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Chemical aspects of human consumption of termites in Africa

Aspects chimiques de la consommation de termites par l'homme en Afrique

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Résumé : Après avoir mentionné l'intérêt de la consommation d'insectes par l'homme, en particulier en Afrique, les termites sont pris pour exemple. Le contraste entre le nombre de publications concernant ce fait et l'information détaillée concernant leurs aspects chimiques est souligné. A peine une quinzaine d'articles fournissent des données fiables concernant à la fois les espèces de termites et le stade concerné. Ces résultats sont détaillés et discutés.

Mots clés : Termites, consommation, Afrique, composition chimique.

Abstract: After having mentioned the interest in the consumption of insects by man, in particular in Africa, termites are chosen as an example. The contrast between the number of publications quoting this fact and the detailed information concerning their chemical aspects is underlined. Barely fifteen papers provide accurate data regarding both the termite species and the stage concerned. These results are detailed and discussed.

Key words : Termites, consumption, Africa, chemical composition.

INTRODUCTION

The utilization of insects as a sustainable and secure source of animal-based food for the human diet has continued to increase in popularity in recent years (SHOCKLEY & DOSSEY, 2014). Africa is no exception in this trend. Coleoptera and Lepidoptera are the two most important Orders from a world point of view. On the other hand, termites – which we will consider as the « Isoptera Order » – are at present, of weak interest. Nevertheless, the consumption of termites in Africa has been quoted in more than 275 papers (MALAISSE, 2019). The number of species eaten, as well as their names, varies according to the authors. MALAISSE (2010) quotes 19 species, providing for each species the reference and the territory or the linguistic unit concerned (Table 1). In a similar way, REIS DE FIGUEIRÊDO et al. (2015) mentions the consumption of termites at world level, 14 species are quoted for Africa, for each species the country as well as the number of references recorded are quoted (Table 2).

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Table 1.- Termite species eaten by man in Africa, bibliographic references, territory or linguistic unit concerned.

FAMILIES Subfamilies	Genera	Species and author	Ethno-linguistic units (Country)	References
HODOTERMITIDAE	*Hodotermes*	*mossambicus* (Hagen)	San, Tswana	Grivetti 1979
	Microhodotermes	*viator* (Latreille)	South Africa	Bodenheimer 1951
TERMITIDAE Macrotermitinae	*Acanthotermes*	*Acanthothorax* (Sjöstedt)	Uganda, Tanzania	Malaisse 1997
	Macrotermes	*bellicosus* (Smeathman)	D.R. Congo, Burkina Faso	Ukhun & Osasona 1985
	Macrotermes	*falciger* (Gerstäcker)	D.R. Congo, Zam bia, Zimbabwe	Nkunika 1998
	Macrotermes	*mossambicus* (Hagen)	Zimbabwe	Logan 1992
	Macrotermes	*muelleri* (Sjöstedt)	Cewa (Malawi)	DeFoliart 2002
	Macrotermes	*natalensis* (Haviland)	D.R. Congo	Bequaert 1921
	Macrotermes	*subhyalinus* (Rambur)	Gingas, Masa, Mofu (Cameroon)	Seignobos et al. 1996
	Macrotermes	*vitrialatus* (Sjöstedt)	Teso (Uganda)	Silow 1983
	Microtermes	sp.	Mbunda (Zambia)	Yagi 1997
	Odontotermes	*badius* (Haviland)	Nandy (Kenya)	Quin 1959
	Odontotermes	*kibarensis* (Fuller)	Pedi (South Africa)	Nyeko & Olubalo 2005
	Odontotermes	*lateritius* (Haviland)	Teso (Uganda)	Nyeko & Olubalo 2005
	Odontotermes	*magdalense* Grassé & Noirot	Mofu (Cameroon) Teso (Uganda)	Seignobos et al. 1996
	Pseudacanthotermes	*militaris* (Hagen)	Tanzania	Harris 1940
	Pseudacanthotermes	*spiniger* (Sjöstedt)	Mbunda, Teso	Silow 1983
	Protermes	sp.	Aka (C.A.R.)	Bahuchet 1985
Apicotermitinae	*Apicotermes*	sp.	Aka (C.A.R.)	Bahuchet 1985
Termitinae	*Megagnathotermes*	*katangensis* Sjöstedt	Sanga (D.R.C.)	Malaisse 1997
Nasutermitinae	*Trinervitermes*	sp.	Luba (D.R.C.)	Callewaert 1922

Table 2.- Termite species eaten by man in Africa, countries concerned (or their number) and number of references (Ref.) quoting their consumption.

Family	Species	Countries	Ref.
Hodotermitidae	*Hodotermes mossambicus* (Hagen, 1853)	Botswana	1
	Hodotermes viator (Latreille, 1804)	South Africa	1
Termitidae	*Macrotermes bellicosus* (Smeathman, 1781)	11	23
	Macrotermes falciger (Gerstäcker, 1891)	5	10
	Macrotermes gabonensis (Sjöstedt, 1900)	Congo Rep.	2
	Macrotermes michaelseni (Sjöstedt, 1914)	Malawi	1
	Macrotermes natalensis (Haviland, 1898)	Nigeria, CAR, Congo, Zimbabwe	8
	Macrotermes subhyalinus (Rambur, 1842)	6	20
	Macrotermes vitrialatus (Sjöstedt, 1899)	Zambia	4
	Odontotermes badius (Haviland, 1898)	South Africa, Zambia, Kenya	5
	Odontotermes capensis (De Geer, 1778)	South Africa	2
	Odontotermes kibarensis (Fuller, 1923)	Uganda	1
	Pseudacanthotermes militaris (Hagen, 1858)	4	7
	Pseudacanthotermes spiniger (Sjöstedt, 1900)	5	10

Some books and papers are essential reading if we are interested in termites, and termite hills. We will quote HEGH (1922), SILOW (1983) and FÉLIX IROKO (1996). These authors provide important information dealing with the collection of termites in Africa, but not regarding the termite's composition. The same is the case for several other very interesting papers, notably « Des moissons éphémères. L'art de collecter et de consommer les termites sous les tropiques » of DOUNIAS (2016), for « Chasse, cueillette et culture chez les Gbaya de Centrafrique » of ROULON-DOKO (1998), for LUPOLI (2016) who wrote « La chimie des insectes et ses implications pour leur consommation ». He points out that the nutritional and chemical composition of insects is well known, but provides only values in % for the proteins, the lipids and the fatty unsaturated acids. Finally, it is noted that insects are rich in carbohydrates, vitamins, minerals and fibres, but nothing more!

