Appetite 95 (2015) 533–543

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

How to use local resources to fight malnutrition in Madagascar? A study combining a survey and a consumer test

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ARTICLE INFO

Article history:
Received 25 November 2014
Received in revised form
16 July 2015
Accepted 10 August 2015
Available online 18 August 2015

Keywords:
Moringa oleifera
Cassava
Madagascar
Children's food choices
Nutritional and health beliefs
Food practices

ABSTRACT

This study aimed to understand consumers' habits and belief structures concerning local food products and to develop a new snack as a way to fight against children malnutrition in Madagascar. A large variety of natural food resources grow in Madagascar, like *Moringa oleifera* (MO) which leaves are rich in nutrients but not consumed. First, a survey conducted in four areas of Madagascar revealed that MO leaves are known for their health benefits but infrequently consumed, probably because of their low satiating power and strong odor. In the studied areas, different levels of consumption were observed, which may be linked to varying levels of familiarity with MO by the local populations, this in turn resulting from different situations regarding geographical and historical availability. In contrary, resources such as cassava are perceived as having negative effects on health but are widely consumed because they are cheap, liked by children and satiating. The second step in the study aimed to propose products that could increase MO consumption without completely changing food practices. The acceptability of snacks associating cassava roots and MO was evaluated by means of hedonic tests performed by children. Between the snacks tested, the preferred snack contained the highest quantity of MO and was sweetened. There was no effect of area on the acceptance of the formulated snacks. This work is an evaluation of the potential of MO in the diet of malnourished population.

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 chronic malnutrition or stunting (FAO, FIDA, & et PAM, 2014), which can lead to increased mortality or lifelong serious damage, 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 arise for two reasons: geographic 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 the poorest households. Economic factors might explains part of this inaccessibility (Smith & Haddad, 2001), but are not the only factors involved. Ramakrishnan and Huffman (2008) observed that poor households in developing countries spend a large part of their income on carbohydrate-rich staple foods, and neglect foods which contain protein and micronutrients. Thus, limited access to food may result not only in insufficient quantities of food consumed, but also in imbalanced intake and poor dietary quality.

In Madagascar, however, poverty alone cannot explain the predominance of the consumption of carbohydrate-rich staple foods. Rice, for example, is not the cheapest carbohydrate staple food, yet it is the food most consumed by the 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 occasionally

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http://dx.doi.org/10.1016/j.appet.2015.08.011
0195-6663/

meat (Hardenbergh, 1997). During seasonal poverty (the period between the two rice harvests), the replacement of rice by cassava roots by poor rural households worsens the nutritional situation (Dostie, Haggblade, & Randriamamonjy, 2002). Cassava is the second staple food in terms of consumed quantities, after rice (Ballet & Randrianalijaona, 2011). Cassava roots contain a higher quantity of carbohydrates than rice but are poorer in other nutrients. Cassava roots are usually boiled and eaten alone, despite the fact that people are aware that these roots cannot fulfill nutritional needs (Ramaroson Rakotosamimanana et al., 2014).

This situation is one of the major underlying causes of protein-energy malnutrition. It thus 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 suffice. A better solution to improve the diets of children in developing countries would be to focus, not on specific nutrients, but on specific types of foods (Schroeder, 2008). To this end, commonly consumed staple foods could be combined 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 well in the Madagascar climate. It was introduced in the northern coastal areas of Madagascar, at the beginning of the twentieth century (Foidl et al. 2001). Its cultivation was first a privilege of the colonists. It did not spread to the central regions of the country until recently, when the National Office for Nutrition (ONN) heightened awareness in the population about its nutritional benefits (ONN., 2008). MO is widely eaten and highly valued in other countries like India, where numerous recipes contain MO leaves. Yet the consumption of these leaves is rather low in Madagascar. When they are consumed, they are probably prepared like other leafy vegetables, i.e. fresh leaves are fried in oil and added to water to prepare a stock used to cook rice and served with it (Chan Tat Chuen, 2010).

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 take precedence over all other determinants of food choice (Blaylock, Smallwood, Kassel, Variyam, & Aldrich, 1999; Glanz, Basil, Maibach, Goldberg, & Snyder, 1998). Availability and price are the elements which constitute the food acquisition power of a household. This must be distinguished from households' food acquisition behavior, that is, the desire to consume a particular food among multiple available and affordable foods. Studies conducted in developed countries have shown that persons of low socioeconomic status are generally less likely to consume healthy diets (Inglis, Ball, & Crawford, 2005, 2009). The financial cost of diets that comply with dietary guidelines has been formulated as one reason. Another explanation could be linked to knowledge about nutrition, 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, whereas local populations in the east have a preference for rice, migrants from northwest India retain their cultural preference for wheat and continue to favor it, even though it is more expensive than rice (Atkin, 2013).

In addition to economic and cultural factors, the sensations associated with the consumption of a food are important in explaining consumers' choices 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 leading 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, such 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 to 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 conducted by 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 carried out in developed countries. A limited number of these studies focused on low income populations (e.g. Burns, Cook, & Mavoa, 2013; Dressler & Smith, 2013) but none were dedicated in understanding food choices in developing countries. Yet such knowledge could help in fighting malnutrition by introducing new, healthy food habits.

The goal of this study was to evaluate whether knowledge about consumers' habits and representations of local food products could help introducing new food products to fight against malnutrition. Our approach was twofold. First, we designed a survey (study 1) aimed at understanding the practices and beliefs concerning the consumption of cassava roots and MO leaves on parents of Malagasy school age children in four areas (two rural and two urban areas), where food habits were previously shown to be different (Ramaroson Rakotosamimanana et al., 2014). We hypothesized that population habits, as well as products satiating properties and local availability, would be the highest determinants of cassava and MO consumption and would explain the differences in consumption of MO leaves among the areas. Secondly, we used the information collected in the survey to develop food products combining the sensory and satiating properties of cassava roots and the nutritional properties of MO leaves. For a better appropriation by consumers, our formulated products corresponded to existing practices. Three formulations containing MO and cassava roots and one formulation containing only cassava roots were evaluated by school age children via a hedonic test (study 2). We hypothesized that differences in MO availability among areas would induce different liking of snacks containing MO by children in these different areas.

