastélum et al. 2010)	(Moyo, Masika et al. 2011)	(Freiberger 1998)	(Richter 2003)	(Sena, VanderJagt et al. 1998)
Origine	Nicaragua	Mexique	Afrique du Sud	Niger	Niger	Niger
Leucine	21,84	17,5±0,2	19,6±0,1	15,5	nd	20,5
Thréonine	11,7	7,9±0,4	13,57±1,24	7,09	8	10
Lysine	14,06	15,3±0,6	16,37±0,06	9,17	11	13
Tryptophane	5,27	nd	4,86±0,01	7,53	7	6,1
Phenylalanine	15,51	8,9±0,3	16,4±0,06	10,5	19	13,9
Tyrosine	9,71	4,8±0,9	26,5±0,15	8,33	nd	9,9
Valine	14,26	11,3±1,1	14,13±0,21	10,8	11	14,8
Methionine	4,97	1,4±0,3	2,97±0,06	2,34	6	3,3
Cystéine	3,39	nd	0,1±0	3,87	nd	3,3
Isoleucine	11,3	8,9±0,7	11,77±0,06	7,82	9	11,9
Histidine	7,5	7±0,4	7,16±0,06	3,78	6	5,1
Acide aspartique	22,16	15,8±1,5	14,3±0,45	12,8	nd	20,5
Acide glutamique	25,65	17,1±1,4	25,3±0,62	20,9	nd	28,4
Serine	10,34	9,4±0,5	10,87±0,35	7,19	nd	9,7
Glycine	13,73	10,3±0,7	15,33±0,6	8,38	nd	10,8
Alanine	18,37	12,5±0,6	30,33±0,06	11	nd	14,1
Proline	13,63	12,4±0,9	12,03±0,6	10,2	nd	14,3
Arginine	15,64	12,2±0,8	17,8±0,1	14,5	12	18,9

(nd : non determiné)

Annexe 17. Composition en acides gras (en % par rapport aux acides gras totaux) dans les feuilles de *Moringa oleifera* d'après la littérature

	(Sánchez-Machado, Núñez-Gastélum et al. 2010)	(Moyo, Masika et al. 2011)	(Amaglo, Bennett et al. 2010)	(Sena, VanderJagt et al. 1998)
C8:0	0.05±0.01	nd	nd	nd
C10:0	nd	0,07±0,064	nd	nd
C12:0	0.12±0.02	0,58±0,402	nd	0,38
C14:0	0.96±0.18	3,66±1,63	0,14	1,69
C14:1n-5	0.53±0.11	nd	nd	0,00
C16:0	23.28±1.38	11,79±0625	25,3	25,00
C16:1n-7	0.43±0.07	nd	0,55	2,54
C16:1n-9	nd	0,17±0,056		
C17:0	nd	3,19±0,155	0,25	0,00
C18:0	4.08±0.15	2,13±0,406	3,02	2,42
C18:1n-7	1.15±0.16	0,36±0,038	6,81	2,75
C18:1n-9	5.12±0.18	3,96±2		
C18:2n-6	6.11±0.83	7,44±0,014	11,4	8,47
C18:3n-3	56.87±1.57	44,57±2,803	50,8	56,36
C18:3n-6	nd	0,20±0,013		
C20:0	0.72±0.08	1,61±0,105	1,38	0,51
C20:1	nd	nd	0,28	nd
C20:4n-6	0.21±0.02	nd	nd	nd
C21:0	nd	14,41±0,194	nd	nd
C22:0	0.70±0.06	1,24±0,383	0,03	nd
C23:0	nd	0,66±0,025	nd	nd
C24:0	nd	2,91±0	0,03	nd
AGS	29.89±1.40	43,31±0,815	30,1	nd
AGMI	7.23±0.27	4,48±1,984	7,64	nd
AGPI	63.19±1.77	52,21±2,792	50,8	nd

(nd : non déterminé)

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Research report

Studying the nutritional beliefs and food practices of Malagasy school children parents. A contribution to the understanding of malnutrition in Madagascar ☆

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ABSTRACT

Madagascar is severely affected by the problem of children malnutrition. The present study aimed at exploring school children Malagasy parents' food practices and beliefs structures about the nutritional value of foods, to better understand the causes of this malnutrition. A combination of Focus Groups (72 participants), and questionnaires (1000 interviewees) was used to evaluate the food beliefs and the nutritional habits of low income parents of school age children in urban and rural areas of Antananarivo and Antsiranana. The respondents' beliefs were shown to focus not only on the nutrient and energetic composition of food, but also to involve more general relations between food and health and particularly the sanitary properties of food. Compared with such sanitary properties, nutrient content was not considered to be the priority in food choice and food preparation. The food category considered to be the most nutritive was cereals, ahead of protein foods, or vegetables and fruit. Nutritional beliefs were not the same in the Antananarivo and Antsiranana areas, nor between urban and rural areas of Antsiranana. Different socio-economic contexts, food availability and information may explain these differences. This study could guide actors involved in nutrition promotion to adapt to specific areas their nutrition programmes in the fight against malnutrition.

Introduction

Madagascar is a country of contradiction: on one hand, a developing country with a high percentage of its population under the poverty line, and on the other, a country rich in natural resources. Two thirds of the population live in rural areas, where the main activity is agriculture (Dostie, Haggblade, & Randriamamonjy, 2002). Like most developing countries, the island is severely affected by the problem of malnutrition, especially in rural areas (Devine, Connors, Sobal, & Bisogni, 2003; Smith, Ruel, & Ndiaye, 2005, WFP & UNICEF, 2011). The term malnutrition is used to refer to suboptimal nutritional health. This problem of malnutrition particularly affects children, with 45–50% of under-fives suffering from stunted growth (Fotso, 2006, WFP & UNICEF, 2011). Two anthropometric indices are commonly used to define children malnutrition: low height for age (stunting) and low weight for height (wasting). In 2008–2009, Madagascar had the sixth highest incidence of stunted growth in the world, according to UNICEF. Stunting is more prevalent in rural areas (prevalence of 48.7%) than in urban areas (WFP & UNICEF, 2011).