VAN HUYS (2017) reviews, in a very detailed way, a wide range of aspects related to the cultural importance of termites in Sub-Saharan Africa. Termites' consumption is a major theme. But again there is no information regarding their composition. The importance of termites as seasonal human food has also been well argued for Burkina Faso by OUÉDRAOGO (2005).

MALAISSE (2019) presents the current knowledge regarding the subject; he provides diverse values, but there is no discussion in detail of how the knowledge is put together. Some papers provide results concerning the chemical composition of termites, but the species concerned are not given for some of them, notably in HEYMANS & EVRARD (1970). MALAISSE (2020) presents a highly diversified reflection regarding termites and termite hills. The diversity of termitophagy is one of the eight subjects reviewed. But there is also no data regarding their composition! On the other hand, recently two papers provide results concerning chemical composition of termites, namely ADEPOJU & OMOTAYO (2014) and MUSUNDIRE et al. (2016). Another example is provided by the paper of PAYNE et al. (2015). Values of mineral composition of termites are provided. Their local names are quoted, namely « ishwa » and « majuru ». They were obtained in markets of the towns Mutare, Nyika and Djairo. But the stages are not given. The values of the four samples (Nr 8 to 11) are very different regarding Na, K, Ca, P, Mn and Zn!

In conclusion, a rigorous study of the chemical composition of termites consumed by man in Africa is necessary. This study has to take into consideration the various species at their different stages, and also the wide range of their composition.

MATERIAL AND METHODOLOGY

Material

As explained above, correctly determined species which share valuable chemical information at different stages are uncommon. Table 3 summarizes our findings.

Table 3. Data available regarding chemical composition of termites consumed by man in Africa.

Termite species	Stages	Matter	Authors
Macrotermes bellicosus (Smeathman)	ad-ww	pc, fa	Kinyuru et al. (2013)
Macrotermes bellicosus (Smeathman)	ad-ww	pc, fa, mi, aa	Ukhun & Osasona (1985)
Macrotermes bellicosus (Smeathman)	ad-ww	li	Ekpo & Onigbinde (2007)
Macrotermes bellicosus (Smeathman)	ad-ww	ans, cpi	Adepoju & Omatoyo(2014)
Macrotermes falciger (Gerstäcker)	♀ ♂	aa	Phelps et al. (1975)
Macrotermes falciger (Gerstäcker)	ad-ww, sol	pc, mi	Malaisse & Parent(1997)
Macrotermes natalensis (Haviland)	ad-ww	gcc	Musundire et al. (2016)
Macrotermes subhyalinus (Rambur)	ad-ww	pc, fa	Kinyuru et al. (2013)
Macrotermes subhyalinus (Rambur)	ad-ww	pc, fa, mi, aa	Niaba et al. (2011)
Pseudacanthotermes militaris Hagen	ad-ww	pc, fa	Kinyuru et al. (2013)
Psedacanthotermes spiniger Stöstedt	ad-ww	pc, fa	Kinyuru et al. (2013)

aa = amino acid composition ; ad = adult ; ans = anti-nutritional substance ; cpi = culinary processing influence ; fa = fatty acid composition ; gcc = global chemical composition, li = lipids ; mi = minerals ; pc = proximate composition ; sol = soldier; ww = without wings.

Methodology

For our synthesis, we will only take into account papers that provide chemical analysis results concerning taxa identified at species level. The chemical indices have been worked out on the basis of FAO/UNU/WHO (2007) data. This calculation gives, according to NGUDI et al. (2003), an accurate prediction of the amount of necessary proteins to cover the needs of essential amino-acids during the growth period.

The chemical index of an amino-acid is calculated by using the following formula: Chemical index = (1mg of amino-acid in 1mg of protein analyzed/1mg of amino-acid in 1mg of reference protein) x100. The amino-acid having the weakest index is the amino-acid limiting the studied protein.

The iodine index values were calculated according the AOCS (1998) formula: Iodine index = sum (127 x 2 x n x %UFA/MM) with n = amount of double chemistry bounds of the fatty acid; MM = molecular mass of fatty acid ester and % UFA = percentage of unsaturated fat acid. This index allows us to determinate the degree of global unsaturation of the lipids of a food. It corresponds to the quantity in iodine grams content per 100 g of fatty matter. The energy value of 100 g of dried termite raw matter in the samples has been calculated by multiplying by 100 the energy value of each of the measured macronutrients, namely: $17kJ.g^{-1}$ for the proteins, $38kJ.g^{-1}$ for the lipids and $17KJ.g^{-1}$ for the carbohydrates, adding them up (AOAC, 2003). To appreciate the nutritional quality of each termite species, we have calculated the following ratio: Ca/P; Ca/Mg; Na/K; PUFA/SFA; leucine/isoleucine and leucine/lysine.

RESULTS

Nutritive values of termites

We will first take into consideration the global chemical composition and the energy value (Table 4). For the global chemical composition values of the proteins, the fat matters and the mineral elements will be given in %; whilst the energy values will be expressed in Kcal.

Table 4: Global chemical composition (g/100g of dry matter) and energy value (Kcal).

Termite species	**Proteins**	**Fatty matters**	**Mineral elements**	**Energy value (Kcal)**
Macrotermes bellicosus (Smeathman)	39.74 (c)	47.03(c)	4.65 (c)	531(e)
Macrotermes falciger (Gerstäcker)	41.8(a)	46.1(a)	4.4(b)	760(a)
Macrotermes subhyalinus (Rambur)	39.34(c)	44.82(c)	7.58(c)	581.5 (d)
Pseudacanthotermes militaris Hagen	33.51(c)	46.59(c)	4.58(c)	588
Pseudacanthotermes spiniger Stöstedt	37.54(c)	47.31(c)	7.22(c)	579

(a) Phelps et al. (1975) ; (b) Malaisse & Parent (1995) ; (c) Kinyuru et al. (2013) ; (d) Niaba et al. (2011) ; (e) Badanaro et al. (2018).

The results presented in this Table indicate that termites are a good proteo-lipidic source with attractive rates of mineral elements. The consumption of termites combined with a varied diet may provide a more interesting dietary complement.

Secondly, we will take into consideration the amino-acids profiles.

Table 5. Amino-acid profiles of three species of *Macrotermes* [(f): values from Ukhun & Osasona, 1985].

