



Cassava Consumption and Biological Adaptation to *Plasmodium Falciparum* Malaria in Man, Côte d'Ivoire

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Abstract:

The biological adaptation of the human organism to *Plasmodium falciparum* malaria infection could be attributable to its endogenous biological potential and to the action of bio-environmental elements. The influence of exogenous biochemical activators, in particular the intake of micronutrients with immune potential, on the protection of the human body from malaria infection is far from being sufficiently studied. The present study examines the effect of varying cassava consumption frequency on biological adaptation to *Plasmodium falciparum* malaria infection. The study involved 83 women and 80 men, aged between 5 and 70 years, living in Man

(Côte d'Ivoire) and admitted for consultations at the regional hospital. The frequency of manioc ingestion was assessed using a 14-item food frequency questionnaire administered face-to-face. Biological adaptation was measured using blood smear and thick blood smear results. The results of Fisher's test show that populations with a high frequency of cassava consumption have a lower proportion of *Plasmodium falciparum* malaria infections than their counterparts with a low frequency of cassava consumption. Cassava consumption therefore improves the individual's biological adaptation, i.e. the protective protein-immune system, to *Plasmodium falciparum* malaria infection.

Keywords: *Biological adaptation, Plasmodium falciparum, Malaria, Cassava, Côte d'Ivoire.*

Introduction

People living in Africa are often exposed to negative external stimuli. One such parasite that frequently affects the body is *Plasmodium falciparum*. *Plasmodium falciparum* is thought to be

responsible for 97% of the two hundred and thirty-four (234) million cases of malaria reported in Africa (World Health Organization, 2020). The organism's response to this



aggression is known as biological adaptation to *Plasmodium falciparum* malaria.

From an anthropoevolutionary perspective, biological adaptation refers to the modification of an anatomical or physiological trait as a result of natural selection (Grandcolas, 2009). It also refers to an inhibition of the parasite resulting from the presence in the individual's body of an unfavourable substance (Traoré et al., 2016). Biological adaptation to *Plasmodium falciparum* malaria therefore refers to all the physiological changes in the individual's body in response to plasmodial infection. It would therefore be a process in the body which allows a reduction in the parasite load or a reduction in susceptibility to microbiological activity which varies according to the biophysiological potential of the individual.

The relationship between adaptation to *Plasmodium falciparum* and bioavailability is specific. It is all the closer because immune status and sensitivity to the pathogen are dependent on the individual's resources (Field, 2002). For example, the physiological effects of trace elements such as iron and zinc are thought to favour the survival and replication of *Plasmodium falciparum* in the host (Katona & Katona-Apte, 2008; Oppenheimer, 2001). Furthermore, the parasite responsible for malaria is an organism that destroys haemocytes in order to obtain nutrients, particularly iron. Thus, iron deficiency in an individual influences the development of Plasmodium (Fillol, 2009). Zinc absorption, meanwhile, appears to help reduce the clinical infection caused by *Plasmodium falciparum*. This nutritional bioavailability tends to improve the body's protection. Such bioimmunity of the body against *Plasmodium falciparum* based on the action of bionutrients could be more resistant if nutrient bioavailability is maximised. The increase in these bioprotectors would generally be achieved through the ingestion of specific foods.

One of the foods considered to be a major source of these bio-substances is manioc (Cressey & Reeve, 2019). Consumption of cassava modifies the metabolism of

haemoglobin in red blood cells by ingesting cyanide compounds (Nartey, 1978). The metabolites provided by cassava, thiocyanate and cyanate, are likely to inhibit the growth and development of *Plasmodium falciparum* (Nagel, 1980). Consumption of cassava is thought to be linked to the supply of specific nutrients to boost the individual's organism.

The relationship between biosynthetic mechanisms and biological adaptability to *Plasmodium falciparum* malaria has interested a number of authors. Published data have documented the influence of population lifestyle on resistance to malaria in the Fulani and Dogon populations of Mali (Traoré, 2017). In this study, an examination of dietary habits showed that the diet was the source of the differences observed in malaria susceptibility between these two ethnic groups. This bioprotection of certain foods was observed in a study of a population in Liberia (Jackson, 1991). The author reported a possible relationship between cassava consumption and irregular Plasmodium falciparum malaria infection.