Fifty-three per cent of households in rural Madagascar have an insufficient consumption of nutritious foods to maintain an active and healthy life (WFP & UNICEF, 2011). The Malagasy diet is based mainly on rice, with an average consumption of 6.2 times a week, vegetables (4.4 times) and tubers (3.9 times), principally cassava. Proteins from vegetable and animal sources are rarely consumed (once and 2.3 times per week respectively) (WFP & UNICEF, 2011). Thus, the proportion of carbohydrates in the dietary energy supply is between 77% and 79%, which is high compared with recommended dietary allowance. Protein consumption is low: about 45 g per person per day, while theoretical needs are 56 g per person per day, and fat consumption extremely low: about 20 g per person per day (theoretical needs: 77 g per day) (FAO, 2005b). This chronic under-nutrition is worsened by seasonal poverty (the period between the two rice harvests), during which the caloric intake of poor rural households decreases by 12% (Dostie et al., 2002).

Food insecurity can result from insufficient food availability, distribution problems, the low purchasing power in poor households

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or inappropriate food consumption in families (FAO, 2005b). The Malagasy government has launched different nutritional policies and programmes to reduce malnutrition problems, but most funds have been attributed to a limited number of communities and policies have remained short term (MAEP, 2012).

Healthy and nutritive foods such as fruit, legumes or leaf vegetables are plentiful in Madagascar. It is not yet understood why these resources are not mainstays of the Malagasy food repertory, as they are available and relatively cheap. According to Rozin (1996), although nature provides a very large variety of products potentially rich in nutrients, only a small subset of these products is considered as food within any given culture. As summarized in Shepherd's food choice model (Shepherd & Raats, 1996), food choice is determined by three classes of factors: foods, individuals and external environment. The first class involves the sensory attributes and anticipated consequences of a food, for example whether it might be poisonous or, on the contrary, healthy. The second class of factors includes psychological factors such as mood or neophobia as well as physiological factors such as sensitivity to tastants. The third class of factors involves the economic and social environment and includes costs, availability of food products as well as social pressure. These three classes of factors interact with one another and are likely to be mediated by the beliefs and attitudes held by the individuals. Beliefs are the simplest form of mental representation (or mental construct) and are defined as a psychological state in which an individual holds a conjecture or premise to be true. They are thought to play a causal role in the production of behaviour. For example, beliefs about the nutritional benefits or harm in eating a food may be more important than the actual nutritional quality and health consequences in determining an individual's choice. When considering children, factors related to parents are also involved. As gatekeepers, parents influence children's food choices by setting rules, providing information, and modelling behaviours. In return, food preference communicated by children affects parents' food choices (Holsten, Deatrick, Kumanyika, Pinto-Martin, & Compher, 2012). While these factors have been widely studied in the context of industrialized countries, there have been very few studies aimed at understanding food choice in developing countries, especially in Madagascar.

The aim of the present study is to explore the school children Malagasy parents' food practices and beliefs structures about the nutritional value of foods, to better understand the causes of the children malnutrition. Our first hypothesis was that in Madagascar, children under-nutrition may be linked not only to general food availability but also to food practices yielded by parent's beliefs towards food nutritional values. Given the importance of environment reported in the literature, our second hypothesis was that parents' food practices and beliefs structures depend on geographical and social context.

To test these hypotheses we used a combination of Focus Groups and questionnaires. Focus Groups are typically used to elicit information and insights from small groups of participants representing the population under investigation (Dammann & Smith, 2010; Neumark-Sztainer, Story, Perry, & Casey, 1999). The questionnaire survey, although furnishing less information than the Focus Groups, is helpful in improving the generalization of results. The Focus Groups and questionnaires were conducted with parents of school age children in urban and rural areas of Antananarivo (AU and AR, respectively) and Antsiranana, also known as Diégo-Suarez (DU and DR, respectively). Antananarivo, the capital of Madagascar, is located in the central part of Madagascar, and is characterized by a heterogeneous population. Antsiranana, the seventh most populated urban area, is located on the northern coast of the island. The choice of these two locations was based on their differences in climate, rain failure and natural resources, resulting in different food availability. Economic status and ethnicity of the population also vary (MAEP, 2003a, 2003b), as well as the food intake typology of the population in the two provinces (Madagascar ISFP, 2008). Fifty per cent of under-five children are affected by chronic malnutrition at Antananarivo, compared with 37% at Diego (MAEP, 2012). Important differences exist also between rural and urban population in these two provinces (MAEP, 2003a, 2003b).

Materials and methods

Participants

Focus Group

Seventy-two parents (six to eight participants per group) of children enrolled in public primary school were recruited in three neighbourhoods (Ambatobe representing AU, Ambatolampy Tsimahafotsy representing AR and Labigorne representing DU) to participate in the discussions. The number of participants totalled 22 in AU (23 women and one man), 26 in AR (24 women and two men) and 24 in DU (23 women and one man).

The recruitment was carried out through the headmasters or teachers of the public primary schools to reach low income parents. Parents who had agreed to discuss the subject of "children's eating habits" took a screening interview. This selection step helped the investigators to balance chattier and less chatty participants in forming the discussion groups. The age range of the participants was between 19 and 62 years old. While the participant selection methods used here cannot be considered likely to yield representative data for the population as a whole, housewives, who are those most likely to be preparing food, comprise the largest proportion of the Focus Groups. Some participants occasionally worked on farms or as domestic help and a few were employed in unskilled jobs (e.g. manual worker in textile fields, selling vegetables). Only a few of them had been educated beyond primary school.

Questionnaire

The questionnaire was administered to 1000 parents (797 women and 206 men) of school age children from different social classes using a face-to-face interview-assisted technique in four different areas: 300 participants were interviewed in AU, 300 in AR, 200 in DU and 200 in DR. The difference between the Antananarivo and Antsiranana sites in the number of interviewees was related to differences in the total number of inhabitants in these two areas. The interviewees' characteristics are shown in Table 1.

To ensure even representation of each area, the questionnaire was administered in 24 neighbourhoods in AU, 18 in AR, 11 in DU and five in DR. Interviewees resided in the neighbourhood of the interviewing location. AR sites were located about 20 km from downtown Antananarivo, and DR sites were located about 20–50 km from downtown Antsiranana.