Amino acids	**(f)**	**(a)**	**(d)**
	M. bellicosus	***M. falciger***	***M. subhyalinus***
Glycine	3.9	4.5	7.44
Alanine	9.0	6.2	6.53
Valine	7.3	5.4	5.91
Leucine	7.8	7.5	6.07

Isoleucine	5.1	4.0	5.76
Serine	1.2	4.0	5.8
Threonine	2.7	4.0	7.86
Arginine	6.9	5.8	5.02
Lysine	5.4	6.6	7.92
Glutamic acid	8.8	10.5	10.08
Aspartic acid	10.4	9.0	10.18
Cysteine	1.9	Traces	
Methionine	0.7	1.6	
Methionine + cysteine	2.6	1.6	2.38
Phenylalaline	4.4	4.6	
Tyrosine	3.0	6.9	
Aromatic amino-acids	7.4	11.5	10.06
Proline	nd	5.6	5.83
Histidine	5.1	3.0	2.97
Tryptophan	nd	Nd	1.97
Leucine / lysine	1.44	1.14	0.76
Leucine / isoleucine	1.53	1.88	1.05
Essential amino-acids / total amino-acids	43.18 %	42.82 %	44.02 %

The termite proteins contain all the essential amino-acids with appreciable quantities, except for tryptophan, which was not established for *Macrotermes bellicosus* and *M. falciger*. Leucine is the major amino-acid in *M. bellicosus*, respectively followed by the aromatic amino-acids (tyrosine + phenylalanine), the lysine, the histidine and the isoleucine; the threonine and the sulphur amino-acids (methionine + cysteine) are more weakly represented. Concerning the two other termite species, *M. falciger* and *M. subhyalinus*, the aromatic amino-acids are the most important, followed respectively by the leucine and the lysine for *M. falciger*, and by lysine, threonine and leucine for *M. subhylinus.* For *M. falciger*, isoleucine, threonine, histidine and the sulphur amino-acids are the amino-acids most weakly represented; for *M. subhyalinus* the essential amino-acids most weakly represented are the aromatic amino-acids, histidine and tryptophan. Nevertheless, compared to the reference protein, these proteins have generally no limiting amino-acids due to the fact that their chemical indices are not below 100 (Table 6), with exception of the sulphur amino-acids of which the chemical index is below 100 for *M. falciger* ; thus they constitute thus the only limiting factor. Thus termites may be used to complete the nutritive requirement for essential amino-acids. For example *M. subhyalinus*, as a very high tryptophan chemical index, may be used to complement chicken, dried fish and shellfish giving an index above100. According to DA SILVA et al. (2006), taking into account the essential amino-acids in well-balanced proportion is of great importance, an excess of leucine in foods interferes with the use of isoleucine (HARPER et al., 1955). In this way, the research of DEOSTHALE et al. (1970) has point out that a ratio leucine/lysine below 4.6 is considered as nutritionally correct. The three involved species have these two ratios below 4.6. The proteins of these *Macrotermes* species have thus favourable leucine/isoleucine and leucine/lysine ratios and offer no problems of imbalance of essential amino-acids.

Table 6. Chemical index based on FAO/UNU/WHO (2007) values.

Essential amino-acids	Reference proteins	Chemical index		
	FAO/UNU/WHO (2007) (g/100g/proteins)	*M. bellicosus*	*M. falciger*	*M. subhyalinus*
Threonine	2.3	117	174	342
Methionine + cysteine	2.2	118	73	108
Isoleucine	3	170	133	192
Leucine	5.9	132	308	265
Phenylalanine + tyrosine	3.8	195	127	103
Lysine	4.5	120	147	170
Histidine	1.5	340	200	198
Tryptophan	0.6	-		328

The ratio between the sum of the essential amino-acids and the sum of the total amino-acids protein of each *Macrotermes* species is above 33 %, thus providing a chemical equilibrium between the different amino-acids (BLANKERSHIP & ALFORD, 1983).

Termites bring mineral elements such as potassium which plays an essential role in the synthesis of amino-acids and proteins (MALIK & SRIVASTAVA, 2015) ; calcium and magnesium which intervene in the carbohydrates and nucleic acid metabolism (MABOSSY-MOBOUNA, 2017) ; sodium, calcium and phosphorus which allow good ossification of the foetal skeleton, favouring the children's growth and strengthening adults' bones (SCHAPIRA, 1981). Magnesium allows a good development of pregnancy seeing that it has a powerful relaxing action on the myometer.

The ratio of sodium/potassium, being lower than one, is favourable to the good functioning of the organism. Indeed, the studies of HE and MACGREGOR (2008) have pointed out that, when the ratio sodium/potassium in a food is below one, this food reduces the blood pressure, the cardiovascular mortality, protects the renal function and prevents the urinary lithiasis and osteoporosis. This low sodium content may be profitable for people suffering from high blood pressure. Nevertheless, foods rich in potassium are generally missing from the diet of persons suffering from a renal insufficiency (MC CAY et al. 1975, SOUDY 2011).

The Ca/P ratio akin to one in *Macrotermes bellicosus* allows an important absorption of calcium but a low fixation in the organism because the Ca/Mg ratio is below two. On the other hand, in *Macrotermes subhyalinus*, this ratio, which is much below one, leads to a low absorption of calcium (COMELADE, 1995), but its fixation is important in the body because the Ca/Mg ratio is nearly equal to two (GAYET & CAZEL, 2002). In this way, the foods eaten with termites in the meal must have more calcium to compensate..

Table 7.- Mineral composition of termites (mg/100 g of dry matter).

Mineral elements	*M. bellicosus* (c)	*M. falciger* (a)	*M. subhyalinus* (d)	*Pseudacanthoter-mes militaris* (c)	*Ps. spiniger* (c)
Potassium	860.30	110	497.96		
Sodium	180.92		402.87		
Magnesium	107.69	26	107.64		
Calcium	152.11	42	225.21	48.31	42.89
Phosphorus	141.29		500.36		
Iron	7.9		70.54	60.29	64.77
Copper	3.81		4.70		
Zinc	19.70		10.97	12.86	7.10
Manganese	8.65		32.5		
Na/K	0.21		0.81		
Ca/P	1.07		0.45		
Ca/Mg	1.41		2.09		

Regarding the fatty acids composition (Table 8), the fifth termite species has important amounts of oleic, palmitic and stearic acids. The content of alpha-linolenic acid is very weak. Regarding the degree of saturation (Table 9), termites containing much monounsaturated fatty acids, followed up by the saturated fatty acids, except for *Macrotermes bellicosus* which has more saturated fatty acids as monounsaturated fatty acids. Moreover those termites have weak contents in polyunsaturated fatty acids. Nevertheless, the unsaturated fatty acids content regarding the five termite species is greater than 50 %, with a lower content in essential unsaturated fatty acids (C18:3 ω3 and C18:2 ω6).

Table 8.- Fatty acid profile (g/100 g of the total of fatty acids) of fatty matters.