On analysis, the research mentioned above isolates the product or foodstuff as an exogenous bioresource whose consumption by the individual provides him with immune proteins that can improve his body's protection against *Plasmodium falciparum* malaria infection. It would appear that, in this research, insufficient emphasis has been placed on the effect of variable cassava consumption frequencies on biological adaptation to *Plasmodium falciparum* malaria. The aim of the present study was to examine the effect of different cassava consumption frequencies on individual protection against *Plasmodium falciparum* malaria infection.

Materials and Methods

Material

The question examined in this study concerns protection against *Plasmodium falciparum* malaria in individuals who regularly consume cassava. Cassava, i.e. the manioc tuber, is one of the foods consumed almost everywhere in the

country. From one region to another, cassava, in various forms or cooked, forms part of people's meals (Yéboué, 2017). In the south, for example, cassava is generally eaten in the form known as 'attiéké'. Tapioka' and 'morcelée' (stew) are the forms eaten by people in the north and centre. Cassava is also eaten in many forms in the west of the country.

In this area, cassava is a food source that is sufficiently cultivated by these populations (Institut National de la Statistique, 2013). In the Tonpki region, it accounts for 26% of household food consumption. This high consumption of cassava can be seen in the region's particularly densely populated rural areas, particularly the town of Man (Institut National de la Statistique, 2016).

Since its communalisation in January 1978, the Man conurbation (Figure 1) has been the capital of the region and sub-prefecture. It occupies a

crossroads position and is experiencing rapid population growth as a result of agriculture and tourism. The population's economic activities are focused on exploiting forestry, agricultural and mining resources (Kadet, 2015). These economic opportunities are leading to migration towards the Tonpki region (formerly the Montagnes region), which is home to 10.4% of the population of Côte d'Ivoire (IAFRISTAT, 2019).

Man grew by 4.2% between 1988 and 1998 (Brou, 2017), and the city's resident population is now estimated at 182,871 (Institut National de Statistique, 2016). As a regional capital and economic hub, Man has a large number of healthcare facilities. In addition to peripheral and community health centres, the city has a primary reference health establishment, a Regional Hospital Centre (RHC) (Figure 1).