Procedure

Focus Group

Nine Focus Groups, three in each location, were held between March and July 2011 in a Focus Groups room for AU, and in classrooms for AR and DU. Each group discussion lasted from 75 to 90 minutes. The discussions were conducted by a moderator in participants' native language (the official Malagasy language for AU and AR and the north dialect for DU). The Focus Group procedure (planning, questioning and moderating) followed recommendations (Morgan, 1998).

At the beginning of the Focus Group discussion, participants were encouraged to participate actively in the discussion and to share their experience. It was explained to the participants that the discussion concerned their own ideas and that there was neither right nor wrong answers. The moderator informed participants that the con-

Table 1
Respondent characteristics in four areas.

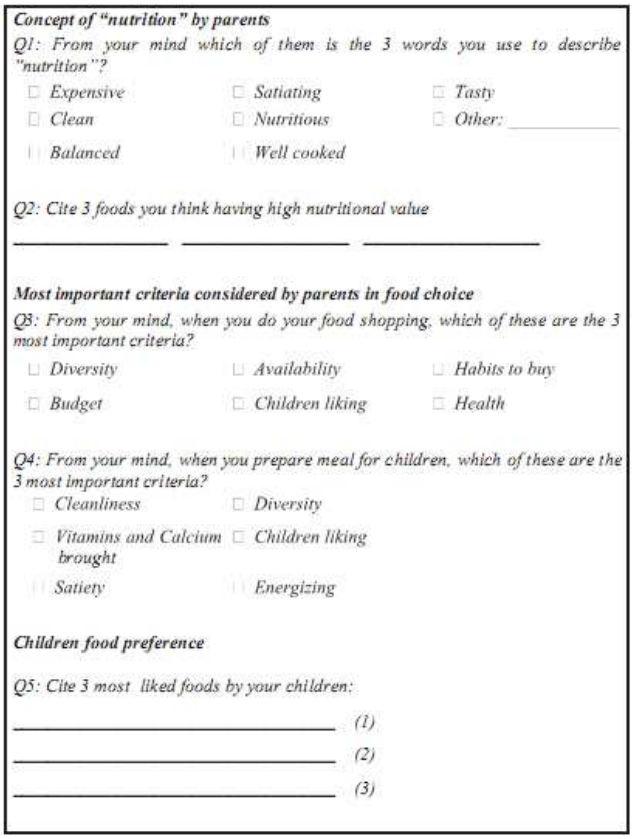
	Areas[a]			
	AU	AR	DU	DR
Age				
18–25 years old	16	29	37	12
26–40 years old	221	232	120	135
41–55 years old	60	36	36	39
>56 years old	27	3	7	14
Sex				
Men	95	65	10	33
Women	205	235	190	167
Education level				
Primary	86	135	21	48
Secondary	107	106	103	115
High school	84	44	54	36
University	23	13	22	1
Number of children in household				
1	34	48	37	14
2–3	196	166	115	94
4–5	61	71	37	71
6–8	9	15	8	15
>9	0	0	3	4
Number of children in primary school				
1	132	155	133	75
2–3	155	140	60	117
4–5	11	5	4	8
>6	2	0	3	0
Kind of school frequented by children				
Public	78	133	55	128
Private	222	167	145	72
Remunerative activities				
Agriculture	46	108	10	163
Farming	34	63	8	123
Fishing	1	8	1	0
Manual worker	9	45	14	5
Domestic work	17	14	34	9
"Road" salesman	157	146	64	47
Independent	104	92	43	30
Salaried	155	79	90	45
Executive	10	7	4	4
Hired man	9	55	2	10
Monthly household income				
<Ar 50,000 (<USD 22.04)	10	30	48	37
Ar 50,000–100,000 (USD 22.04–44.09)	53	113	50	51
Ar 100,000–200,000 (USD 44.09–88.17)	91	94	47	56
Ar 200,000–300,000 (USD 88.17–132.26)	85	28	18	41
Ar 300,000–500,000 (USD 132.26–220.43)	48	20	24	14
>Ar 500,000 (>USD 220.43)	13	14	13	1

[a] (AU, Antananarivo Urban; AR, Antananarivo Rural; DU, Antsiranana Urban; DR, Antsiranana Rural).

versation would be audio recorded but that the tapes would be used only in the framework of academic research and that participants would remain anonymous. Participants then briefly introduced themselves to break the ice.

To access the parents' food practices we first asked them a question on their habits (*what are the foods that you frequently consume?*) Then, to access parents' food beliefs structures, we used an association task in which participants were prompted with a stimulus word (nutrition) and were asked to indicate all the words that came to their minds (*What comes to your mind when I say nutrition?*). The free association task reflects the relative strength (measured by how many participants produced a given word) of automatic associations between concepts. The comparison between the terms generated in the four groups of participants gives some insights into the main beliefs associated with the nutritional value of food in the different areas of Madagascar.

Then we focused on participants' food choice criteria to evaluate the link between their implicit beliefs (association task) and the criteria they explicitly declare using when buying their food and


Concept of "nutrition" by parents
Q1: From your mind which of them is the 3 words you use to describe "nutrition"?
☐ Expensive ☐ Satiating ☐ Tasty
☐ Clean ☐ Nutritious ☐ Other: _____
☐ Balanced ☐ Well cooked

Q2: Cite 3 foods you think having high nutritional value
_____ _____ _____

Most important criteria considered by parents in food choice
Q3: From your mind, when you do your food shopping, which of these are the 3 most important criteria?
☐ Diversity ☐ Availability ☐ Habits to buy
☐ Budget ☐ Children liking ☐ Health

Q4: From your mind, when you prepare meal for children, which of these are the 3 most important criteria?
☐ Cleanliness ☐ Diversity
☐ Vitamins and Calcium brought ☐ Children liking
☐ Satiety ☐ Energizing

Children food preference
Q5: Cite 3 most liked foods by your children:
_____ (1)
_____ (2)
_____ (3)

Fig. 1. Questionnaire.

their children's food (*What are the most important criteria you use to decide what to eat? For you and your children?*).

Questionnaire

The Focus Groups allowed us to assess school children parents' food practices and beliefs structures about the nutritional value of foods. The beliefs structures and food practices that emerged from this technique were then validated using a close-ended questionnaire with a larger population.