2. Study 1: Survey on the practices and beliefs about the consumption of cassava roots and MO leaves by parents of Malagasy school age children

2.1. Materials and methods

2.1.1. Localisation

The study was conducted in urban and rural areas in two regions of Madagascar. Analamanga is located in the central part of Madagascar. Its principal city is Antananarivo, the capital of Madagascar, (2 million inhabitants in 2011), and is characterized by a heterogeneous population. Diana, the second region, is located in the northern coastal area. Its principal city is Antsiranana (105 000 inhabitants in 2008), mostly populated by two ethnic populations. Urban areas of Analamanga (AU) and Diana (DU) mentioned in this study correspond, respectively, to Antananarivo and Antsiranana. Rural areas of Analamanga (AR) were located about 20 km from downtown Antananarivo and rural areas of Diana (DR) were

Table 1
Characteristics of interviewed parents.

	Areas[a]			
	AU	AR	DU	DR
Number of respondents	300	300	200	200
Remunerative activities[b]				
Agriculture, farming, fishing	60	122	17	169
Manual worker, domestic work, "road" salesman, hired man	183	200	110	69
Independent	104	92	43	30
Salaried	165	86	94	49
Monthly household income				
<Ar 50,000 (<USD 22.04)	10 (3)	30 (10)	48 (24)	37 (18.5)
Ar 50,000–100,000 (USD22.04–44.09)	53 (18)	113 (38)	50 (25)	51 (27.5)
Ar 100,000–200,000 (USD 44.09–88.17)	91 (30)	94 (31)	47 (23,5)	56 (28)
Ar 200,000–300,000 (USD 88.17–132.26)	85 (28)	28 (9)	18 (9)	41 (20.5)
Ar 300,000–500,000 (USD132.26–220.43)	48 (16)	20 (7)	24 (12)	14 (7)
>Ar 500,000 (>USD220.43)	13 (4)	14 (5)	13 (6.5)	1 (0.5)

Numbers in parentheses are percentages of total responses per area. Other numbers are counts.
[a] (AU, Analamanga Urban; AR, Analamanga Rural; DU, Diana Urban; DR, Diana Rural).
[b] Total number of responses for "remunerative activities" is superior to number of respondents because interviewees could declare up to four activities, in accordance with the local situation, where people often cumulate paid jobs.

located about 20–50 km from Antsiranana.

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 in the number of interviewees recruited in the Analamanga and Diana sites was related to differences in the total number of inhabitants in these two areas.

2.1.3. Questionnaire

The questionnaire used in this study is part of a larger research project aimed at understanding the food practices and beliefs structures in parents of Malagasy school children. 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 elements 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 food practices and belief structures concerning cassava and MO in parents of school children, the following questions were inserted in the focus groups: "*What foods do your children eat frequently*?","*What do you think about the nutritional value of cassava roots?*" If respondents answered that the nutritional content of cassava was low, the next question was then "*What foods do you think can be added to cassava roots to make a nutritious meal*?". If respondents did not answer that the nutritional content of cassava was low, they were told that cassava had been shown to be nutritionally incomplete, before being asked the question. The next question was "*Can you cite some examples of leafy vegetables which can be added to cassava roots*?" If respondents mentioned Moringa then the following question was "*Do you have a specific reason for citing Moringa leaves*?" The last question was "*Do you think that it is possible to make a food made of cassava roots and Moringa leaves*?"

A thematic analysis of the focus groups was carried out and used to build the questionnaire. 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 was used to verify whether the questions and proposed answers were clear to the interviewees. It 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. Among the 31 questions, 13 were related to cassava roots and MO leaves. The aim of the first question was to determine which foods respondents consume when rice is not available or not affordable and the reasons why they select these products. A list of foods identified during the focus group as possible replacers of rice was provided to respondents (*maize, breadfruit, cassava roots, banana plantain, sweet potatoes, taro and pasta)*. For each of these products, respondents were asked "*Can this product replace rice?*" If their answer was "YES", respondents had to specify the principal reasons for this choice ("price", "availability", "nutritional value" and "taste").

The next series of questions was related to cassava. It started with a question aimed at determining the nature of knowledge and beliefs about cassava roots that had emerged from the focus group. This question was divided into two parts. In the first part respondents had to indicate "*Of the following, which are the three principal characteristics of cassava roots*"? ("contain energy and vitamins", "satiating", "cause some stomach upset" "cause teeth bleeding", "decalcifying", "allow to diversify meals"). These proposals were taken from the focus group verbatims related to health and the nutritional properties of cassava roots. We retained the original expressions in the questionnaire and have translated them literally into English in this article. In the second part respondents were again asked to indicate "*the three principal characteristics of cassava roots*" among the following items: "*not tasty*", "*affordable*", "*occasional meal*", "*not easy to find*", "*emergency food supply*", "*consume sugar*".[1] These items were again taken directly from the focus group. The following questions concerned respondents' practices: "*Do you plant cassava?*", ("yes"/"no"). If yes, *"Do you eat the cassava you plant?"* ("yes"/"no"). Then all respondents were probed on their consumption habits: *"In this list of ingredients, which ones do you add to cassava roots?"* (*"coconut"/"sugar"/"salt"/"oil"/"peanut"/"leafy vegetable")* and on their children's consumption patterns: "*Do your children like eating cassava roots?*" ("yes"/"no"); "How frequently do your children consume cassava roots?" ("never"/rarely"/"frequently"/"every day"); "When do your

[1] The expression « consume sugar » was taken literally from the focus group. It is a metaphoric expression that Malagasy people use to express the idea that eating cassava is not good for their health. It is difficult to translate in English but was meaningful for the participants.

children consume cassava roots?" ("snack in the afternoon "/" breakfast"/" lunch"/" dinner"). This question was skipped if the answer to the previous one was "never".