Fatty acids	*M. belli-cosus* (c)	*M. falciger* (a)	*M. subhya-linus* (d)	*Pseudacan-thotermes militaris* (c)	*Pseud. spiniger* (c)
Caprilic acid (C10:1)	0.42	nd	nd	nd	0.39
Capric acid (C10:0)	0.24	nd	nd	0.21	0.31
Lauric acid (C12:0)	0.18	nd	nd	nd	0.22

Myristic acid (C14:0)	1.16	0.9	1.06	nd	0.76
Palmitic acid (C16:0)	38.35	29.6	27.65	26.04	28.04
Palmitoleic acid (C16:1)	0.63	nd	4.17	5.84	3.24
Stearic acid (C18:0)	9.53	8.4	6.34	5.92	6.12
Oleic acid (C18:1)	41.74	49.1	48.60	50.26	49.27
Linoleic acid (C18:2)	5.03	8.8	10.75	11.54	10.48
Linolenic acid (C18:3)	0.87	nd	1.43	0.20	0.78

Table 9.- Saturation degree of diverse fatty acids (%) and diverse ratio.

	M. bellicosus (e)	*M. falciger* (a)	*M. subhyalinus* (d)	*Pseudacanthotermes militaris* (c)	*Pseud. spiniger* (c)
Saturated fatty acids	49.46	39.3	35.05	32.17	35.84
Monounsaturated fatty acids	44.64	51.8	52.77	56.10	52.90
Poly-unsaturated fatty acids	5.90	8.8	12.18	11.73	11.26
Unsaturated fatty acids	50.54	60.6	64.65	67.83	64.16
ω6/ω3	5.80		7.50	57.70	13.40
PUFA/SFA	0.12	0.22	0.34	0.36	0.31

Table 10.- Iodine index of each species (MAGE = **m**ono**a**cyl**g**lycerol **e**ster).

Fatty acids	MAGE	*M.b.* (c)	*M.f.* (a)	*M.s.* (c)	*P.m.* (c)	*P.s.* (c)
Caprilic acid (C10:1)	184	0.58	nd	nd	nd	0.54
Capric acid (C10:0)	186	0	0	0	0	0
Lauric acid (C12:0)	214	0	0	0	0	0
Myristic acid (C14:0)	242	0	0	0	0	0
Palmitic acid (C16:0)	270	0	0	0	0	0
Palmitoleic acid (C16:1)	268	0.60	nd	3.95	5.53	3.07
Stearic acid (C18:0)	298	0	0	0	0	0
Oleic acid (18:1)	296	35.82	42.13	41.70	43.13	42.28
Linoleic acid (C18:2)	294	8.69	15.21	18.57	19.94	10.11
Linolenic acid (C18:3)	292	2.27	nd	3.73	0.52	2.04
Iodine index		47.96	57.34	67.95	69.12	58.04

The iodine indices (Table 10) are less important (<80), which indicates that their fats do not accelerate drying. The ω6/ω3 ratio of the fatty acid of these termites (Table 9) is greater than 5, which is not favorable to a good functioning of the organism. Indeed an excess of ω6 in the dietary ratio prevents the organism from adequately exploiting the ω3 sources. This imbalance induces, among others, a physiological state favourable to cardiovascular diseases, osteoporosis, obesity and diabetes as well as allergic and inflammatory disorders (FAO, 2014). It also induces micro-vascularisation disorders, a chronic inflammation, plaque aggregation and endothelial dysfunctions (OTSUKA et al., 2002). Moreover an excess of ω6 will favour the DPA (C22: 5 n-6) synthesis to the detriment of the EPA and the DHA. Thus it prevents the optimal using of ω3 for the organism. It is thus of importance to keep an equilibrium between the ω3 fatty acids and the ω6 fatty acids. The necessity of associating termites with food having this very weak ratio appears to be necessary. The majority of termites possess a PUFA/SFA ratio >0.20 (BANJO et al., 2005), associated with a low level of cholesterol and weak risk of coronary artery disease. However, *Macrotermes bellicosus* present such a ratio <0.20, that is linked to a high level of cholesterol and high risk of coronary troubles.

Detailed study of the fatty mass of Macrotermes bellicosus

Table 11. Total lipid and lipid fractions in ***Macrotermes bellicosus*** oil.
[Values from Ekpo & Onigbinde, 2007]

Lipid and lipid fractions	% composition
Total lipid	31.46 ± 0.57 (wet weight)
	32.16 ± 0.28 (dry weight)
Neutral lipid	69.87 ± 0.73
Phospholipid	19.14 ± 0.06
Glycolipid	10.81 ± 0.40

Table 12. Physicochemical characteristics of ***Macrotermes bellicosus*** oil.
[Values from Ekpo & Onigbinde, 2007]

Physical characteristics	**Values**
Specific gravity	0.90 ± 0.01
Solidifcation value	10-14°C
Refractive index	1.2 ± 0.01
Acid value	3.60 ± 0.06
Iodine value	108 ± 0.15
Sapoification value	193.40 ± 0.31
Unsaponifiable matter	12.40 ± 0.11
Free cholesterol (mg/100g lipid)	8.73 ±1.01
Total cholesterol (mg/100g lipid)	41.80 ± 0.15
Total phosphorus (mg/g lipiud)	47.18 ± 0.03

Table 13. Fatty acid composition of ***Macrotermes bellicosus*** oil.
[Values from Ekpo & Onigbinde, 2007]

Fatty acid	**% composition**
Lauric acid (C 12:0)	1.50 ± 0.28
Myristic acid (C 14:0)	2.17 ± 0.06
Palmitic acid (C 16:0)	42.45 ±0.20
Palmitoleic acid (C 16:1)	2.10 ± 0.02
Stearic acid (C 18:0)	2.86 ± 0.10
Oleic acid (C 18:1)	15.84 +0.40
Linoleic acid (18 :2)	24.24 ± 1.08
Linolenic acid (18 :3)	3.90 ± 0.60
Arachidonic acid (C 20:4)	4.94 ± 0.15

Table 14. Fatty acid composition of lipid fractions in ***Macrotermes bellicosus*** oil.
[Values from Ekpo & Onigbinde, 2007]

Fatty acids	**Neutral lipid**	**Phospholipid**	**Glycolipid**
Lauric acid (C 12:0)	1.03 ± 0.08	0.92 ± 0.11	trace
Myristic acid (C 14:0)	2.80 ± 0.17	4.86 ± 0.21	1.0 ± 0.03
Palmitic acid (C 16:0)	41.54 ± 0.90	33.15 ± 0.40	40.03 ± 0.60
Palmitoleic acid (C 16:1)	2.09 ± 0.28	4.10 ± 0.11	2.14 ± 0.15
Stearic acid (C 18:0)	2.30 ± 0.19	2.31 ± 0.20	1.89 ± 0.17
Oleic acid (C 18:1)	11.84 ± 0.55	13.02 ± 0.35	35.38 ± 0.91
Linoleic acid (C 18:2)	31.42 ± 0.25	34.14 ± 0.45	15.20 ± 0.20
Linolenic acid (C 18:3)	3.85 ± 0.01	2.01 ± 0.10	4.36 ± 0.21
Arachidonic acid (C 20:4)	3.13 ± 0.15	5.49 ± 0.05	trace

Table 11 and Table 15 confirm the high level of unsaturation in *Macrotermes bellicosus* oil. Palmitic and linoleic (an essential fatty acid) acids are the major fatty acids in insect oil as well as in the neutral and phospholipid fractions, while the glycolipid fraction has palmitic and oleic acids as the major fatty acids.