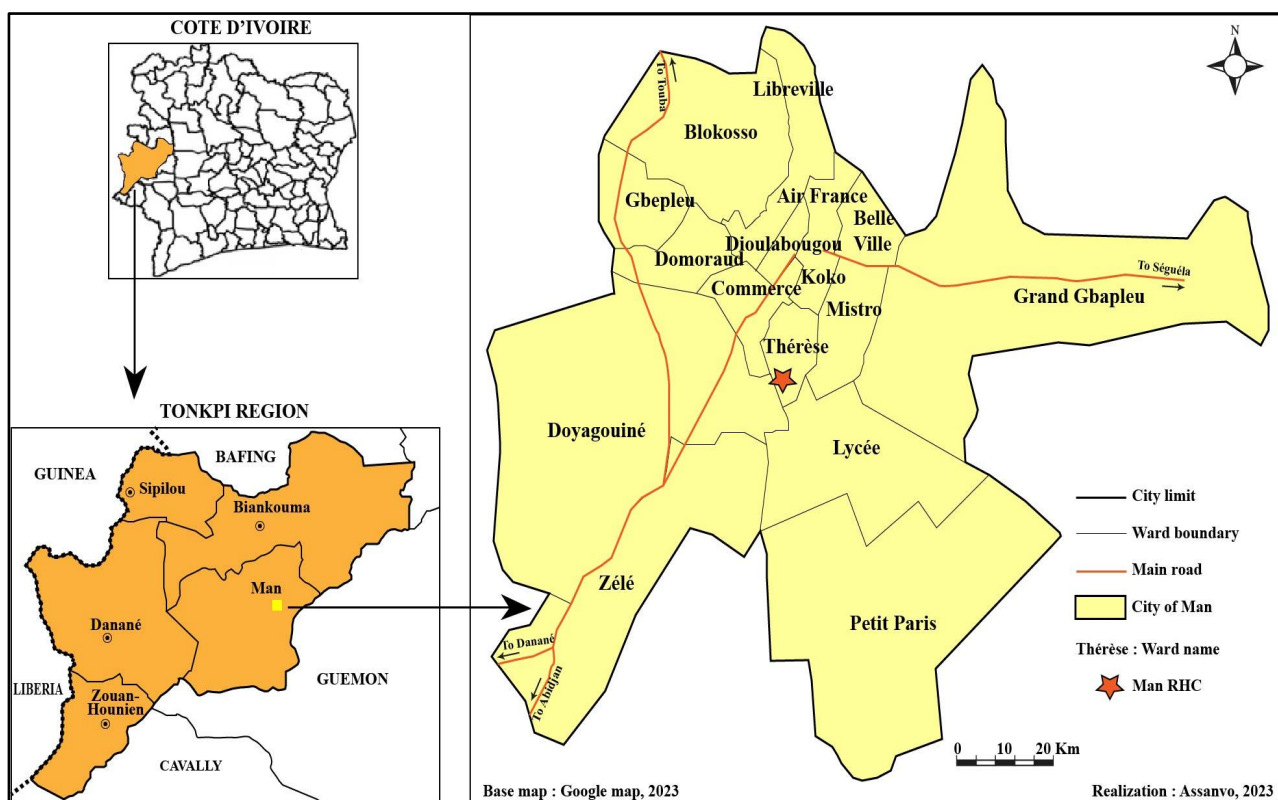


Figure 1. Location and the Map of Man, Cote d'Ivoire

The Man Regional Hospital Centre has a medical biology laboratory, enabling it to carry out

various microbiological examinations for the purpose of refining the diagnosis of pathologies

and the appropriate management of diseases such as malaria. In view of the above, the observation of adaptation to malaria in association with cassava consumption therefore seems more likely in the town of Man.

The central location of the CHR de Man makes it easy for people to reach. They are mostly men and women of different age categories and professions. Some groups of individuals were not included in this study because of immune deficiencies or erythrocyte pathology. These were children under 5 years of age, pregnant women, people with HIV-AIDS and those with haematological disorders, in particular sickle cell trait. Application of the selection criteria resulted in 163 individuals of different sexes (83 women and 80 men), aged between 5 and 70, living in the town of Man. This fraction of individuals constituted the sample on which the study was based.

Methods

The study was explanatory and cross-sectional. It concerns a sample of 163 subjects (83 women and 80 men) aged between 5 and 70 years observed on the premises of Man General Hospital during the period from October to December 2018. The individuals were observed over a period of three (3) months using the "reasoned choice" method applied to all the people who came for examinations in the medical biology unit of the Man General Hospital. This field trial was preceded by a preparatory phase. This consisted of creating a framework for observation that complied with scientific research ethics. Firstly, we obtained the agreement of the regional and departmental health authorities to allow free access to the Man regional hospital and to the parasitological and clinical data collected there. Secondly, the participants agreed to take part in the study by signing an informed consent form. The participation and observation of minors was preceded by the approval of their parents or guardians, after they had been informed of the study.

These preliminary operations were necessary in order to organise a preliminary observation phase. To this end, a number of people suffering

from malaria (4) or not (4) were subjected to the sampling and measurement questionnaire developed. This test of the tool took place at the Cocody University Hospital. The results of this process of comparing the tool with the facts made it possible to reformulate a number of items, to move others around and thus to validate the tool. The completion of this twofold ethical-experimental exercise created the right conditions for the actual observation.

This was done by subjecting the subjects to a sampling questionnaire. The items in this tool concerned socio-demographic characteristics, frequency of consumption of cassava-based dishes (Attiéké, attoukpou, placali, foutou, gari), 24-hour recall, knowledge-attitudes-practices regarding malaria and medical history. Parasitological data for malaria diagnosis were collected from thin-thick smear examinations. The samples were taken and read under the microscope by biology technicians from the Man medical biology laboratory. Each participant in the observation was identified by a unique code to ensure anonymity and to link the results of the biological examination to those of the questionnaire.