The remaining questions were related to *MO*. A first block of questions aimed at evaluating the respondents' familiarity with MO: "*Have you ever heard of Moringa leaves?*" ("yes"/"no"); "*Have you ever seen Moringa leaves?*" ("yes"/"no"), "*If yes, where have you seen them* ?" ("by the roadside or in neighbors' gardens"/"at the market or in a shop"/"in your garden") "*If you have it in your garden, did you plant it by yourself* ("yes"/"no"). The next block of questions was related to consumption patterns "*Have you (has your household) ever eaten Moringa leaves?*" ("yes"/"no"); "*Do your children like eating Moringa leaves?*" ("yes"/"no"); "How frequently do your children consume Moringa leaves?" ("never"/rarely"/"frequently"/"every day"); "When do your children consume Moringa leaves? ("snack in the afternoon "/" breakfast"/" lunch"/" diner"), "In this list of ingredients, which ones do you add to Moringa leaves?" A list of foods was provided to respondents ("*coconut*"/"*sugar*"/"*salt*"/"*oil*"/"*peanut*"/"*leafy vegetables*"). The last question in this series aimed at evaluating respondents' knowledge and beliefs about *MO*: "*, In your view, what are the characteristics of Moringa leaves?*": "You need them for your health"/"they cure"/"they protect from illness"/"they provide nutrients"/"they have a strong odor"/"they should not be cooked a long time"/"they are not different from other leafy vegetables".

Ten interviewers were recruited and trained to use identical questioning techniques. To complete the questionnaire, interviewees were helped by the interviewers who read the questions aloud to them. Each interview lasted for about 15 min. Interviewees were encouraged to give responses related to their own experiences and were told that there were neither right nor wrong responses. To ensure even representation of each area, the questionnaires were administered in 24 neighborhoods in AU, 18 in AR, 11 in DU and 5 in DR. Interviewees resided in the neighborhood of the interviewing location.

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 the α risk set at 0.05. Whenever a significant difference was found, the Marascuilo procedure (Marascuilo, 1966) was used to explain the difference.

2.2. Results

2.2.1. Cassava roots: practices and beliefs

When rice is not affordable, poor households replace it with cassava roots more often than richer households. Indeed, 41% of households with a monthly income of less than Ar 50 000 (about USD 22) declared replacing rice with cassava roots, versus only 17% of households with a monthly income of more than Ar 500 000 (about 220 USD) (data not shown).

As shown in Table 2, there is a clear effect of area on respondents' practices in terms of cassava plantation. Percentages of households which plant cassava in their familial field were higher in rural than in urban areas especially in the Diana areas (74.5% of respondents in DR vs. 9.5% in DU). In all areas, a large percentage of planted cassava is consumed by households (68.4%–96.8%, Table 2). Fig. 1 shows the ingredients most often associated with cassava by respondents in the four studied areas. A small number of respondents seem to consume cassava alone, since they indicated never associating cassava roots with the proposed items (46 in AR, 4 in AU and 1 in DU). The most frequently added ingredient is sugar (at least 77% of responses) followed by coconut (from 6% in AR to 47% in DR) and salt (from 5% in AU to 33.5% in DR). In contrast, it was not a frequent custom to add leafy vegetables, peanut or oil (less than 20% of respondents in all areas) to cassava roots. An effect of region is observed for the addition of coconut, salt and leafy vegetables, addition which were more frequent in Diana (DU and DR) than in Analamanga (AU and AR).

In all 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, $\chi^2 = 11{,}11$; $p < 0{,}05$). They also stated that their children ate them more often as a snack, especially in the afternoon (65–86%) 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, DU and DR. In AR, the consumption was balanced between "rarely" or "frequently" (more than two times per month) (Table 2). However, this result should be taken with caution because it is known that cassava consumption is mostly seasonal. It was probably difficult for respondents to estimate their mean consumption of cassava.

Fig. 2 shows the characteristics that parents associate with cassava roots. Among the items related to health, "decalcify" was the most cited in all locations. In the Analamanga urban area (AU), the three items related to negative health characteristics were the most cited ("decalcify", "stomach ache" and "teeth bleeding"). In the Analamanga rural area (AR), these three negative characteristics were also largely cited but "satiating" was in third position after "decalcify" and "stomach ache". In Diana (DU and DR), the second most cited item was "satiating". "Stomachache" and "teeth bleeding" were cited less often than in Analamanga, and less often by DR than by DU respondents. The items the least often cited in all areas (less than 30%) were "contain energy and vitamins" and "diversify meals".

As for items related to aspects other than health, cassava roots were principally considered to be an affordable and emergency food, in all four areas. In DR, "consume sugar" was more cited than in other areas. Cassava roots are more often consumed as an occasional meal in urban than in rural areas.

2.2.2. Moringa oleifera (MO) leaves: practices and beliefs

18% and 30% of respondents from AU and AR respectively were not familiar with MO, while almost all respondents from Diana were (Table 2). In Diana (DU and DR), MO was more often grown in the respondents' gardens than in Analamanga (AU and AR) (Fig. 3). About half of the Diana respondents (DU and DR) who had MO in their gardens had planted it themselves, versus 15% in AR and 25% in AU (Fig. 3). In AU and AR, respondents who had already seen MO had principally seen it in a place of purchase.

98.5% and 100% of respondents from DR and DU had already eaten MO, versus only 40% and 29% in Analamanga urban (AU) and rural (AR) respectively (Table 2). Respondents who had already eaten MO were asked if their children liked it. 79% and 70% of children who had already eaten MO liked it in AU and AR respectively, versus 91% and 96% in DU and DR respectively. Only 7% and 15% of the children who liked MO consumed it frequently or more in AU and AR, versus 78% and 57% in DR and DU respectively (Table 2). Thus, 2.3% and 3% of the children of all respondents ate MO frequently or more in AU and AR, versus 69% and 55% in DU and DR respectively.

MO leaves are mostly eaten salty (Fig. 4), particularly in Diana. In Analamanga households, respondents reported eating them with oil. 10%–20% of all households in the four areas ate *MO* with other leafy vegetables. The least frequently added ingredients were coconut, sugar and peanut. The large majority of respondents indicated that their children most frequently consumed MO leaves at lunch. Among children who had already eaten MO leaves, 79% and

Table 2
Response distribution concerning cassava and MO plantation and consumption, for parents of Malagasy school age children in the four studied areas (% of total responses)[a].