The questionnaire was first elaborated in French as French was the common language among the researchers involved in the study, and then translated by the first author into the Malagasy language. To ensure that the original meaning had been maintained, the translation was verified by a bilingual person who was not involved in the conception of the questionnaire.

A pre-test was carried out with 40 interviewees. This first trial led to a reduction in the number of questions and to changes in the formulation of the questions. As a non-negligible proportion of the interviewees had difficulty reading, the interviewers had to read the questions aloud to them, which caused some memory problems in terms of the ranking questions. To avoid such problems, ranking questions were replaced by multiple choice questions in which interviewees had to select three items from among seven possibilities. The final version of the questionnaire consisted of three parts and included 31 main questions (29 close-ended, two open-ended questions) as well as 11 socio demographic questions. Only the questions related to food beliefs, food habits and socio demographic information are presented in this paper (Fig. 1).

Ten interviewers were recruited and trained to use identical questioning techniques. Each interview lasted for about 15 minutes.

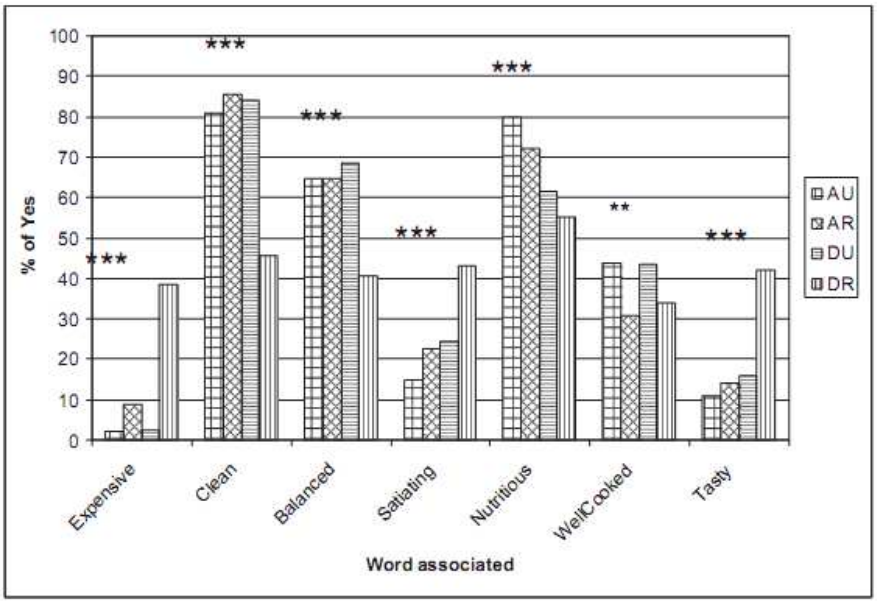


Fig. 2. Frequency distribution of terms given by participants related to the word "Nutrition" in four areas (**$p < 0.01$ and ***$p < 0.001$). (AU, Antananarivo Urban; AR, Antananarivo Rural; DU, Antsiranana Urban; DR, Antsiranana Rural).

Interviewees were encouraged to give responses related to their own experiences and were told that there was neither right nor wrong response.

All interviews were carried out in July 2011.

Data analysis

The audio-recorded discussions of all the Focus Groups were fully transcribed on the days after discussion. The moderator and the assistants independently analysed each transcription using the notes taken by the assistants to supplement the tape recordings. The results were then compared and adjusted after consensus had been reached.

Survey data were first analysed by compiling the frequency count for each question in each interviewing area (AU, AR, DU and DR). The effect of interviewing area was then tested using Pearson and McNemar's (χ^2) chi-square tests with an α risk set at 5%. A Bonferroni's correction was applied to correct the alpha inflation problem caused by multiple tests.

Finally, a Factorial Correspondence Analysis using SPAD version 5.5 (Coheris, France) was performed to visualize relationships among the questions.

Results

Results from Focus Groups and questionnaires are presented conjointly in order to avoid redundant information. Verbatim taken from the Focus Groups are used to explain the quantitative data obtained in the questionnaire. We start by presenting respondents' food practices and we follow with participants' food beliefs and food choice criteria.

Respondents' food practices

When asked to indicate the kind of food they eat, some Focus Groups participants declared that they ate three times a day (breakfast, lunch, dinner). They indicated that their diets were largely composed of rice – "*Especially rice, three times a day in our case*" – eaten *with "laoka", made up of vegetables or leafy-vegetables and possibly meat or fish on the days when there was enough money*". The questionnaire confirmed that rice is consumed everyday by 99% of the respondents, and even two or three times a day by some of them (68% and 27% respectively). Salads of raw vegetables and fruits as desserts were sometimes added: "*We make salad once a week; during the week just rice and laoka*". Breakfast varied depending on the habits of the households. For example, rice or other kinds of food were cited: "*In the morning we don't eat rice but just tea [infusion] and bread*".

Tubers like cassava roots in rural areas of Antananarivo, and plantain banana in Antsiranana, were most often cited after rice: "*For us [from the north coast], food that can replace rice might be: plantain banana with meat, with coconut. . . . Very tasty! It can replace rice*". This may be eaten instead of rice in a meal or as a snack between main meals.

Low-income parents' beliefs towards food nutritional value as a function of geographical origin (centre vs north) and urbanization (rural vs urban areas)

The words that were more frequently cited in the association task during the Focus Groups were "clean", "balanced", satiating", "nutritious", "well cooked", "tasty" and "expensive". The frequency of citation of these terms obtained via the questionnaire is shown in Fig. 2 as a function of the interviewing areas. A χ^2 analysis revealed an effect of interviewing area with the main difference appearing between DR and the three other areas. In DR, the seven items were almost equally cited with a proportion of citation of around 40%, except "Nutritious" which exceeded 50%. This finding should be interpreted with caution, however, as it might reflect either the fact that respondents in DR did not understand the question and answered randomly, or that they found all the items equally important.