Table 15. Degree of saturation of ***Macrotermes bellicosus*** oil (% composition).
[Values from Ekpo & Onigbinde, 2007]

Parameter	Whole	Neutral	Phospholipid	Glycolipid
TSFA	48.98	47.67	41.24	42.92
TUFA	51.02	52.33	58.76	57.08
MUFA	17.94	13.93	17.12	37.52
PUFA	33.08	38.40	41.64	19.56

TSFA = Total saturated fatty acid. TUFA = Total unsaturated fatty acid.
MUFA = Monounsaturated fatty acid. PUFA = Polyunsaturated fatty acid.

Nutritive value of termite variations

Table 16 . Amino acid profiles of males and females of ***Macrotermes falciger*** (% of proteins content).
[Values from Phelps et al., 1975]

Amino acids	Males	Females
Glycine	4.5	4.6
Alanine	6.2	6.1
Valine	5.4	5.6
Leucine	7.5	7.4
Isoleucine	4.0	4.1
Serine	4.0	4.1
Threonine	4.0	4.0
Arginine	5.8	6.5
Lysine	6.6	6.9
Glutamic acid	10.5	10.4
Aspartic acid	9.0	8.9
Cysteine	traces	traces
Methionine	1.6	1.5
Methionine + cysteine	1.6	1.5
Phenylalaline	4.6	4.6
Tyrosine	6.9	6.2
Aromatic amino-acids	11.5	10.8
Proline	5.6	5.0
Histidine	3.0	3.1
Tryptophan	nd	nd

The sex of each individual has no influence on the amino-acid profiles of the termites (Table 16).

Table 17. Fatty acid (%) composition profiles of ***Macrotermes falciger*** according to castes involved. [Values from Lognay & Malaisse, 2010]

Fatty acids	**Alate adult**	**Soldier (small)**	**Soldier (large)**
Myristic acid (C14: 0)	0.9	nd	nd
Pentadecyclic acid (C15: 0)	0.2	0.7	0.8
Palmitic acid (C16: 0)	29.6	8.3	3.7
Palmitoleic acid (C16: 1)	2.7	0.8	nd
Margaric acid (C17: 0)	0.1	2.1	1.4
Stearic acid (C18: 0)	8.4	16.3	10.8
Oleic acid (C18:1)	49.1	54.3	63.7
Linoleic acid (C18:2)	8.8	18.4	19.6
Linolenic acid (C18:3)	nd	nd	nd
SFA	39.2	27.4	16.7
MUFA	51.8	54.3	63.7
PUFA	8.8	18.4	19.6
PUFA/SFA	0.22	0.67	1.17

The fatty acid composition varies very significantly according to the termites castes (Table 17). The winged adults are richer in saturated fatty acids than the soldiers, but poorer in polyunsaturated acids; large soldiers are richer in monounsaturated fatty acids than the smaller soldiers but poorer in polyunsaturated fatty acids. Whatever the termite castes, the PUFA/SFA ratio is > 0.20, which suggests that the consumption of these insects is linked to a low risk of some coronary illnesses.

Table 18. Protein digestibility (%) of four castes of ***Macrotermes subhyalinus***. (Values from Ajayi, 2012]

Termite caste	Protein digestibility (%)
Queen	84.72
Worker	82.37
Soldier	81.10
Alate	83.41

These results show that proteins, in the four castes of *Macrotermes subhyalinus*, are highly digestible (Table 18). However protein digestibility varies according to castes, the queen having the highest digestibility value. On the other hand the lower values for soldiers can be explained by their work in search of food and again in defending the colony.

Table 19. Anti-nutrient content (%) of four castes of ***Macrotermes subhyalinus***. (Values from Ajayi, 2012]

Termite caste	Oxalate (%)	Phytate (%)	Tannin mg TA/100 g)
Queen	0.0068	0.0175	4.7×10^{-8}
Worker	0.0117	0.1300	5.5×10^{-8}
Soldier	0.0084	0.0286	4.8×10^{-8}
Alate	0.0054	0.0156	4.8×10^{-8}

While numerous plant products contain anti-nutrient substances that reduce their bioavailability, Table 19 shows that the termites consumed by man contain very low quantities of anti-nutrient substances, which allows them to be considered as feed with high nutritional quality, concerning both their digestibility and their biodiversity.

The anti-nutrient levels of *Macrotermes subhyalinus* are lower than those reported for some animal and plants products. The low level of anti-nutrients recorded for the four castes of this species confirms that this termite species is safe for human and animal consumption (AJAYI, 2012).

Table 20. Physicochemical properties of the oil of four castes of ***Macrotermes subhyalinus***.
(Values from Ajayi, 2012)

Termite castes	Refractive index (20°C)	Density (29°C)	Colour	Acid value (mgKOH /g)	Peroxyde value (mgKOH /g)	Iodine value (mg/g)	Saponification value (mgKOH /g)	Free fatty acid value (mgKOH /g)	Unsaponifiable matter (%)
Queen	1.46	N.D.	brownish	1.08	0.44	138.21	2.15	157.18	2.22
Soldier	1.46	N.D.	brownish	1.83	2.49	208.07	260.69	3.67	2.10
Worker	1.46	N.D.	golden yellow	1.81	2.20	143.23	338.58	3.63	1.95
Alate	1.47	0.92	golden yellow	1.46	0.78	118.60	108.45	2.95	2.25

These results show that the termite castes oils are good for domestic and industrial purposes as well (Table 20). In conclusion, all the castes are safe for human consumption and of immense nutritional benefit for the body due to their high protein digestibility (AJAYI, 2012).

Cooking effects on the nutritive value of termites

The various effects of cooking will be approached through four new Tables, namely Table 21 to 24.