Question asked and possible answer	Response frequency in AU[b] (out of 300 responses)	Response frequency in AR[b] (out of 300 responses)	Response frequency in DU[b] (out of 200 responses)	Response frequency in DR[b] (out of 200 responses)	P value χ^2 test
Do you plant cassava?					
- Yes	31.7	51.7	9.5	74.5	<0.0001
- No	68.3	48.3	90.5	25.5	
If yes, do you eat the cassava planted?					
- Yes	86.3	96.8	68.4	86.6	0.000
- No	13.7	3.2	31.6	13.4	
How frequently do your children consume cassava roots?					
- Never	2.3	6.7	4.0	1.5	0.006
- Rarely	63	40.3	59.5	61.5	<0.0001
- Frequently	19.3	51.3	36.5	36.5	<0.0001
- Every day	3	1.7	0	0.5	0.029
Have you ever heard of Moringa leaves?					
- Yes	82.0	70.3	98.5	100	<0.0001
- No	18.0	29.7	1.5	0	
Have you ever seen Moringa leaves?					
- Yes	58.042.0	42.357.7	98.51.5	1000	<0.0001
- No					
Have you ever eaten Moringa leaves?					
- Yes	40.0	28.7	98.5	100	<0.0001
- No	60.0	71.3	1.5	0	
Do your children like eating Moringa leaves? *(asked only to those who have already eaten MO leaves. 120 answers in AU, 86 in AR, 197 in DU, 200 in DR):*					
- Yes	79.2	69.8	90.9	96	<0.0001
- No	20.8	30.2	9.1	4	
How frequently do your children consume Moringa leaves *(asked only to those whose children like MO. 95 answers in AU, 60 in AR, 179 in DU, 192 in DR):*					
- Never	0	0	0	0	–
- Rarely	92.7	85	21.9	42.7	<0.0001
- Frequently	7.3	15	73	57.3	<0.0001
- every day	0	0	5.1	0	0.000
When do your children consume Moringa leaves? *(asked only to those whose children like MO. 95 answers in AU, 60 in AR, 179 in DU, 192 in DR):*					
-Breakfast	1	5	1.1	1.6	0.214
- Snack (morning)	0	0	0	0	–
- Lunch	86.3	60	94.4	98.4	<0.0001
- Snack (afternoon)	1	0	3.4	0	0.028
- Dinner	15.8	40	5.6	0.5	<0.0001

[a] Except for the three last questions, where the number of answers is specified.
[b] AU: Analamanga urban; AR: Analamanga rural; DU: Diana urban; DR: Diana rural.

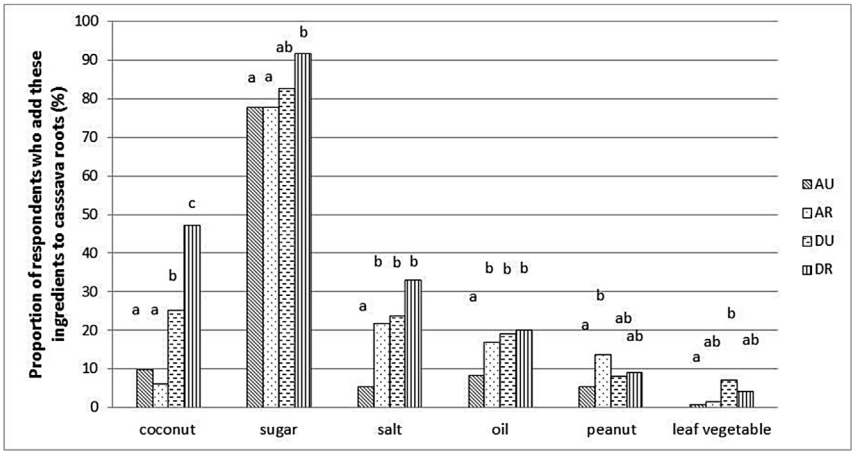

Fig. 1. Ingredients consumed frequently or daily with cassava roots by parents of Malagasy school age children, in the four studied areas (AU: Analamanga, urban, AR: Analamanga, rural, DU: Diana, urban and DR: Diana, rural). For each ingredient, when adjusted χ^2 test results (α risk: 0.05) showed a difference between the four areas, the Marascuilo procedure was used to compare areas. The areas noted with the same letter (a–c) are not significantly different at a confidence level of 95%.

70% in AU and AR liked it compared to 91% and 96% in DU and DR respectively.

Fig. 5 shows the characteristics parents associated with MO leaves. The characteristic "provide nutrients" was cited equally in the four areas. Health related characteristics were more often cited by urban than by rural respondents and more often in Diana than in Analamanga. In AR, the health related properties of MO were less well known than in other areas, and respondents from DR more likely to consider MO leaves as being identical to other leafy vegetables. Results related to the sensory and culinary properties of MO leaves were cited mostly by respondents from Diana, confirming they had more knowledge about MO leaves than those from Analamanga.