In AU, AR and DU, the most frequently cited item was "Clean" (more than 80%), before "Nutritious" (between 61% and 80%) and "Balanced" (between 64% and 69%). A large number of participants related nutrition to hygienic concerns ("*Cleanliness*"). In

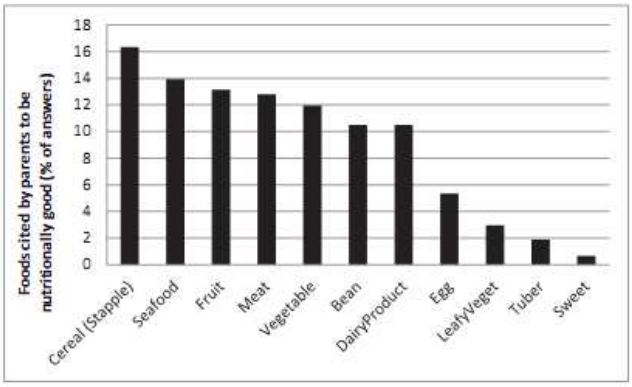


Fig. 3. Foods considered by parents as nutritionally good.

AU and AR, Focus Groups participants' discussions revealed how important cleanliness was in the handling, preparing and eating of foods. "*The most important aspect is cleanliness (. . .). When meals are served, the plates have been previously cleaned well, hands should be washed. . . that's cleanliness. . . Even during consumption, cleanliness is necessary*". In line with the importance of cleanliness "Well cooked" was cited by between 31% and 44% of interviewees in the three areas.

Qualitative aspects of foods (supply of important nutrients and "balanced") were also important. "Balanced" meals, which can be understood as a diversity of foods, were related to variety in nutrients: "*Changing menus corresponding to the six kinds of foods [carbohydrates, fats, proteins, water, vitamins and minerals]*". One way to obtain a balanced intake was to make a different meal each day: "*For me, the thing to do: when I do [cook] this one today I should not repeat it the next day if I can afford it.*" But some participants understood "balanced" in a different way: for them it corresponded to using the same ingredients in different recipes. "*Diversity is like that: with vegetables. . . I can buy for example vegetables every day, but I modify my way of cooking them*". "Satiating", "Tasty" and "Expensive" were the items cited the least frequently: between 16% and 24% in AU, between 11% and 16% in AR and between 2% and 9% in DU.

To further understand participants' food beliefs, we considered the three food products cited as being the most nutritive together, for each participant. Results indicate that a total of 86 food products were generated by participants in the questionnaire as being nutritive. The items most frequently cited as being nutritive were meat, fish and rice. The lists of foods produced by the parents were grouped into 11 categories (Fig. 3). Leafy vegetables and vegetables were separated into two different categories because leafy vegetables represent a specific category in the Malagasy food repertory. Among those categories, cereals were more often cited as nutritionally good (16% of the interviewees). This category includes rice, pasta, and maize. Rice was the most frequently cited food in this category. The second class included foods positioned in the middle: beans, dairy products, vegetables, meat, seafood and fruit.

The last class included categories which were spontaneously less cited as having high nutritional value by parents: sweets, tubers, leafy vegetables and eggs. Tubers, such as cassava roots, were considered as incomplete, judging from Focus Groups discussions: "*If cassava is eaten alone, it is not a healthy food. . . only if you prepare it by adding other ingredients.*" This category of food was identified by the respondents as lacking in certain nutrients. It may be surprising to find that eggs and leafy vegetables were as negatively judged as tubers and sweets. Indeed, eggs are the most complete source of amino acids and leafy vegetables are a source of vitamins, minerals and fibres.

Figure 4 presents the two first components of the correspondence analysis showing the categories of foods judged nutritive by parents in the four areas. Factor 1, which represents 56% of the variance, opposes the Antananarivo areas (AR and AU) to the rural Antsiranana area (DR). Rural Antsiranana households cited protein rich foods, and more particularly seafood, meat and eggs. Factor 2, which represents 27% of the variance, opposes the urban Antsiranana area (DU) to urban Antananarivo (AU). DU households more often cited vegetables as nutritionally sound foods, and less often beans, than households from other areas. In AR and AU, parents more often cited fruit, dairy products, tubers and staples as being nutritionally sound.

As no individual food can be considered to be nutritionally complete on its own, after having looked at individual foods, we explored the associations of foods cited by the respondents to evaluate whether their beliefs structures take into account this necessity of associating foods. To do that, cited food products were categorized into six groups, corresponding to the six classes of nutrients they contained (on the basis of the French food pyramid (Absolonne, Sirjacobs, Guggenbühl, & Colin, 1999): (1) products high in complex carbohydrates (cereals, legumes and tubers), (2) products with a high protein content (meat, seafood and eggs), (3) dairy products, (4) fruits/vegetables, (5) sweets, and (6) fats. Next, the number of groups corresponding to the three food products cited by each participant was determined (Table 2). The contingency table revealed a very significant link between areas and number of food groups ($p = 0.0003$). Respondents from rural areas, especially from DR, more often cited three foods belonging to the same group than interviewees from urban areas. Compared with other areas, respondents from AU cited more frequently foods from three groups.

Respondents' food choice criteria

In general, the mother of the family or the maid takes care of preparing food in Malagasy households. Shopping for food is a daily activity, due to the lack of refrigeration. Figure 5 shows the percentages of global citation of food purchase criteria when shopping and when preparing meals for children in the four areas. Considering food purchase criteria when shopping, "Price" was frequently cited (>80%). Monetary considerations were often mentioned during the Focus Group discussions; for example: "*I look at everything and the lowest price is the one I buy*". Most households interviewed cannot afford to buy certain categories of food like meats, except on the days when they receive their salary (once or twice a month): "*When we find a bit of money we buy a bit of meat, after work [temporary work]*".

"Health" and "Diversity" were frequently cited (more than 60%). Health may be interpreted either as related to a food's nutrient content or to its sanitary properties. In the Focus Groups discussions, health was related to food content. A mother said: "*For me, when I go shopping, I aim at making meals complete [nutritionally], which means providing energy and force for children, to make them healthy*". Another mother said: "*About vegetables, when we go to the doctor – we go to the doctor frequently – he always says that we should give children vegetables and fruits. If meals contain vegetables and fruits, for me it's alright*". "Availability" (about 40%), "Children liking" (30%) and "Habit of buying it" (about 15%) were the least frequently cited items.

