INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 3, No. 1, p. 58-69, 2013

RESEARCH PAPER OPEN ACCESS

Quality characteristics of biscuits made from sorghum and defatted *Macrotermes subhyalinus*

Niaba Koffi P.V.[*1,2], Brou Kouakou[1], Gbassi K. Gildas[3], Amani Thierry[2], Kone N'golo[4], Gnakri Dago[1]

[1]*Laboratoire de Nutrition et de Sécurité Alimentaire, Unité de Formation et de Recherche en Sciences et Technologie des Aliments, Université Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire*

[2]*Laboratoire National de la Santé Publique, 18 BP 2403 Abidjan 18, Côte d'Ivoire*

[3]*Département de Chimie Analytique, Chimie Générale et Minérale, Unité de Formation et de Recherche en Sciences Pharmaceutiques et Biologiques, Université FHB, BPV 34 Abidjan 01, Côte d'Ivoire*

[4]*Laboratoire de biologie et cytologie animale, Université Nangui Abrogoua, Côte d'Ivoire*

Key words: Sorghum, protein density, carbohydrate, biscuits.

Article published on January 20, 2013

Abstract

Deffated *Macrotermes subhyalinus* Flour (DMF) was mixed with sorghum flour for the manufacturing of biscuits. Varying amounts of DMF were added for a maximum content of 25 % (w/w). The code for the biscuit control was BS0 and the code for the biscuit enriched for example with 25 % of DMF was BS25. Physical characteristics and nutritional and sensory qualities of biscuits were determined. Biscuit protein levels increase with incorporation of DMF. Values increased from 09.64% (BS0) to 21.66% (BS25). The fat content down from 21.51% (BS0) to 19.03% (BS25). The rate of carbohydrate down from 60.02% (BS0) to 47.35% (BS25). The ash and cellulose contents increase respectively from 2.26% (BS0) to 3.54% (BS25) and 2.63% (BS0) to 4.44% (BS25). The pH of biscuits increase with the incorporation of DMF but the difference was not significant ($p<0.05$). As for the total acidity, it decreases in the various types of biscuits, but this decrease was not significant ($p<0.05$). Total sugar content, reducing sugar content, non-reducing sugar content and starch decrease with the increase of DMF. Protein density increases significantly with incorporation of DMF, whereas lipid density decreases. The mineral composition increases in the same direction as the DMF incorporation. The diameter of biscuits increases gradually when the DMF content increased (47.90 mm to 48.57 mm from BS0 to BS25). The thickness of biscuits decreases significantly from 3.41 mm (BS0) to 2.23 mm (BS25). Mass, volume and specific volume of biscuits vary slightly despite the incorporation of DMF. Sensory analyzes show that the biscuits are acceptable up to 25% of DMF incorporation.

* **Corresponding Author:** Niaba Koffi P.V. ✉ valryniaba@yahoo.fr

Introduction

For many years, edible insects contribute to the diet of different populations in the world. Consumption of insects is an important adjunct in the diet of many people in the tropics (Sodjinou, 2002). There are more than 400 known species of edible insects (Allotey and Mpuchane, 2003). In Africa, many insect species have been used as traditional foods among indigenous populations (Sutton, 1988).*Macrotermes subhyalinus*, simply called "Termite" is an important part of the diet in some regions of the tropics. In Côte d'Ivoire, termites emerge with the first rains at the end of the dry season. These termites have a high nutritional value (Niaba *et al.,* 2011). In Kenya, the communities of Victoria Lake recommend termites for children and pregnant women (Kinyuru *et al.,* 2009). Termites are eaten raw or fried, usually in the context of a complete meal or with tapioca, bread or maize (Kinyuru *et al.,* 2009). Ordinarily, the termites are not used as emergency food during shortages, but are included as a planned part of the diet throughout the year or when seasonally available (Banjo *et al.,* 2006).