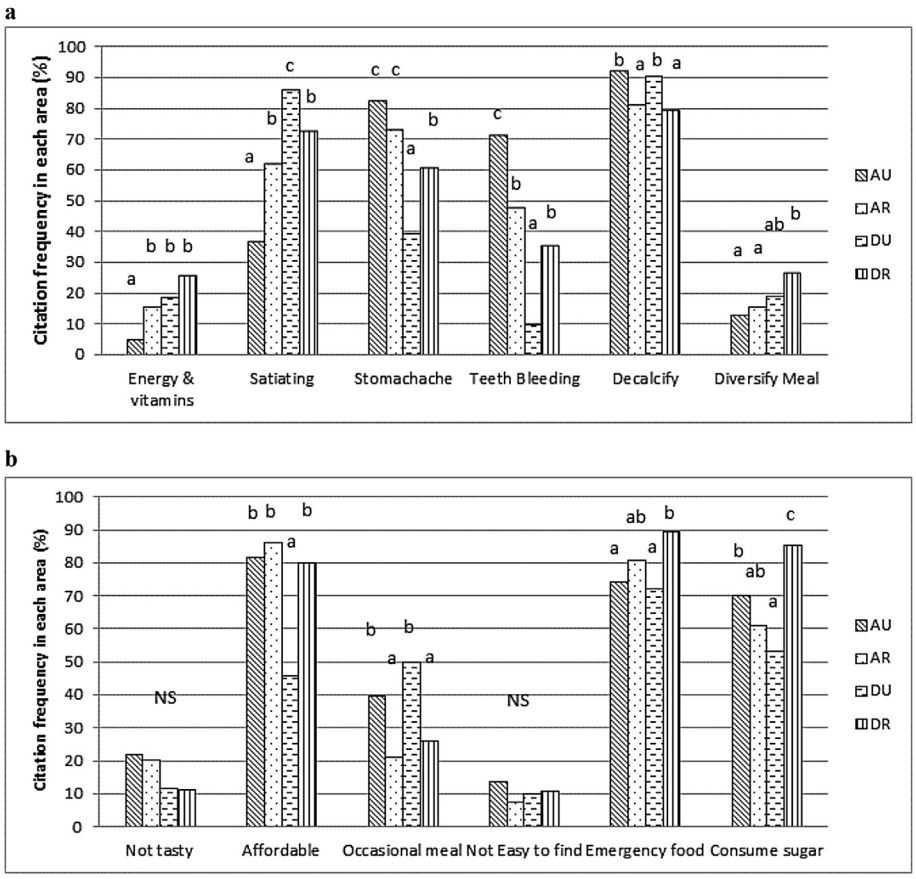

Fig. 2. Principal characteristics of cassava roots according to parents of Malagasy school age children, in the four studied areas (AU: Analamanga, urban, AR: Analamanga, rural, DU: Diana, urban and DR: Diana, rural). a: characteristics related to nutrition and health, b: characteristics related to other aspects. For each ingredient, adjusted χ^2 test results (α risk: 0.05) are indicated as following: NS: no significant difference between the four areas. When χ^2 test results showed a difference between the four areas, the Marascuilo procedure was used to compare areas. The areas noted with the same letter (a–c) are not significantly different at a confidence level of 95%.

2.3. Discussion

On the one hand, cassava was considered by respondents as having a negative impact on health, but was consumed in relatively large quantities. In three of the studied areas, at least one respondent out of every three indicated that his/her children consumed it "frequently" or "often". However, the mean consumption frequency declared by parents must be taken with caution, because it

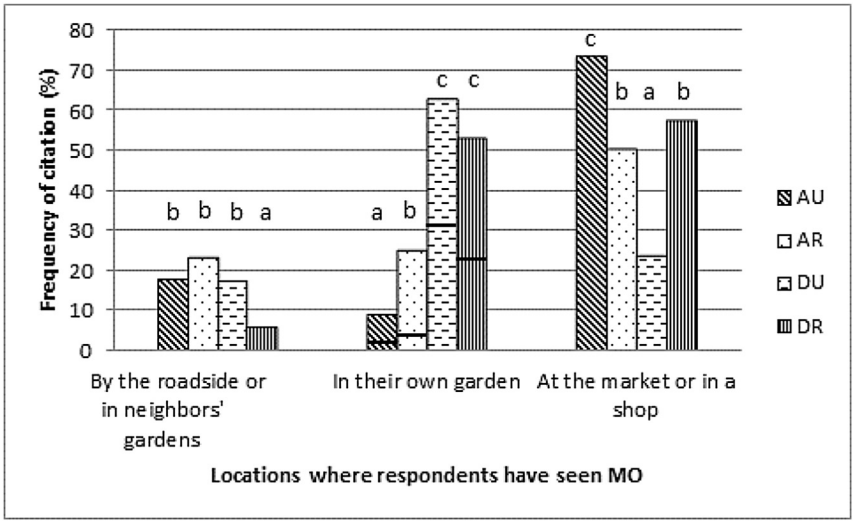

Fig. 3. Locations where respondents had seen Moringa oleifera (MO), in the four studied areas (Analamanga urbain (AU), Analamanga rural (AR), Diana urbain (DU) and Diana urbain (DU)). Respondents to this question were only those who had already seen MO (174 in AU, 127 in AR, 197 in DU and 200 in DR). In the bars corresponding to "in their own garden", the proportion of respondents who had planted MO in their gardens themselves is indicated by black horizontal lines. For each location, the areas noted with the same letter (a–c) are not significantly different at a confidence level of 95%.

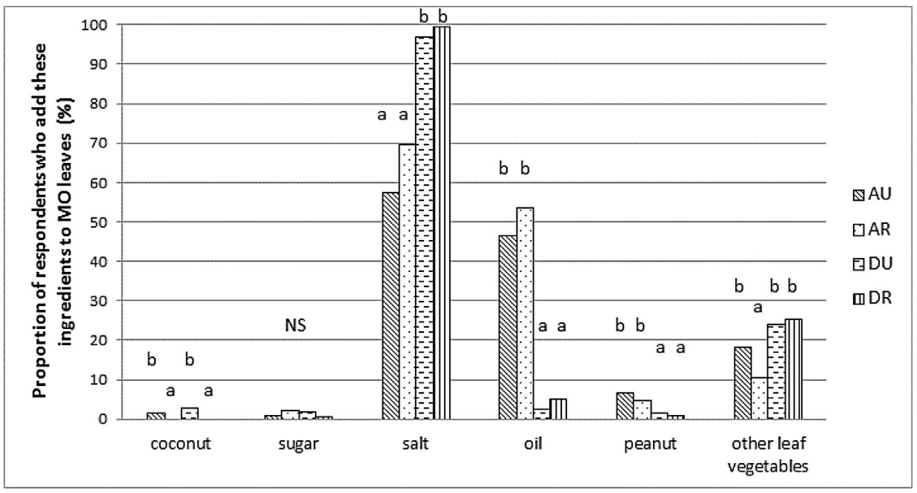

Fig. 4. Ingredients consumed with MO leaves according to respondents in the four studied areas (AU: Analamanga, urban, AR: Analamanga, rural, DU: Diana, urban and DR: Diana, rural). Respondents to this question were only those who had already eaten MO (120 in AU, 86 in AR, 197 in DU and 200 in DR). For each ingredient, adjusted χ^2 test results (α risk: 0.05) are indicated as following: NS: no significant difference between the four areas. When χ^2 test results showed a difference between the four areas, the Marascuilo procedure was used to compare areas. The areas noted with the same letter (a–b) are not significantly different at a confidence level of 95%.