Table 21. Global chemical compositions (%) and energetic chemical compositions (KJ/100g) of raw and cooked *Macrotermes bellicosus*. (values from Badanaro et al., 2018)

Reviewed parameters	Raw *M. bellicosus*	Cooked *M. bellicosus*
Water	7.23 ± 0.35	3.61 ± 0.43
Total ashes	6.79 ± 1.08	6.83 ± 0.93
Total proteins	38.34 ±1.03	39.54 ± 0.15
Fatty matters	39.51 ± 1.33	42.44 ± 1.07
Total fibres	5.66 ± 0.20	5.23 ± 0.11
Easely digested fibres	0.38 ± 0.29	0.34 ± 0.09
Metabolizable energies	2218.55 ± 35.03	2324.28 ± 37.36

The water content of raw *M. bellicosus* is weak compared with the value of the cooked product. The protein content of the cooked *M. bellicosus* termites is significantly higher than that of the raw termites (BADANARO et al., 2018)

Table 22. Mineral composition (mg/100 g) of raw and cooked *M. bellicosus* (values from Badanaro et al., 2018).

Reviewed parameters	Raw *M. bellicosus*	Cooked *M. bellicosus*
Sodium (Na)	180.92 ± 0.87	350.6 ± 0.29
Potassium (K)	860.30 ± 1.02	360.28 ± 1.05
Calcium (Ca)	152.11 ± 0.98	154.44 ± 3.22
Magnesium (Mg)	107.69 ± 1.47	100.6 ± 1.50
Phosphorus (P)	141.29 ± 0.97	124.95 ± 2.55
Iron (Fe)	7.9 ± 0.62	10.27 ± 0.47
Zinc (Zn)	19.70 ± 0.32	17.70 ± 0.32
Manganese (Mn)	8.65 ± 0.4	6.81 ± 0.15
Copper (Cu)	3.81 ± 0.12	3.43 ± 0.06
Sodium/Potassium	0.21	9.7
Calcium/Phosphorus	1.07	1.23

Table 23. Vitamin composition (mg/100 g) of raw and cooked *M. bellicosus* (values from Badanaro et al., 2018).

Reviewed parameters	Raw *M. bellicosus*	Cooked *M. bellicosus*
Retinol (A)	0.03 ± 0.01	0.01 ± 0.00
Thiamin (B1)	0.91 ± 0.10	0.26 ± 0.01
Riboflavine (B2)	2.16 ± 0.16	1.29 ± 0.07
Niacine (B3)	6.13 ± 0.01	6.03 ± 0.14
Tocopherol (E)	4.55 ± 0.05	6.18 ± 0.07

Table 24. Fatty matters (FM) characterization of *M. bellicosus* (values from Badanaro et al., 2018).

Culinary technology	Acid Index (mg of KOH/g of FM)	Peroxyde Index (meq of oxygen/kg of FM)	Iodine Index (g of iodine/100 g of FM)
Raw *M. bellicosus*	3.95 ± 0.14	5.25 ± 0.00	91.82 ± 4.10
Cooked *M. bellcosus*	4.7 ± 0.33	7.27 ± 0.01	88.1 ± 1.45

With cooking, the fat content increases. Nevertheless, the nutritional value of the cooked forms is markedly reduced as indicated by their fat index being slightly higher than the recommended values and their iodine index is low. The peroxide indices are significantly higher in the fatty matters of the cooked insects. What indicates that, during the cooking, the fatty matters undergo a significant deterioration. Concerning the minerals, the contents in mineral elements have varied, according to the element. The differences between the ratio sodium/potassium and calcium/phosphorus of the cooked and raw forms are weak and located below or very close to the limit values that are respectively of 1 and 1.3. After cooking the contents of hydrosoluble vitamins decrease, while the contents of liposoluble vitamins increase for the insects analysed after (BADANARO et al., 2018).

DISCUSSION

In the present period, where a healthy diet combined with a respect for the environment is a fundamental consideration for a very great part of tropical Africa, termites may locally and during relatively short periods provide a solution, though certainly limited but not negligible. Our study has focused on the various aspects rarely investigated and, when they have been considered, mostly with a lack of a profound study.

Of the 32 termite species consumed by man that we have been able to list in the scientific literature, 24have been identified to the species level and 8 only at genus level. These termites belong to two families, the Termitidae and the Hodotermitidae, with a broad predominance of the Termitidae (93.75 %); the sub-family of the Macrotermitidae representing 84.4% of the edible termites. However the important species vary according to the countries considered.

Among these edible species, only five have been the subject of profound chemical studies that have pointed out a good nutritional balance in essential amino-acids and mineral elements, and generally a good PUFA/SFA ratio. Nevertheless these termites present a low content of ω3 fatty acids, conducting to a ω6/ω3 ratio which is very high compared to the actual recommendations (FAO, 2010). In this way, the food which is served with the termites needs to have more ω3 in order to move the ratio to 5. Moreover, these termites are very rich in oleic acid, a fatty acid that provides a favourable action on the health providing “good” cholesterol (FAO/OMS, 1993; FAO, 2014). This richness in oleic acid ensures good stability during the frying and cooking because this fatty acid is subject few sensible to oxidation (MABOSSY-MOBOUNA et al., 2017).

These termites also contain high contents of palmitic acid which is reputed to be atherogenic. Nevertheless, its action could be appeased by the simultaneous presence of stearic and oleic acids. Indeed, these two fatty acids each contribute to the increase in HDL-cholesterol (FAO/OMS, 1993 ; FAO, 2014).

The low iodine rating of the fatty matter of these termites indicates that this matter is very slowly oxidizable.

The energy value of these termites is similar to that indicated by the FAO (2004), which noted a high energy in the edible insect flour, so that their incorporation into flour for children has been encouraged.

Finally we should underline that the diverse stages of the termites are to be taken into consideration for they present different characteristics. In the same way the method of cooking modifies their nutritive values.

CONCLUSION

This study provides a general view of the nutritive value of the termites consumed in tropical Africa. Termites are important sources of proteins with high biological value, lipids rich in ω6 fatty acids and significant amount of minerals. They should be able to contribute to the fight against dietary insecurity, protein-energy malnutrition and nutritional deficiency in Africa. Termites consumed in Africa could be mixed into the food of pregnant women and of nursing mothers, of infants during weaning periods, for senior citizens and persons suffering from some nutritional deficiencies.

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REFERENCES

ADEPOJU O.T. & OMOTAYO O.A., 2014. Nutrient composition and potential contribution of winged termites (*Macrotermes bellicosus* Smeathmann) to micronutrient intake of consumers in Nigeria. *British Journ. of Applied Science & Technology*, **4**(7): 1149-1154.

AL DIN GUIRGIS S., 2013. Nutrient and anti-nutrients in eatable termites (*Macrotermes bellicosus*) collected from Ibesikpo Asutar, Nigeria. *Amer. J. Natural Sci.*, **2013**(3): 1-5.