Consumption of termites could be greatly improved using modern technical of drying and storage. The current traditional cooking and drying cause problems of acceptability and food hygiene. Given the shortages of food reserves in sub-Saharan Africa, the use of insects as food should be encouraged to fight against malnutrition. In this context, the incorporation of the insect in the manufacture products must be considered.In this study, we propose to incorporate *Macrotermes subhyalinus* in sorghum flour to manufacture sorghum biscuits and to assess the nutritional and sensory qualities of such products.

Material and methods

Sampling

Termites (*Macrotermes subhylanus*) were collected in Abobo-Doumé, village located in the municipality of Attécoubé (Abidjan, Côte d'Ivoire). Once collected, termites were transported in coolers to the laboratory. The taxonomic identification of the species was carried out in the Laboratory of Animal Biology and Cytology (University Nangui Abrogoua). Sorghum flour was purchased commercially.

Preparation of defatting Macrotermes subhyalinus flour

Termites were cleaned and rinsed with water, drained and spread on trays and dried in an oven at 65 °C during 72 h. They were subsequently stripped of their wings, ground in a blender and sieved to obtain *Macrotermes subhyalinus* flour. 3 g of this flour were dispersed in 10 ml of hexane under magnetic stirring during 1 h. The mixture was decanted on vacuum to separate hexane from fat residue. This process was repeated twice and the final residue obtained was dried at room temperature during 24 h. The residue corresponding to the defatted *Macrotermes subhylanus* flour (DMF) was preserved at 4 ° C.

Table 1. Proportions of sorghum flour and DMF.

CODE Flour	Sorghum flour	DMF
FS0	100%	0%
FS5	95%	5%
FS10	90%	10%
FS15	85%	15%
FS20	80%	20%
FS25	75%	25%

FS0: Sorghum flour , Control sample

Evaluation of the biochemical composition of simple flour and flour mixed

Biochemical compositions of DMF and flour sorghum were evaluated. A mixture of both flours was conducted in varying proportions. Flour mixed codified obtained are presented in Table 1.

Formulation of biscuits

The nature of the ingredients used in the manufacture of biscuits is shown in Table 2.

Physicochemical characterization of biscuits

The pH was determined according to AOAC method (1990) and total acidity according to the method described by Obiri-Danso *et al.* (1997). Moisture, ash and cellulose were determined according to AOAC method (1995). Proteins were assayed according to Kjedhal method (BIPEA, 1976). The fat was extracted according to AOAC method (1995) using the soxhlet. Sugars were analyzed after extraction with ethanol 80% (v/ v). Total sugars were determined by the phenol-sulfuric acid method (Dubois *et al.,* 1956), reducing sugars were determined by the method of Bernfeld (1955) and non-reducing sugars were obtained by difference. Carbohydrates were assayed by the method of Bertrand and Thomas (1910). Starches were calculated as the difference between total carbohydrates and sugars by the coefficient 0.9. Energy value corresponding to the available energy was calculated using the specific coefficients of Atwater and Benedict (1902) for proteins, lipids and carbohydrates. Nutrient density was calculated according to the method of Favier *et al.* (1995). Atomic absorption spectrophotometer was used to determine minerals according to their own wavelengths.

Table 2. Nature of ingredients used in the manufacture of biscuits.

Ingrédients (g)	BS0	BS5	BS10	BS15	BS20	BS25
Sorghum flour (g)	225	213.75	202.5	191.25	180	168.75
DMF (g)	0	11.25	22.5	33.75	45	56.25
Sugar (g)	56	56	56	56	56	56
Sunflower oil (g)	66	66	66	66	66	66
Baking powder (g)	1.5	1.5	1.5	1.5	1.5	1.5
Vanilla essence (g)	13.5	13.5	13.5	13.5	13.5	13.5
Water (g)	70	75	80	85	90	105
Total weight of pasta (g)	4 30	437	442	449	458	469

BS0 : Biscuit of Sorghum, biscuit control ; BS5: Biscuit of Sorghum with 5% of DMF, biscuit test ; BS10 : Biscuit of Sorghum with 10% of DMF, biscuit test ; BS15 : Biscuit of Sorghum with 15% of DMF, biscuit test ; BS20 : Biscuit of Sorghum with 20% of DMF, biscuit test ; BS25 : Biscuit of Sorghum with 25% de DMF, biscuit test.