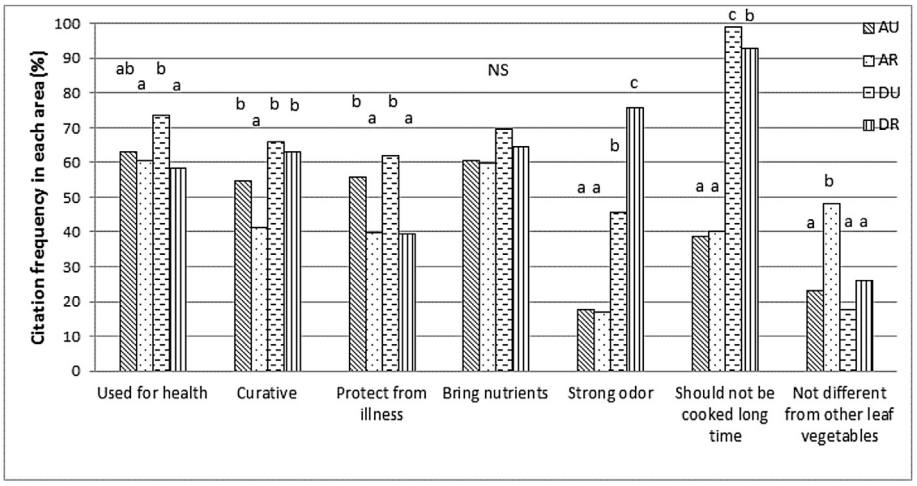

Fig. 5. Principal characteristics of Moringa oleifera according to parents of Malagasy school age children, in the four studied areas (AU: Analamanga, urban, AR: Analamanga, rural, DU: Diana, urban and DR: Diana, rural). Respondents to this question were only those who had already heard about MO (246 people in AU, 211 in AR, 197 in DU, 200 in DR). For each ingredient, adjusted χ^2 test results (α risk: 0.05) are indicated as following: NS: no significant difference between the four areas. When χ^2 test results showed a difference between the four areas, the Marascuilo procedure was used to compare areas. The areas noted with the same letter (a–c) are not significantly different at a confidence level of 95%.

probably does not reflect a regular consumption. Indeed, cassava is recognized to be a "shock absorber" food for less advantaged households, where it is mostly consumed during the lean period, when rice is not affordable (Dostie, Randriamamonjy, & Rabesolo, 1999). During this period, if each portion of rice was replaced by a portion of cassava, the consumption of cassava would be two or three portions a day. FAO has 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 Analamanga. It was consumed more frequently by Diana children. This discrepancy between the relatively large consumption of cassava despite its negative health effects and the limited consumption of MO despites its positive health effects can be explained in terms 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 of food acquisition. It depends either on the local growing of the food or its presence on the local market. Respondents consumed cassava with similar frequencies in the four studied areas. The growing of cassava in gardens was widespread in the two rural areas, where the availability of varied food in markets may be more limited than in urban areas, showing that cassava was readily available for the entire studied population. This finding is in accordance with the easy availability of cassava observed in Madagascar: 2,366,250 tons in 2002 according to data from the Agricultural ministry of Madagascar (MAEP, 2004). This criterion could favor the widespread consumption of cassava despite its poor nutritional properties: 157 g per person per day in Antananarivo and 48 g per person per day in Antsiranana (Dostie et al., 1999). Concerning MO, the situation was quite different. As expected, it was not only more frequently consumed but also better known in the northern 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 of its consumption, but our results show that the reverse is not always true: an available product can be neglected as a food. This was observed in the case of MO which is available in AU but not frequently consumed. The historical availability of MO in the two regions seems to influence its consumption more than its current availability.

Price is probably another explanation for the attractiveness of cassava in poor households. In our study, the poorest households are twice as likely as the richest households to replace rice with cassava roots when rice is not affordable. Cassava is one of the cheapest staple foods consumed in Madagascar. Our study shows that in rural areas, at least half the households plant cassava, thus making it even more affordable than in the market. One kilogram of these roots cost Ar 1000 (~USD0.45) on the market in 2013, and can feed a family of four or five at lunch. MO is also planted by half the households in the Diana areas (DR and DU). Its price is higher in the markets of Antananarivo (AU) than in those of Antsiranana (DU), probably due to its easier availability in the northern coastal area. Nonetheless, although the role of price is of major importance, it cannot explain the limited consumption of MO in Analamanga. According to Malagasy practice, leafy vegetables are eaten in small portions and usually accompany rice (Randrianatoandro, Avallone, Picq, Ralison, & Trèche, 2010). The proportions of leafy vegetables and rice in "laoka" are estimated at 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 with cassava, but without accompanying it with leafy vegetables, as shown by our results. This is true despite the fact that the association of cassava and MO would put the meal at the same cost or even cheaper than an equivalent quantity of rice alone: about Ar 2000 per kilogram during high season (0.9 USD).

Our results show that knowledge about the positive properties of MO in health terms has reached the population of the central part of the country, yet its consumption has not spread among the entire population. Cassava is widely consumed, despite consumers' awareness of its low nutritional interest. These results confirm findings previously reported in developed countries, that knowledge of the nutritional and health properties of a food does not systematically increase its consumption (Ginon, Lohéac, Martin, Combris, & Issanchou, 2009). To our knowledge, there is no information in the literature about the impact 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 perilous to compare our results with results obtained in developed countries. Nevertheless, one study may shed light on our results. This study focused on the hierarchy of determinants of choice for low income consumers in developed countries (Burns et al., 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 the perceived healthiness of a food. It seems that this also describes the behavior of the respondents in our study. "Satiating" was among the most frequently cited items associated with cassava. The weakness of cassava in terms of nutrient composition is probably a minor consideration compared to this perceived property of satiating hunger. The sensation of satiety afforded by cassava and by staple foods in general is very important when considered in relation to their price, and this may be an important factor in food choice, as demonstrated in the study by Burns et al. (2013). The 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 not considered sufficiently satiating for their price and for that reason, are consumed in smaller quantities than staple foods.