The data collected were tabulated and purified using Microsoft Excel 2007, then analysed using SPSS version 2.0 statistical software for Windows. The data obtained is ordinal qualitative and describes three groups of subjects according to the frequency of cassava consumption. Fisher's exact test appears to be the appropriate statistical tool for verifying the existence of a link between the frequency of cassava consumption and biological adaptation to *Plasmodium falciparum* malaria. The α risk or statistical significance level was set at $p < 0.05$.

Results

Observation of participants' biological adaptation to *Plasmodium falciparum* malaria in relation to cassava consumption made it possible to obtain data on subjects' malaria status according to the frequency of consumption. The processing of these data led to results showing different malaria diagnoses depending on the

frequency of cassava consumption. For example, the results relating to the malaria status of children aged 5 to 9 years show that individuals with a high or medium frequency of cassava consumption had a higher proportion of negative malaria diagnoses than their counterparts with a low frequency of cassava consumption (100% and 50% respectively

compared with 14.29%). Children who ate cassava-based meals with medium or high frequency increased their level of protection against *Plasmodium falciparum* malaria infection. These results are supported by those obtained using Fisher's exact test (p-value = 0.012, see Table 1).

Table 1. Comparison of the Malaria Status of Children Aged 05 to 09 Years with High Cassava Consumption with that of Their Counterparts with Medium or Low Cassava Consumption

Frequency of cassava consumption	N	Malaria diagnosis		Fisher exact test (p-value)
		Negative	Positive	
High	6	100%	0.0%	0.012 s
Medium	6	50%	50%	
Low	7	14.29%	85.716%	

Children aged between 10 and 14 appear to have similar adaptations to those in the previous group. Children in this age group with a high frequency of cassava consumption have a lower

susceptibility to *Plasmodium falciparum* malaria than their counterparts with medium or low consumption (Table 2).

Table 2. Comparison of the Malaria Status of Children Aged 10-14 Years with High Cassava Consumption with that of Their Counterparts with Medium or Low Cassava Consumption

Frequency of cassava consumption	N	Malaria diagnosis		Fisher exact test (p-value)
		Negative	Positive	
High	13	92.30%	7.70%	0.007 s
Medium	14	50%	50%	
Low	10	30%	70%	

This advantageous biological adaptability is confirmed by the results of the statistical test (p-value = 0.007). When considering individuals aged 15 to 24 years (Table 3) and those aged 25

to 49 years (Table 4), high frequency of cassava consumption appears to provide better biophysiological adaptation to *Plasmodium falciparum* malaria.

Table 3. Comparison of the Malaria Status of Individuals Aged 15 to 24 with High Cassava Consumption with that of Their Counterparts with Medium or Low Cassava Consumption

Frequency of cassava consumption	N	Malaria diagnosis		Fisher exact test (p-value)
		Negative	Positive	
High	15	80%	20%	0.011 s
Medium	18	38.9%	61.1%	
Low	20	30%	70%	

Comparison of the cassava-consuming groups shows that individuals aged 15 to 24 with a high frequency of cassava consumption had a high

frequency of negative malaria diagnoses (80% negative compared with 20% positive) (Table 3).

Table 4. Comparison of the Malaria Status of Individuals Aged 25 to 49 with High Cassava Consumption with that of Their Counterparts with Medium or Low Cassava Consumption

Frequency of cassava consumption	N	Malaria diagnosis		Fisher exact test (p-value)
		Negative	Positive	
High	10	90%	10%	0.006 s
Medium	10	50%	50%	
Low	26	30.77%	69.23	

On the other hand, the proportion of positive malaria diagnoses was higher in individuals with average (61.1%) or low (70%) cassava consumption. Examination of the influence of consumption frequency on protection against *Plasmodium falciparum* in individuals aged 50 and

over reveals invariability between individuals in this age group, whatever the frequency of cassava consumption (Table 5). The relative differences observed in this group were not statistically significant (p-value = 0.229).