Physical characterizations of biscuits

Physical parameters such as diameter, thickness, spread and specific volume were determined using AOAC procedure (2000).

Diameter of biscuits was measured by laying six biscuits edge to edge with the help of a scale rotating them 90° and again measuring the diameter of six biscuits (mm) and then taking average value. Thickness was measured by stacking six biscuits on top of each other and taking average thickness (mm). Weight of biscuits was measured as average of values of four individual biscuits with the help of digital weighing balance. Spread ratio was calculated by dividing the average value of diameter by average value of thickness of biscuits.

Specific volume: The biscuit is placed in a container of given volume. The latter is filled with the selected particles with and without the sample biscuit. The amount of particles excluded when filling in the presence of the sample after weighing allows deducing the volume of the biscuits. Based on its weight, the volume is converted into specific volume.

Sensory Evaluation

Sensory attributes like color, flavor, taste, texture, appearance and overall acceptability were evaluated by trained judges using 7-Point Hedonic Score System. The panelist gives score 7-1 to the product, ranging from 'like extremely' to 'disliked extremely' to find out the most suitable composition of biscuit.

Statistical analysis

Experiments were repeated three times, the results were subjected to analysis of variance (ANOVA). The Duncan comparison test was applied when a significant difference ($p<0.05$) between the products was revealed through software SPSS 19.

Results

Biochemical composition of sorghum flour and simple DMF

Table 3 shows the biochemical composition of sorghum flours and Deffated *Macrotermes subhyalinus* flour (DMF). DMF has a high content of protein (65.41%) and ash (12.74%) but a low content of carbohydrate, fat and cellulose with respective values of 13.89%, 1.82% and 6.14%. Sorghum flour has a high value in carbohydrate (73.30%) and low content in protein, ash, fat and cellulose (13.54%, 3.36%, 6.72% and 3.08% respectively).

Table 3. Proximate composition of raw materials.

Parameter (%)	Deffated *Macrotermes subhyalinus* Flour (DMF)	Sorghum flour
Dry Matter	90,40^{a} ± 0,88	86,80^{b} ± 0,79
Protein	65,41^{a} ± 0,68	13,54^{b} ± 0,71
Fat	1,82^{a} ± 0,08	6,72^{b} ± 0,34
Total Carbohydrate	13,89^{a} ± 0,2	73,30^{b} ± 1,7
Ash	12,74^{a} ± 0,7	3,36^{b} ± 0,7
Crude fiber	6,14^{a} ± 0,15	3,08^{b} ± 0,04
Energy (Kcal/100g)	333,58^{a} ± 1,55	407,84^{b} ± 0,41

Values are mean ± standard deviation of three measurements (n = 3). The same letter in the same row index indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$).

Biochemical composition of mixture of sorghum flour and DMF

The addition of varying amounts of DMF in sorghum flour changes the biochemical composition of resulting mixture (Table 4).The protein content increases from 13.54% (FS0) to 27.32% (FS25). The carbohydrate content decreases from 73.30% (FS0) to 57.14% (FS25). The Cellulose content increases significantly from 3.08% for the control flour FS0 to 5.73% for the test flour FS25. The ash content increases from 3.36% (FS0) to 4.33 (FS25). The fat decreases from 6.72% (FS0) to 5.48% (FS25). Energy value decreases significantly from 407.84 kcal / 100g of dry matter (FS0) to 387.16 kcal / 100g of dry matter (FS25).

Biochemical composition of sorghum biscuits supplemented with DMF.

Table 5 shows the biochemical composition of sorghum biscuits supplemented with DMF. The protein content of biscuits increases with the incorporation of DMF (from 09.64% BS0 to 21.66% BS25). The ash content increases from 2.26% for the biscuits control BS0 to 3.54% for the biscuits BS25. The cellulose content increases from 2.63% for the biscuits control BS0 to 4.44% for the biscuits BS25. Carbohydrate and fat decreases with the incorporation of DMF. The carbohydrate content decreases from 60.02% for the biscuits control BS0 to 47.35% for the biscuits test BS25. The fat decreases from 21.51% for the biscuits control BS0 to 19.03% for the biscuits test BS25.