Additional factors such as *fady* (cultural dietary taboos) may explain, at least in part, 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 thus vary a lot between different tribes. *Fady* can concern all types of food. One example of *fady* concerns noble people from the Antsirabe region (about 74 miles south of Antananarivo) who should not consume *Bidens pilosa* leaves, which are thought to cause swelling of the knees (François, 1968; Graeber, 2007). The importance of *fady* should not be overemphasized however, since they have 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 rather as accompaniments, which is probably the reason for their limited consumption compared to carbohydrate rich staple foods (Razafimanantsoa et al., 2013).

Another factor influencing food choices is sensory properties. Children like cassava and our results showed that a large majority of the children who had already eaten MO leaves liked them as well (however only a small % of children had eaten MO in the central areas). This led us to envisage the formulation of a product containing cassava and MO to increase the consumption of MO in Madagascar. The formulation needed to take into account the practices of Malagasy people concerning the two products. A way to increase MO consumption without increasing cassava consumption would be to formulate a product that corresponds to the way cassava is consumed while introducing a new way of consuming MO. Cassava roots are mainly eaten boiled. In our survey, respondents declared consuming cassava most frequently with sugar (Fig. 1), while MO was eaten added with salt, and with oil in in Analamanga (Fig. 3). Respondents from Diana, who know MO well, underlined its strong odor as a limiting factor. This strong odor could origin from the way MO is usually consumed. Thus, MO could be prepared differently to be served to children. One solution could be to develop sweet products associating boiled cassava and MO, first to increase the palatability of these products for children, who are known to like sweet products, and secondly to correspond to the way cassava is generally eaten while introducing a new way to consume MO.

In order to determine whether children would like such a product, we performed a sensory study with three snacks containing cassava and *MO* leaf powder, and one snack containing cassava only (Study 2).

3. Study 2: Hedonic test of snacks made with cassava and MO

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

3.1. Materials and methods

3.1.1. Assessors and localization

A total of 424 children between the ages of 6 and 13 participated in the hedonic tests (67 girls and 52 boys in AU, 62 girls and 38 boys in AR, 54 girls and 47 boys in DU, and 60 girls and 42 boys in DR) Sessions were conducted in four public schools located in four neighborhoods. Depending on the location, 0%–2% of the children were under the age of 7, 13%–19% were 7 and 8 years old, 27%–38% were 9 and 10 years old, 27%–39% were 11 and 12 years old, and 10%–17% were older than 12.

3.1.2. Products

Four products, made with cassava roots, MO leaves (which we

reduced to powder in order to incorporate them in a repeatable way in the products) 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. A Moulinex Masterchef 9000 machine was used for these two steps. The diameter of grated cassava pieces was about 2 mm. MO leaves were from Antananarivo. They were sun-dried for 48–96 h, following a standard practise in Madagascar, then ground to powder using a domestic blender (Moulinex Masterchef 9000). The powder form was chosen for practical reason (powder is easier to store than fresh leaves). The mixture was cooked for 45 min in a steam cooker (Simply Invent, SEB VC101501), also for practical reason (control and repeatability of the cooking). The mixture was cooled to room temperature and samples of about 25 g were distributed in 25 mL glasses. Tests took place less than 3 h after the cooking of the samples.

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 the children before or during the test. The children were assisted by experimenters to score their overall liking on 7-point pictorial scales (Fig. 6). The children's answers were transformed into scores to analyze the results (extremely disliked: picture on the left = 1, extremely liked: picture on the right = 7). Experimenters also filled out the second part of the form regarding the age, gender and education level of children. At the end of the test, the children chose one of the products as a reward for their participation in the test. To ensure they did not choose on the basis of the quantity remaining in each sample, they were given takeaway samples especially prepared, and not the samples used for the test. The code of the chosen product was recorded on the form by the experimenter. The test was performed in the native language of each location.

The tests were performed during snack time (between ten and twelve o'clock), before lunch. Children had not eaten for at least 2 h before the 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 × area + error. Whenever 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.

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. Whenever a significant difference was found, the Marascuilo procedure (Marascuilo, 1966) was used to explain the difference.

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; M1: *Moringa oleifera* leaf powder at the lower content; M2: *Moringa oleifera* leaf powder at the higher content; S: Sugar.

Fig. 6. Seven-point structured scale used in hedonic test.

3.2. Results

3.2.1. Acceptance of foods made with 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 indicated that the sweet products (C + M1 + S and C + M2 + S) received higher average 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, $p < 0.001$). A SNK test carried out by area indicated that there was no difference in 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. 7).

3.2.2. Products chosen by the children

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

Next, to evaluate the effect of area on children's choices, the frequency at which each product was chosen was computed for each area (Fig. 8). In AU, DU and DR, C + M1 + S and C + M2 + S were the most often chosen, at similar frequencies (χ^2 between 0 and 3.2 at $\alpha = 0.05$), whereas in AR, C + M2 + S was chosen the most often. C + M1 was chosen the least often 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 $\alpha = 0.05$).

3.3. Discussion

The addition of MO leaf powder did not decrease liking of products based on cassava roots, except in AU where the product containing leaf powder without sugar was slightly disliked. Moreover despite the differences in consumption frequency of MO in the four areas, the more frequently chosen products were those containing MO and sugar in the four areas. Indeed, study 1 revealed that in AU and AR, respectively 2% and 4% of respondents declared that their children consumed MO frequently or more, versus 69% and 55% in DU and DR. It is noteworthy that in AR the percentage of children who had chosen the product with a double amount of MO powder (C + M2 + S) was higher than the percentage of children who chose the three other formulations. In this area, the population more frequently consumes green leafy vegetables than in the three other areas (Rakotonirainy et al., 2012). As leafy vegetables are more widely available in AR fields (Rakotonirainy et al., 2012), perhaps familiarity with green leafy vegetables may have guided