Table 5. Comparison of the Malaria Status of Individuals Aged 50 and Over with High Cassava Consumption with that of Their Counterparts with Medium or Low Cassava Consumption

Frequency of cassava consumption	N	Malaria diagnosis		Fisher exact test (p-value)
		Negative	Positive	
High	2	100%	0.0%	0.229 ns
Medium	3	66.66%	33.33%	
Low	3	0.0%	100%	

Discussion

Nutrients in the diet appear to play an important role in maintaining an 'optimal' immune response. Insufficient or excessive dietary intake can therefore have a negative impact on immune status and susceptibility to a variety of pathogens (Field, 2002). The present study is part of this approach. It examines the effect of repeated consumption of cassava on biological adaptation to *Plasmodium falciparum* malaria. Observations made on patients at the Man regional hospital led to specific results.

The results of these observations show that individuals with a high frequency of consumption have greater protection against *Plasmodium falciparum* malaria than their counterparts with a medium or low frequency of consumption. In other words, there is a very low proportion of positive malaria diagnoses among

people who frequently consume food made from cassava. This rate is almost identical, whatever the age group of the individuals considered (Tables 1, 2, 4, 5). Different results are obtained when we compare the number of cases of *Plasmodium falciparum* malaria in individuals with a low frequency of consumption with that of their peers with a high frequency of consumption. The rates of positive diagnoses observed for low cassava consumption frequencies are significantly higher (Tables 1, 2, 3, 4, 5).

There therefore appears to be a positive effect of repeated consumption of cassava on protection against *Plasmodium falciparum* malaria. The source of this relationship is the bio-immunity provided by cassava consumption. Daily consumption of cassava tends to provide metabolites, thiocyanate and cyanate, which appear to improve resistance to *Plasmodium falciparum*.

These metabolites, derived from the degradation of cyanide, have a lower toxicity than that suggested by their theoretical equivalents, hydrocyanic acid (Cressey & Reeve, 2019). In the body, thiocyanate (SCN) is used by the innate immune system to enhance host defence against infection. Cyanate, which is formed from the oxidation of thiocyanate, is a sickle inhibitor. Ingesting cyanate and thiocyanate could therefore reduce sickle cell disease in genetically-affected individuals.

Changes in the physico-chemical properties of erythrocytes are thought to prevent the penetration and development of *Plasmodium*. Consequently, populations that consume cassava regularly and have sub-lethal levels of cyanide compounds in their blood show a reduction in parasite viability and a levelling off of malaria infection. These metabolite derivatives are thought to create an environment that is not conducive to parasite activity, similar to that caused by the action of anti-malarial molecules.

The impact of dietary habits on protection against *Plasmodium falciparum* malaria can also be explained by the bioavailability of iron in the body. Nutritional iron status plays a key role in the host-pathogen interaction. In the individual, iron is an essential element for the body to function, particularly in the haemoglobin of red blood cells. The iron molecule is a biochemical element required for the development and replication of the parasite. Altering the availability of iron would therefore inhibit the growth and replication of the parasite. As a result, iron-deficient individuals in malaria-endemic regions appear to have greater immune suppression and increased susceptibility to *Plasmodium*.

Biological adaptation to *Plasmodium falciparum* malaria therefore appears to be a mechanism that can be activated and regulated by an individual's diet. The results of this study are certainly convincing, but require further investigation. Further research, taking into account bioprotective mechanisms, from a longitudinal perspective and on a larger sample, could help to generalise our results.

Conclusion

Questions relating to the impact of bio-environmental factors on biospecific adaptation to *Plasmodium falciparum* malaria have been insufficiently explored. The present study attempts to provide some answers by examining the effect of repeated consumption of cassava on protection against *Plasmodium falciparum* malaria. The observations made as part of this study produced relatively significant results. Taken together, the results reveal the positive role played by the frequency of cassava consumption in the individual's bioprotection against *Plasmodium falciparum*.

This study represents a new approach to understanding the contribution of dietary metabolic derivatives to the functioning of the human body's susceptibility to malaria. It reinforces the idea that food, and more specifically tropical plants, influence the physiology of human cells. In the absence of an effective vaccine and in the face of resistance to antimalarial drugs, the identification of foods likely to improve the protection of the most vulnerable individuals represents a new avenue of research in the strategy to combat the scourge of malaria. Measuring the bionutrients provided by cassava consumption and their action on the cells involved in adaptability to *Plasmodium falciparum* should make it possible to develop dietary prophylaxis.

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