Physicochemical characteristics of sorghum biscuits supplemented with DMF

The physicochemical characteristics of sorghum biscuits supplemented with DMF are shown in Table 6. Total acidity of biscuits decreases with the incorporation of DMF. However, the pH increases without significant difference ($p<0.05$). pH values vary from 5.64 (BS0) to 5.85 (BS25). Total acidity values increases from 4.01 meq/100 g of dry matter (BS0) to 2.70 meq/100 g of dry matter (BS25). Total sugar content, reducing sugar content, non-reducing sugar content and starch decreases with the increase of DMF. Total sugar content vary from 18.97% (BS0) to 18.21% (BS25). Reducing sugar content varies from 08.07% (BS0) to 07.82% (BS25) and non-reducing sugar content varies from 10.90% (BS0) to 10.39% (BS25). Starch content varies from 39.31% (BS0) to 30.02% (BS25). Protein density significantly increases with the incorporation of

DMF (1.99 for BS0 and 4.66 for BS25). Lipid density decreases with the incorporation of DMF without significant difference (4.45 for BS0 and 4.10 for BB25).

Table 4. Proximate composition of mixed flour (Sorghum flour / DMF).

Parameter (%)	FS0	FS5	FS10	FS15	FS20	FS25
Dry Matter	86,80^{a} ± 0,79	87,40^{a} ± 0,45	87,90^{ab}±0,26	88,50^{abc}±0,7	89,50^{bc} ±1,4	89,90^{c} ±1,5
Protein	13,54^{a} ± 0,71	15,02^{b} ± 0,06	17,00^{c}±0,15	20,20^{d}± 0,36	23,36^{e}±0,84	27,32^{f}±0,18
Fat	6,72^{a} ± 0,34	6,46^{b} ± 0,12	6,21^{b}±0,09	5,97^{b} ± 0,06	5,72^{b}±0,11	5,48^{b}±0,06
Total Carbohydrate	73,30^{a} ± 1,7	70,88^{b} ± 0,90	68,67^{c}±1,50	65,11^{d} ±0,8	61,50^{e}±0,50	57,14^{f} ± 1,1
Ash	3,36^{a} ± 0,37	3,62^{ab} ± 0,40	3,84^{ab}±0,60	4,03^{b}±0,20	4,22^{c}±0,80	4,33^{c}±0,29
Crude Fiber	3,08^{a} ± 0,04	4,02^{b} ± 0,14	4,28^{c}±0,05	4,69^{d}±0,07	5,20^{e}±0,09	5,73^{f}±0,33
Energy (Kcal/100g)	407,84^{a} ± 0,41	401,74^{b} ± 1,17	398,57^{c}±1,35	394,97^{d}±2,48	390,92^{e}±0,71	387,16^{f}±2,81

Values are mean ± standard deviation of three measurements (n = 3). The same letter in the same row index indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$).

Table 5. Proximale composition of biscuits.