In terms of food purchase criteria when preparing meals for children, "Cleanliness" was the most frequently cited item. Parents interviewed in Focus Groups discussions related that foods sold in small restaurants were not safe because they are very exposed to microbiological contamination. Consequently, parents preferred

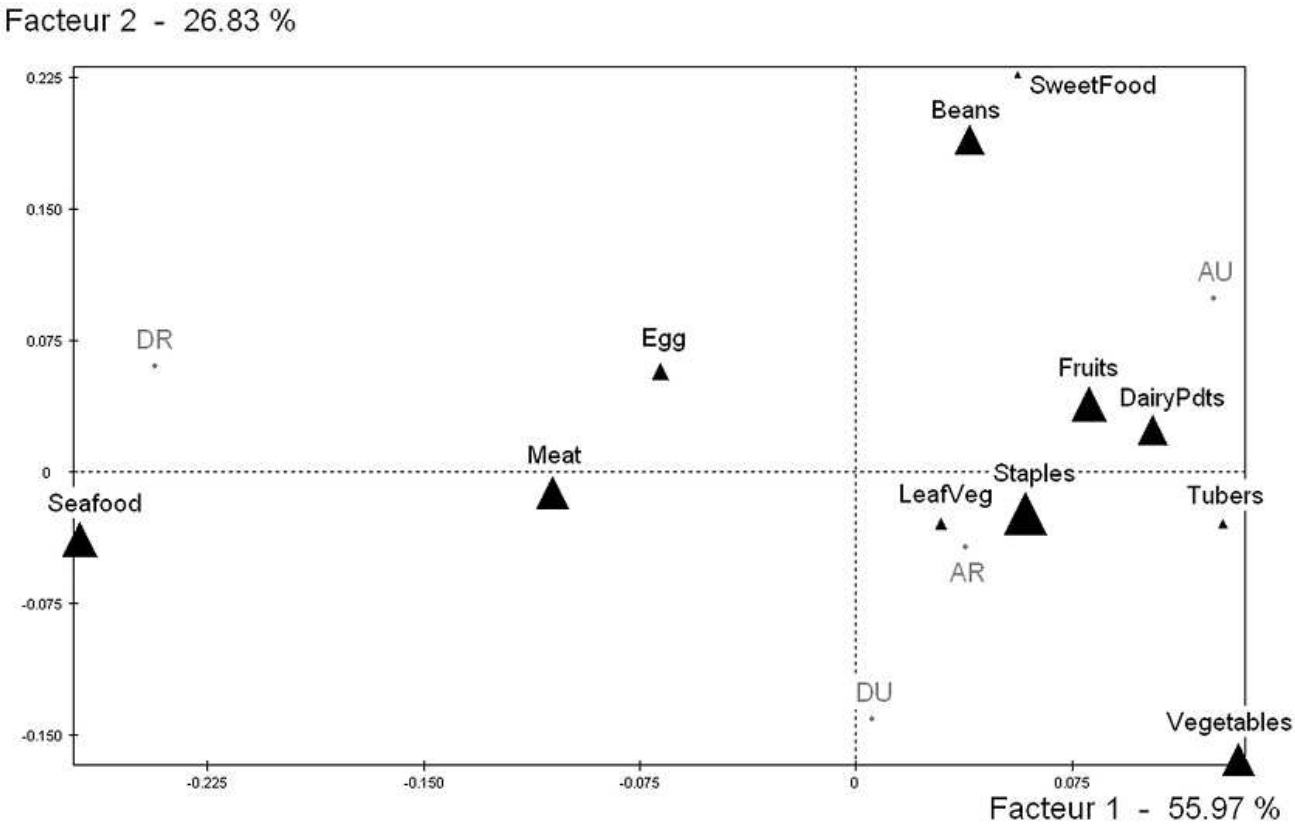


Fig. 4. Factorial analysis of categories of foods viewed as nutritious by parents in four areas (AU, Antananarivo Urban; AR, Antananarivo Rural; DU, Antsiranana Urban; DR, Antsiranana Rural).

preparing their meals themselves in order to control hygienic conditions during cooking. After "Cleanliness", food content in terms of vitamins and minerals ("Vitamins") and caloric content ("Energizing") were also frequently cited (>65%). "Satiety" and "Diversity" were cited by between 30% and 40% of parents. "Children liking" was the criterion least cited by parents.

Chi square calculation with Bonferroni correction (corrected $\alpha = 0.044$) revealed highly significant differences among the four areas concerning both food purchase criteria and food preparation. Figure 6 shows the first two components of the correspondence analysis carried out on the food purchase and meal preparation criteria by geographic area contingency table. The first dimension, which represents about 61% of the variance, opposes the Antsiranana areas to the Antananarivo areas. Participants from Antananarivo (AU and AR) seemed to use similar criteria and emphasized health concerns more ("Health", "Clean", "Vitamin and mineral contents", "Energizing") and "Children liking" (when shopping) than participants from the Antsiranana areas (DU and DR). The second dimension, which represents about 36% of the variance, opposes mostly DU participants who seemed to favour "Children liking" and "Diversity" (when preparing meals) to DR participants who seemed to rely more on "Availability", "Habit of Buying it" and the "Satiating" power of foods.

Table 2
Number of food groups considered by the interviewees as good nutritionally (expressed in percentages).

	AU	AR	DU	DR
Frequency of citation of foods belonging to only one group	5[a]	9[b]	5[a]	13[b]
Frequency of citation of foods belonging to two groups	51[a]	56[b]	61[c]	62[c]
Frequency of citation of foods belonging to three groups	44[c]	35[b]	34[b]	25[a]

[a–c] Chi-square results at a confidence level of 95%. Different letters in a row indicate that results are significantly different between areas.