AJAYI O.E., 2012. Biochemical Analyses and Nutritional Content of Four Castes of Subterranean Termites, *Macrotermes subhyailnus* (Rambur) (Isopetra: Termitidae): Differences in Digestibility and Anti-nutrient Contents among Castes. *International Journal of Biology*, **4**(4): 54-59.

AOAC, 2003. Official methods of Analysis of AOAC International. 18^{th} ed. Arlington (Texas, U.S.A.), 275 p.

BADANARO F., HOUNDJI B.V.S., MELILA M., AMEVOIN K. & AMOUZOU S.K.E., 2018. Potentiel nutritionnel de Macrotermes bellicosus (Smeathman, 1781) (isoptera : termitidae), une des espèces d'insectes comestibles les plus commercialisées au Togo. *Journal de la Recherche Scientifique de l'Université de Lomé*, **20**(3): 41-50.

BAHUCHET S., 1985. *Les Pygmées Aka et la forêt centrafricaine*. (Ethnoscinces n° 1), Paris, Selaf/CNRS, 640 p., 148 fig., 31 tableaux, 40 planches h.-t.

BEQUAERT J.C., 1921. Insects as food. *J. Amer. Mus. Nat. Hist.*, **21**: 191-200.

BLANKERSHIP D.C. & ALFORD B.B., 1983. Cottonseeds, the new staff of life. A monograph of cotton seeds protein research conducted by Scientists at Texas Woman's. University Press, Denton, Texas 76: 204.

BODENHEIMER E.S., 1951. *Insects as human food: a chapter of the ecology of man.* Den Haag (The Netherlands), W.Junk, 352 p.

CALLEWAERT R., 1922. Witte mieren in Kasai. *Congo*, **2**: 335-355.

COMELADE E., 1995. Technologie et hygiène alimentaire-1er cahier : les nutriments. 7eme ed., Paris : Jacques Lanor, 144p.

DA SILVA F.L., MONTEZE G.V., GONCALVES DE BARROS E., MOREIRA M., DOS SANTOS D.L.A., GORETI DE ALMEIDA O.M., CHAMEL J.L. & TAVARES DE REZENDE S., 2006. Biochemical composition and indigestible oligosaccharides of Phaseolus vulgaris L. seeds. *Plant Foods for Human Nutrition*, **61**(2): 87-89.

DEFOLIART G.R., 2002. *The Human Use of Insects as Food Resource: A bibliographic account in progress.* www.food-insects.com (10.5.2009).

DEOSTHALE Y.G., MOHAN V.S. & RAO K.V., 1970. Varietal deficiencies in protein, lysine and leucine content of grain sorghum. *Journal of Agriculture and Food Chemistry*, **18**: 644-646.

DOUNIAS E., 2016. Des moissons éphémères. L'art de collecter et de consommer les termites sous les tropiques. *In* E. Motte-Florac & P. Le Gall (Dir.), « *Savoureux insectes. De l'aliment traditionnel à l'innovation gastronomique* ». Table des Hommes, Tours (France), Presses universitaires François Rabelais de Tours /

Rennes (France), Presses universitaires de Rennes / Marseille (France) Institut de Recherche pour le Développement, 237-272.
EKPO K.E. & ONIGBINDE A.O., 2007. Characterization of Lipids in Winged Reproductives of the Termite *Macrotermes bellicosus*. *Pakistan Journal of Nutrition*, **6**(3): 247-251.
FAO, 2004. *Les insectes comestibles, importante source de protéines en Afrique centrale.* Rome (Italie) 45 p.
FAO, 2014. *Graisses et acide gras dans la nutrition humaine.* Rapport d'une consultation d'experts. Genève (Suisse). FAO, 178 p.
FAO/OMS, 1993. *Les graisses et huiles dans la nutrition humaine.* Rapport d'une consultation mixte d'experts. Rome, FAO, 26 p.
FAO/UNU/WHO, 2007. Protein and amino acid requirements in human nutrition. Report of a Joint WHO/FAO/UNU Expert Consultation. WHO Technical Report Series 935. Geneva (Switzerland), WHO, 284 p.
FELIX IROKO A., 1996.*L'homme et les termitières en Afrique.* Éditions Karthala, Paris, 298 p.
GAYET B. & CAZEL A.R., 2002. Les clés de la nutrithérapie. Précis de nutrition orthomoléculaire. Escalquens (France), Edit. Quintessence, 341p.
GRIVETTI L.E., 1979. Kalahari agro-pastoral-hunter-gatherers: The Tswana example. *Ecology of food and Nutrition*, **7**: 235-256.
HARPER A.E., BENTON D.A. & ELVEHJEM C.A., 1955. L- Leucine, and isoleucine antagonist in the rat. *Archives of Biochemistry and Biophysics*, **57**: 1-12.HARRIS W.V., 1940. Some Notes on Insects as Food. *Tanganyika Notes Records* (Dar es Salaam), **9**: 45-48.
HE F.J. & MACGREGOR G.A., 2008. Beneficial effects of potassium on human health. *Physiol. Plant*., **133**(4): 725-735.
HEGH E., 1922. *Les termites. Partie générale. Description.- Distribution géographique.- Classification.- Biologie.- Vie sociale.- Alimentation.- Constructions.- Rapports avec le monde extérieur.* Imprimerie Industrielle et Financière. Bruxelles, 756 p.
HEYMANS J.-C. & EVRARD A., 1970. Contribution à l'étude de la composition alimentaire des Insectes comestibles de la Province du Katanga (R.D.C.). *Probl. Soc. Congolais (Bull. Trimest. C.E.P.S.I.)*, **90-91**: 333-340.
KINYURU J.N., KONYOLE S.O., ROOS N., ONYANGO C.A., OWINO V.O., OWUOR B.O., ESTAMBALE B.B., FRIIS H., AAGAARD-HANSEN J. & KENJI G.M., 2013. Nutrient composition of four species of winged termites consumed in western Kenya. *Journ. of Food Composition and Analysis*, **30**: 120-124.
LOGAN J.W.M., 1992. Termites (Isoptera) a pest or resource for small farmers in Africa. *Trop. Sci.*, **32**: 71-77.
LOGNAY G. & MALAISSE F., 2010. Table 2.10.9. *In* : MALAISSE (2010), page 253.
LUPOLI R., 2016. La chimie des insectes et ses implications pour leur consommation. *In* E. Motte-Florac et P. Le Gall (Dir.), *Savoureux insectes. De l'aliment traditionnel à l'innovation gastronomique.* Table des Hommes, Tours (France), Presses universitaires François Rabelais de Tours / Rennes (France), Presses universitaires de Rennes / Marseille (France) Institut de Recherche pour le Développement, 207-219.
MABOSSY-MOBOUNA G., 2017. *Caractérisation et valorisation alimentaire des chenilles d'Imbrasia truncata (Aurivillius, 1908) au Congo-Brazzaville.* Thèse de doctorat de Nutrition humaine, Université Marien Ngouabi, Faculté des Sciences et Techniques, Congo-Brazzaville, 171 p.
MABOSSY-MOBOUNA G., KINKELA T. & LENGA A., 2017. Apports nutritifs des chenilles d'*Imbrasia truncata* consommées au Congo-Brazzavile. *Journal of Animal & Plant Sciences*, **31**(3): 5050-5062.
MALAISSE F., 1997. *Se nourrir en forêt claire africaine. Approche écologique et nutritionnelle.* Gembloux (Belgique) : Les Presses agronomiques de Gembloux / Wageningen (The Netherlands) : Centre technique de coopération agricole et rurale (C.T.A.), 384 p.
MALAISSE F., 2010. *How to live and survive in Zambezian open forest (Miombo ecoregion).* Gembloux (Belgium). Les Presses Agronomiques de Gembloux, 422 p. + CD.
MALAISSE F., 2019. Human termitophagy in Africa. *Geo-Eco-Trop*, **43**(1): 1-24.
MALAISSE F., 2020. Termites and termite mounds – Some selected observations. *Bull. Séanc. Acad. R. Sci. Outre-Mer*, **63**: 89-122.
MALAISSE F. & PARENT G., 1997. Chemical composition and energetic value of some edible products provited by hunting and gathering in the open forest (Miombo). *Geo-Eco-Trop*, **21**: 65-71.
MALIK C.P. & SRIVASTAVA A.K., 2015. *Textbook of Plant Physiology*. New Delhi, Kalyani Publishers.
MC CAY C.M., MC CAY J.B. & SMITH O., 1975. The nutritive value of potatoes. *In*: Talburt W.F. & Smith O. (Eds.), Potato Processing. Westport (Connacht, Irlande), 3rd Ed., 235-273.
MUSUNDIRE R., ZVIDZAI C.J., CHIDEWE C., SAMENDE B.K. & CHEMURA A., 2016. Habitats and nutritional composition of selected edible insects in Zimbabwe. *Journal of Insects as Food and Feed*, **2**(3): 145-152.