Paramètres (%)	BS0	BS5	BS10	BS15	BS20	BS25
Dry Matter	96,06^{a} ± 0,36	95,91^{a} ± 0,45	95,17^{a}±0,75	95,05^{a} ± 0,84	94,90^{a}±0,56	94,81^{a}±0,78
Protein	09,64^{a} ± 0,21	11,61^{b} ± 0,56	13,43^{c}±0,38	16,45^{d}± 0,34	19,90^{e}±0,44	21,66^{f}±0,40
Fat	21,51^{c}± 0,43	20,26^{b} ± 0,87	20,08^{b}±0,66	19,99^{b} ± 0,75	19,59^{ab}±0,84	19,03^{a}±0,92
Total Carbohydrate	60,02^{e} ± 0,95	58,76^{e} ± 0,78	57,27^{d}±0,84	53,37^{c} ±0,69	49,18^{b}±0,74	47,35^{a}± 0,93
Ash	2,26^{a} ± 0,12	2,33^{ab} ± 0,17	2,42^{bc}±0,23	2,49^{c}±0,19	3,11^{d}±0,24	3,54^{e}±0,31
Crude Fiber	2,63^{a} ± 0,14	2,95^{a} ± 0,13	2,97^{a}±0,17	3,77^{b}±0,25	4,12^{b}±0,18	4,44^{b}±0,11
Energy (Kcal/100g)	482,73^{d} ± 2,1	475,66^{c} ± 1,72	475,42^{c}±1,23	474,17^{c}±1,17	469,1^{b} ±2,13	464,26^{a}±1,75

Values are mean ± standard deviation of three measurements (n = 3). The same letter in the same row index indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$).

Mineral composition (mg/100g of dry matter) of sorghum biscuits supplemented with DMF

The mineral composition (Table 7) of sorghum biscuits increases gradually with the incorporation of DMF. Macro-minerals including sodium, potassium, calcium, phosphorus and magnesium increase significantly ($p<0.05$). Sodium varies from 08.81 mg (BS0) to 54.66 mg (BS25), potassium from 271.17 mg (BS0) to 478.33 mg (BS25), calcium from 24.40 mg (BS0) to 74.68 mg (BS25), phosphorus from 250.55 mg (BS0) to 454.68 mg (BS25) and magnesium from 131.94 mg (BS0) to 232.33 mg (BS25). Micro-minerals also increase with significant difference ($p<0.05$). Iron varies from 13.52 mg (BS0) to 43.33 mg (BS25), copper from 3.46 mg (BS0) to 9.69 mg (BS25) and zinc from 3.62 mg (BS0) to 12.85 mg (BS25).

Physical characteristics of sorghum biscuits supplemented with DMF

The physical characteristics of sorghum biscuits are shown in Table 8. Diameter of biscuits significantly increases with incorporation of DMF. The diameter of BS0 is 47.90 mm while that of BS25 is 48.57 mm. The thickness decreases significantly with respective values of 3.41 mm (BS0) and 2.23 mm (BS25).

Weight, volume and specific volume decreases slightly without significant difference (p<0.0

Table 6. Chemical characteristic of biscuits.

	BS0	BS5	BS10	BS15	BS20	BS25
pH	5,64^{a} ± 0,81	5,67^{a} ± 0,08	5,70^{a}±0,99	5,73^{a} ± 0,12	5,79^{a}±0,23	5,85^{a}±0,41
Total Acidity (méq/100g de ms)	4,01^{a} ± 0,36	3,87^{a} ± 0,25	3,56^{a}±0,21	3,21^{ab}± 0,45	2,95^{b}±0,74	2,70^{a}±0,12
Total sugar (%)	18,97^{d}± 0,75	18,71^{c} ± 0,25	18,60^{bc}±0,56	18,46^{b} ± 0,71	18,30^{a}±0,85	18,21^{a}±0,43
Reducing sugar (%)	08,07^{b} ± 0,23	08,04^{b} ± 0,47	08,00^{b}±0,72	07,86^{a} ±0,29	07,85^{a}±0,52	07,82^{a}± 0,48
Non-Reducing sugar (%)	10,90^{a} ± 0,78	10,64^{c} ± 0,39	10,60^{bc}±0,54	10,60^{bc}±0,72	10,45^{ab}±0,63	10,39^{a}±0,92
Starch (%)	39,31^{e} ± 0,98	38,69^{e} ± 1,23	37,47^{d}±0,48	34,81^{c}±0,27	31,50^{b}±0,59	30,02^{a}±0,84
Protein density (g/100kcal)	1,99^{a}±0,03	2,44^{b}±0,22	2,82^{c}±0,09	3,46^{c}±0,08	4,24^{e}±0,10	4,66^{f}±0,08
Lipid density (g/100kcal)	4,45^{a} ± 0,06	4,26^{a} ± 0,02	4,22^{a}±0,03	4,21^{a}±0,06	4,17^{a}±0,03	4,10^{a}±0,10

Values are mean ± standard deviation of three measurements (n = 3). The same letter in the same row index indicates that there is no significant difference between samples for the parameter concerned (p<0.05).