Discussion

Our first hypothesis was that in Madagascar, children undernutrition may be linked not only to general food availability but also to food practices yielded by parents' beliefs. In agreement with this hypothesis, our study highlighted the role of parents' beliefs structures in children malnutrition. In all four areas, "cleanliness" was one of the words most closely related to the prompt "nutrition" in the association task and one of the most often cited criterion when preparing meals. It has been pointed out that in Madagascar, food contamination has serious health effects: the lack of hygiene, inadequate hand washing and ignorance of risk are at the origin of microbiological toxicity in Madagascar (Sarter & Sarter, 2012). Respondents were aware of the importance of this problem. This association between cleanliness and nutrition probably comes from the well-known synergy of malnutrition and infection as the leading cause of morbidity and mortality in developing countries. Indeed, malnutrition reduces resistance to infection and infection affects nutritional status (FAO, 1997). The importance of the belief that a nutritive food is a food that does not make you sick was shown to lead to food preparation habits detrimental to nutritional quality, such

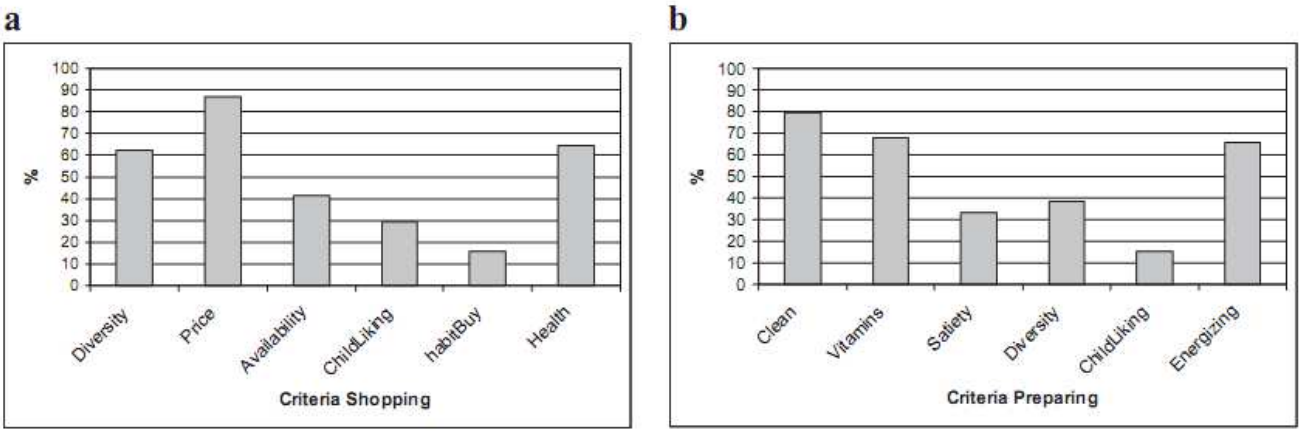


Fig. 5. Percentage of food purchase criteria considered by parents when shopping (a) and when preparing meals for children (b).

as overcooking foods. This was revealed in our study by the item "well cooked", which was chosen by 30–45% of the respondents in each area. It is well known that lengthy cooking decreases certain vitamin contents in foods; this is the case with vitamins C, B_1, B_2, B_5, B_8 and B_{12}. So, whatever the initial nutritional value of the foods eaten by the Malagasy population, the cooking process reduces available nutrients and tends to worsen nutrient deficiencies in the population.

The nutritional composition of foods seems to play the second role, after cleanliness, but before satiating potential, in Malagasy food beliefs structures. The fact that respondents did not particularly associate the satiating property of foods with the concept of nutrition, suggests that they believe that they have enough food to satisfy their hunger. Yet, Malagasy food supplies are considered to be hardly enough to cover the energetic needs of the population (FAO, 2005a) and for this study, the respondents were chosen among the poorest households in zones highly and moderately concerned by malnutrition. One explanation is that while not meeting energetic needs, Malagasy meals are nonetheless sufficiently satiating. This assumption is plausible because of the very high proportion of complex carbohydrates in Malagasy meals. Indeed, the products consumed the most are cereals and tubers, which are at once satiating and poor in energy and essential nutrients. In contrary, leafy vegetables, which are described in the literature as good sources of protein as well as some vitamins and minerals (Uusiku, Oelofse, Duodu, Bester, & Faber, 2010) and are not expensive and largely available in Madagascar were believed by parents to have a low nutritional value.

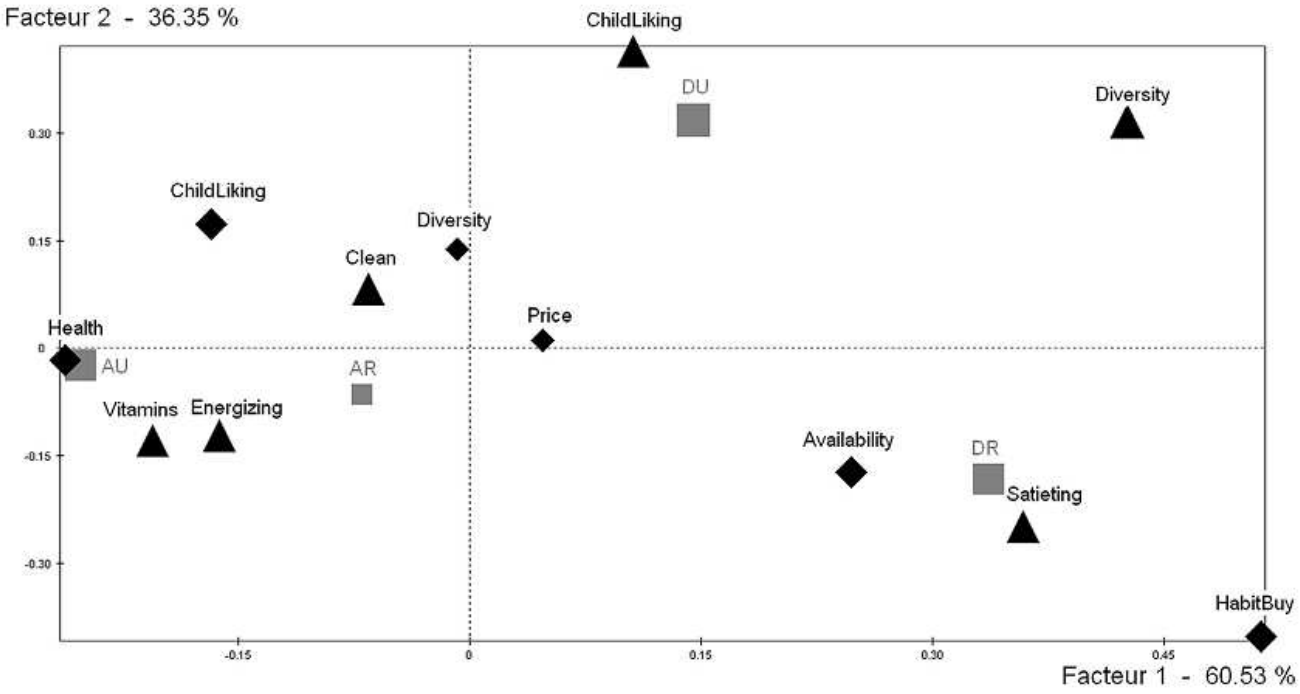


Fig. 6. Factorial analysis of food purchase in four areas when shopping (◆) and when preparing meals (▲). (AU, Antananarivo Urban; AR, Antananarivo Rural; DU, Antsiranana Urban; DR, Antsiranana Rural).