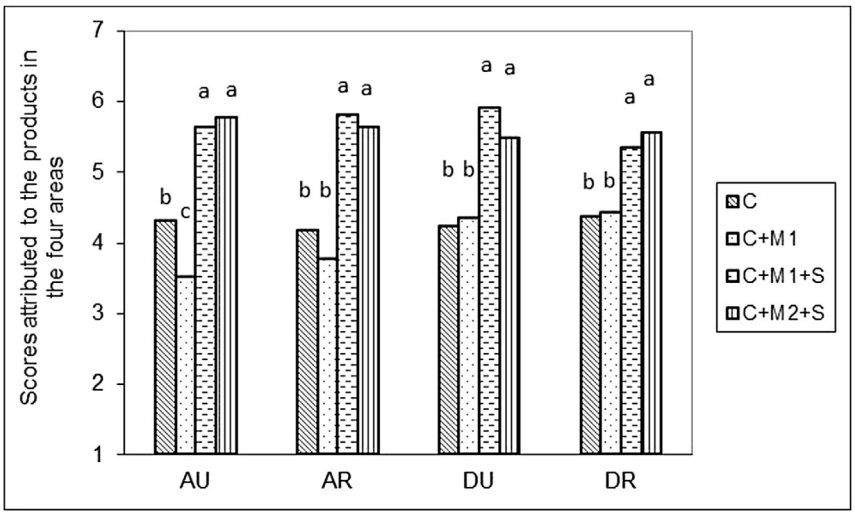

Fig. 7. Scores given to the tested products during acceptance tests, in the four areas. A score of 1 corresponds to a product extremely disliked and a score of 7 to a product extremely liked. (AU: Analamanga urban, AR: Analamanga rural, DU: Diana urban and DR: Diana rural). (C: cassava roots; M1: Moringa oleifera leaf powder in the lower proportion; M2: Moringa oleifera leaf powder in the higher proportion; S: sugar). In each area, means with the same letter are not significantly different (SNK tests at $\alpha = 0.05$).

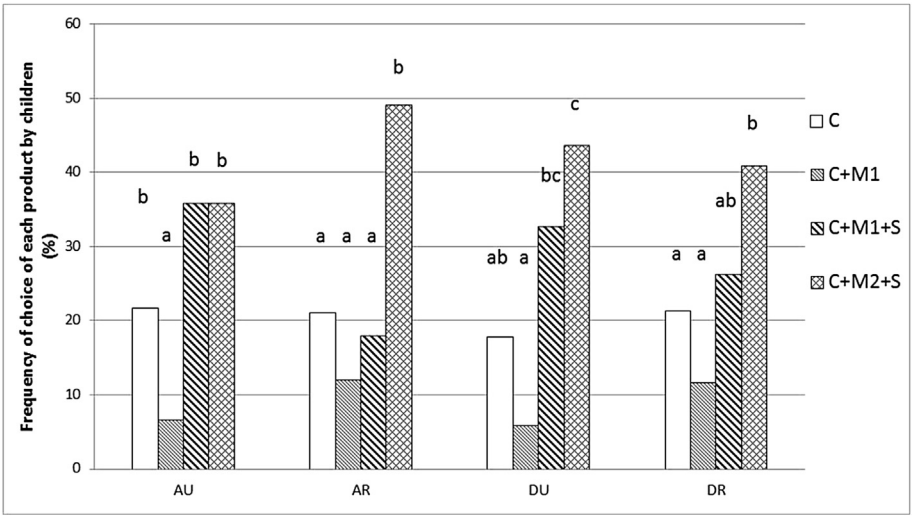

Fig. 8. Products chosen by children as a reward (%) in the four areas. (AU: Analamanga urban, AR: Analamanga rural, DU: Diana urban and DR: Diana rural; C: cassava roots, M1: Moringa oleifera leaf powder in the lower proportion, M2: Moringa oleifera leaf powder in the higher proportion, S: sugar). For each area, frequencies of choice of products noted with the same letter (a–c) are not significantly different at a confidence level of 95%.

them in their choice of C + M2 + S over the other products.

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

250 g of the product containing 1.2% of Moringa provides at least 9% of recommended dietary allowance (RDA) for essential amino acids (up to 27% for Trp) for a child of 15 kg, and respectively 19%, 7%, 4.5%, of RDA for alpha-linolenic acid (ALA), Calcium and Magnesium (Ramaroson Rakotosamimanana, 2014; FAO/WHO/UNU. 2007). The addition of sucrose might raise objections 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 increased children's liking of products containing MO leaf powder. Thus children can be expected to consume a sweet product more readily than a product containing only cassava and MO. The presence of sucrose in the formulation could thus promote a higher consumption of micro-nutrients, ω3 fatty acids and essential amino acids in children.

The prices of the four formulations were calculated by considering that all ingredients were bought at the local market. Each sample of 100 g cost 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. The addition of MO and sugar therefore increase the cost 300%. One solution to make a cheaper product would be to promote the plantation of MO in local family fields, for example.

4. Conclusion

This study found that the most important factor explaining the widespread consumption of cassava is its satiating power. Habits and availability may also explain why cassava roots are the second most common staple food after rice. The situation of MO was different. Its consumption primarily depends on the population's familiarity with the plant, and on cultural practices of eating it in a given geographic area. The availability of MO in the north (DU and DR) is also a major driving force behind its consumption. MO was considered to have positive properties and was appreciated by those who consumed it. But it is difficult to imagine MO leaves holding a central place in the Malagasy food repertory, as it is not satiating enough. Our suggestion was to propose a food containing both cassava and MO. Our formulation was well accepted by children and could be suggested to parents as a snack which both satiates and provides their children with -more essential aminoacids and ALA than the foods containing cassava only. More studies would be needed to further enhance the content of amino acids, ALA and micronutrients in the snacks by increasing the quantity of MO, while maintaining a good acceptability. Furthermore, an awareness program concerning the nutritional properties of MO leaves could be used to encourage households to grow MO.

Acknowledgments

The authors warmly thank Louisette Razanamparany, who initiated this research program, for her contribution to this study. The authors would also like to thank the supervisors of EPP Ambatobe, Labigorne and Ambatolampy Tsimahafotsy for collaborating in the recruitment of parents, the students who carried out the interviews and all the collaborators who offered advice and aid. The sensory study was partly funded by the French Embassy in Madagascar via the Parrur Project.

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