Table 7. Mineral composition (mg/100 g DM) of sorghum biscuits.

Minerals	BS0	BS5	BS10	BS15	BS20	BS25
Sodium	08,81^{a} ± 0,81	19,33^{b} ± 2,08	26,37^{c}±1,99	33,67^{d} ± 2,12	48,10^{e}±1,23	54,66^{f}±2,41
Calcium	24,40^{a} ± 2,18	26,37^{ab} ± 1,16	31,13^{b}±2,01	37,92^{c}± 1,87	47,67^{d}±1,69	74,68^{e}±1,62
Phosphorus	250,55^{a}± 3,21	275,42^{b} ± 2,66	298,52^{c}±2,52	365,13^{d} ± 2,89	437,55^{e}±2,41	454,68^{f}± 3,45
Potassium	271,17^{a} ± 2,36	340,33^{b} ± 1,25	384,08^{c}±3,21	407,33^{c} ±2,45	453,61^{d}±2,74	478,33^{d}±3,12
Magnesium	131,94^{a} ± 1,32	152,27^{a} ± 1,54	176,00^{b}±1,52	206,11^{c}±1,47	225,16^{cd}±1,56	232,33^{d}±1,78
Iron	13,52^{a} ± 0,96	18,27^{b} ± 0,85	26,19^{c}±0,27	31,55^{d}±0,45	36,85^{e}±0,67	43,33^{f}±0,93
Copper	3,46^{a}±0,63	4,37^{ab}±0,12	4,70^{b}±0,85	6,15^{c}±0,56	8,74^{d}±0,26	9,69^{e}±0,52
Zinc	3,62^{a} ± 0,12	5,41^{ab} ± 0,24	7,36^{bc}±0,36	7,67^{bc}±0,48	8,61^{c}±0,51	12,85^{d}±0,74

Values are mean ± standard deviation of three measurements (n = 3). The same letter in the same row index indicates that there is no significant difference between samples for the parameter concerned (p<0.05).

Organoleptic characteristics of sorghum biscuits supplemented with DMF

Organoleptic characteristics of sorghum biscuits are shown in Table 9. According to the panelists, there was no significant difference between the color of biscuits BS5 to BS20 and the control biscuit BS0. The aroma remained constant with the incorporation of DMF. Biscuits have a flavor and a texture similar to the control BS0. The incorporation of DMF improved the taste. Biscuits test are less apparent than the control biscuits (p<0.05). Biscuits enriched with DMF have the same criteria of acceptability as biscuits control (p<0.05).

Table 8. Physical characteristics of biscuits.

	BS0	BS5	BS10	BS15	BS20	BS25
Diameter (mm)	$47{,}90^{b} \pm 0{,}36$	$47{,}54^{b} \pm 0{,}54$	$47{,}93^{a}\pm0{,}37$	$48{,}06^{a} \pm 0{,}40$	$48{,}20^{a}\pm0{,}86$	$48{,}57^{a}\pm0{,}25$
Thickness (mm)	$3{,}41^{b} \pm 0{,}07$	$2{,}91^{c} \pm 0{,}14$	$2{,}66^{c}\pm0{,}27$	$2{,}58^{ac}\pm 0{,}17$	$2{,}44^{ac}\pm0{,}32$	$2{,}23^{a}\pm0{,}12$
Spread ratio	$14{,}02^{a} \pm 0{,}34$	$16{,}34^{b} \pm 0{,}96$	$18{,}01^{c} \pm1{,}94$	$18{,}62^{c} \pm 1{,}34$	$19{,}75^{d} \pm 2{,}41$	$21{,}78^{e} \pm 1{,}2$
Weight (g)	$5{,}30^{b} \pm 0{,}67$	$5{,}13^{ab} \pm 0{,}59$	$5{,}00^{a} \pm 0{,}37$	$4{,}70^{a} \pm0{,}19$	$4{,}47^{a}\pm0{,}32$	$4{,}39^{a}\pm 0{,}38$
Volume (cm^3)	$5{,}15^{d}\pm 0{,}15$	$4{,}80^{cd}\pm 0{,}15$	$4{,}61^{bc}\pm 0{,}39$	$4{,}30^{ab}\pm 0{,}21$	$4{,}00^{ab}\pm 0{,}6$	$3{,}80^{a}\pm 0{,}16$
Specific volume (cm^3/g)	$0{,}97^{a} \pm 0{,}09$	$0{,}94^{a} \pm 0{,}08$	$0{,}92^{a} \pm 0{,}02$	$0{,}91^{a} \pm 0{,}04$	$0{,}89^{a} \pm 0{,}06$	$0{,}87^{a} \pm 0{,}07$