Our study also showed that school children Malagasy parents' beliefs led to food practices that could be linked to children malnutrition. Rice, which is central in Malagasy meals, was one of the foods most spontaneously cited by the respondents as being nutritionally valuable. It has previously been observed among poor households suffering from malnutrition that the diet consists predominantly of cereals, with very few "protective" foods like fruits, pulses and milk (Gopalan, 2000). In Madagascar, rice provides 53% of consumed energy and 50% of consumed proteins (FAO, 1993). The highest percentage of food expenditure is spent on rice (32% in 2010), followed by tubers (8%) (WFP & UNICEF, 2011). But this important cereal consumption does not cover nutritional needs, especially those of children. Indeed, among the major nutritional problems prevalent in rice-consuming countries, imbalanced dietary intake is the most important one. The protein content of rice is the lowest among the cereals. In combination with other factors, it leads to the prevalence of protein-energy malnutrition, iron deficiency, vitamin A deficiency and iodine deficiency disorders. This analysis is in agreement with the reports of NGOs which have observed that the highest occurrence of stunting is not among the very poor, as they eat the vegetables that they grow instead of selling them, and these are rich in nutrients. "The worst cases are those who can afford white rice" (IRIN, 2012).

However, beliefs towards food nutritional value are not the only food determinant. Our results showed that food availability can modulate the impact of beliefs on food practices. As an example, while most respondents believed that tubers are not good nutritionally, tubers are still widely consumed, depending on location. Food availability can explain this phenomenon. Indeed, previous work reported that tubers are consumed by poor households in the centre of the country between two rice harvests, for example, when they cannot afford to buy rice, (Dostie et al., 2002). During the lean season, the simple substitution of rice by cassava cannot provide balanced nutrients. Tubers and particularly cassava have extremely low protein content (less than 1%) (FAO, 1997). Thus, cassava is especially unsuitable as the main source of energy for young children. It also lacks lipids and certain vitamins and minerals. It seems thus that parents' food beliefs structures interacts with food availability to give rise to food practices that may lead to children undernutrition. Changing these food practices, and thus decrease the rate of children under-nutrition, would therefore require to act both at the level of food availability and of parents' beliefs.

Our second hypothesis was that parents' food practices and beliefs structures depend on geographical and social environment. In agreement with this hypothesis we observed some differences between the studied areas. The differences might be explained by food availability in the four areas. Antsiranana (north) and Antananarivo (centre) climate and geographical situation are different, resulting in different natural resources and food availability. Differences in economic status between the four areas may also be responsible for differences in access to food.

First, a difference between rural and urban areas of Antsiranana was observed. Among the four studied areas, urban area of Antsiranana is the wealthier, resulting in a higher availability of food products of different groups. In DU, children's liking a food was taken most often into account, as if people could afford to fulfil their children's expectations because their access to healthy food was higher than in the other three locations studied. On the contrary, the rural area of Antsiranana is poor, but it is a farming region, where crops are more available than animal products. As a result, DR respondents particularly valued meat and seafood as nutritive foods, compared with other areas. That is probably why they considered nutritive food to be expensive. DR respondents emphasized availability as a criterion of food choice, showing the diversities of situations concerning access to food from different groups. As a result of this limited access, satiating properties and diversity were more a source of preoccupation in DR than in other locations. When defining "nutrition", respondents in DR did not give as much importance to cleanliness as other respondents. This relative lack of concern for cleanliness could be due to the absence of household facilities in this area (having neither electricity nor running water), as well as a reduced education about sanitary properties of food. Thus, beliefs towards nutritional value of food are clearly different in DR and DU. Such differences between rural and urban areas were not observed at Antananarivo, probably for two reasons. First, in Antananarivo, the rural areas chosen for the study were closer to the urban areas (20 km) than in Antsiranana, where the nearest rural commune was 40 km away from the city. Secondly, in the capital (Antananarivo), rural migration is frequent, making the urban population quite similar to the rural one.

Differences were also observed between Antananarivo and Antsiranana. Despite the relative poverty of their region compared with Antsiranana, parents from Antananarivo seemed to be more sensitive to health concerns than parents from Antsiranana. This is probably due to the fact that in the capital there is more access to media and residents have higher levels of education than in the rest of the country. There are also more educational programmes devoted to food and nutrition than in the provinces, and this situation could be responsible for the differences observed between the centre and the northern areas in terms of beliefs towards food. In agreement with this interpretation parents in Antananarivo cited foods belonging to more classes than parents from Antsiranana, when asked to cite "nutritive foods", suggesting they knew more about nutrients contained in foods. As no individual food can be considered to be nutritionally complete, each answer highlights the nutrients that respondents consider to be important in a healthy diet. Respondents who only cite items belonging to a single group either do not know nutrients and cite current foods, or believe that particular nutrients are intrinsically good or bad. On the contrary, respondents who cite items from three different categories might know that particular nutrients are not intrinsically good or bad but that the key issue is to balance their meals. Another result in favour of the role of nutritional education in the capital is that parents from Antanaraviro cited foods frequently mentioned in nutritional education programmes while in the north (DU and DR) parents who have probably not received nutritional information cited foods which were familiar and/or locally available (e.g. seafood, tubers).

Conclusion

This study showed that current food practices in Madagascar are underlined by an interaction between food availability and food beliefs structures. Recommendations aiming at changing food practices to decrease children undernutrition must take into account these two factors. Nutritional information focusing on the complementarity between foods should be associated with the promotion of local production. These recommendations should be adapted to the geographical areas as we showed rural vs urban, as well as geographical, differences in both food availability and beliefs structures. Yet, this study focuses only on two areas of Madagascar and thus need to be extended to other areas to provide a wider picture of food practice and beliefs in Madagascar.

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