NIABA K.P.V., GBOGOURI G.A., BEUGRE A.G., ATCHIBRI O.-A. & GNAKRI D., 2011. Potentialités nutritionnelles du reproducteur ailé du termite *Macrotermes subhyalinus* capturé à Abobo-doumé, Côte d'Ivoire. *Journal of Applied biosciences*, **40**: 2706-2714.

NGUDI D., KUO V.H. & LAMBIEN F., 2003. Amino-acid profiles quality of cooked Cassava or « saka-saka. *J. Sci. Agri.*, **83**: 529-534.

NKUNIKA P.O.Y., 1998. *Termite survey, identification, damage and control in southern province.* Lusaka (Zambia): Land Management and Conservation Farming. Soil Conservation and Agroforestry Extension report.

NYEKO N. & OLUBAYO F.M., 2005. *Participatory assessment of farmers' experiences of termites problems in agroforestry in Tororo district, Uganda.* Agricultural Research and Extension Network. Network paper N° 143. London: The Overseas Development Institute. 19 p.

OTSUKA M., YAMAGUCHI K. & UEKI A., 2002. Similarities and differences between Alzheimer's disease and vascular dementia from the viewpoint of nutrition. *Ann. New York Acad. Sci*., **977**: 155-161.

OUÉDRAOGO M., 2005. *Les termites ailés sont une source précieuse en période de soudure alimentaire au Burkina Faso*. Thèse annexe, Faculté Universitaire des Sciences Agronomiques de Gembloux, Belgique, 26 p.

PAYNE C.L.R., UMEMURA M., DUBE S., AZUMA A., TAKENAKA C. & NONAKA K., 2015. The mineral composition of five insects as sold for human consumption in Southern Africa. *African Journal of Biotechnology*, **14**(31): 2443-2448.

PHELPS R.J., STRUTHERS J.K. & MOYO S.J.L., 1975. Investigations into the nutritive value of *Macrotermes falciger* (Isoptera: Termitidae). *Zoologic Africana*, **10**(2): 123-132.

QUINN P.J., 1959. *Foods and feeding habits of the Pedi.* Johannesburg (South Africa), Witwatersrand University Press, 278 p., 134 plates.

REIS DE FIGUEIRÊDO R.E.C., VASCONCELLOS A., POLICARPO I.S. & NÓBREGA ALVES R.R., 2015. Edible and medicinal termites : a global overview. *J. Ethnobiol. Ethnomed.*, **11**:29 doi : 10.1186/s13002-015-0016-4

ROULON-DOKO P., 1998. *Chasse, cueillette et culture chez les Gbaya de Centrafrique.* Éditions L'Harmattan, Collection Anthropologie – Connaissances des hommes, Paris, 539 p.

SEIGNOBOS C., DEGUINE J.P. & ABERLENC H.P., 1996. Les Mofu et leurs insectes. *J. Agric. Trad. Bot. Appl .*, **38**(2): 35-87.

SHOCKLEY M. & DOSSEY A.T., 2014. Insects for Human Consumption. *In* J.A. Morales-Ramos, M. Guadalupe & D.I. Shapiro-Ilan (Eds.). *Mass Production of Beneficial Organisms : Invertebrates and Entomopathogens*, Academic Press, 617-652.

SILOW C.A., 1983. Notes on Ngangela and Nkoya Ethnozoology. Ants and Termites. Goeteborg, Etnografiska Musem, *Etnologiska Studier*, **36**: 177 p.

SOUDY I.D., 2011. Pratiques traditionnelles, valeur alimentaire et toxicité du taro (Colocasia esculenta L. Schott) produit au Tchad. Agricultural Science, Université Blaise Pascal Clermond Fernand II, 152 p.UKHUN M.E. & OSASONA M.A., 1985. Aspects of the nutritional chemistry of Macrotermis bellicosus. *Nutrition Reports International*, **32**(5): 1121-1130.

VAN HUYS A., 2017. Cultural importance of termites in sub-Saharan Africa. *J. Ethnobiol. Ethnomed.*, **13**(1): 8. DOI 10.1186/s13002-017-0137/z

YAGI S., 1997. *Case Study of Edible Insects in Enzaro Village, Kenya.* http://jircas.affrc.go.jp/english/publication/annual/1997/divisions/cropprod.pdf (9.12.2019).