Values are mean ± standard deviation of three measurements (n = 3). The same letter in the same row index indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$).

Table 9. Sensory evaluation of biscuits.

	BS0	BS5	BS10	BS15	BS20	BS25
Colour	$5{,}85^{a} \pm 0{,}89$	$5{,}70^{a} \pm 0{,}78$	$5{,}60^{a}\pm0{,}45$	$5{,}55^{a} \pm 0{,}32$	$5{,}50^{a}\pm0{,}91$	$5{,}50^{a}\pm0{,}36$
Aroma	$5{,}25^{a} \pm 0{,}86$	$5{,}85^{a} \pm 0{,}65$	$5{,}75^{a}\pm0{,}81$	$5{,}20^{a}\pm 0{,}47$	$5{,}55^{a}\pm0{,}72$	$5{,}75^{a}\pm0{,}93$
Texture	$5{,}90^{a} \pm 0{,}64$	$5{,}60^{a} \pm 0{,}37$	$5{,}60^{a}\pm0{,}53$	$5{,}15^{a} \pm 0{,}57$	$5{,}45^{a}\pm0{,}43$	$5{,}45^{a}\pm0{,}51$
Taste	$4{,}90^{a} \pm 0{,}63$	$5{,}10^{a} \pm 0{,}60$	$5{,}15^{a}\pm0{,}12$	$5{,}15^{a} \pm0{,}40$	$5{,}25^{a}\pm0{,}53$	$5{,}32^{a}\pm 0{,}21$
Appearance	$5{,}80^{a} \pm 0{,}18$	$5{,}70^{a} \pm 0{,}36$	$5{,}30^{a}\pm0{,}65$	$5{,}25^{a}\pm0{,}43$	$5{,}20^{a}\pm0{,}39$	$5{,}25^{a}\pm0{,}15$
Overall acceptability	$5{,}40^{a} \pm 0{,}54$	$5{,}20^{a} \pm 0{,}76$	$5{,}65^{a}\pm0{,}32$	$5{,}65^{a}\pm0{,}79$	$5{,}55^{a}\pm0{,}54$	$5{,}60^{a}\pm0{,}34$

The same letter in the same row index indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$).

Discussion

The development of biscuits with sorghum supplemented with DMF was preceded by the establishment of DMF and purchase of sorghum flour. Analyzes showed that defatting flour *Macrotermes subhyalinus* had a significant influence on the biochemical composition of the flour. The protein and carbohydrate content were significantly increased compared to the non-defatted flour of *Macrotermes subhyalinus*. Indeed, the levels of protein and carbohydrate in not defatted flour of *Macrotermes subhyalinus* were respectively 38.2% and 03.0% (Niaba *et al.,* 2011). After defatting, these levels reached 65.41% and 13.89%. This improvement is explained by nutrient concentration of nutrients DMF after lipid removal. According to Srivastava *et al.* (2010) flour obtained after oil extraction improved nutritional properties. The influence of delipidation on the biochemical composition of foods is also highlighted by the work of Meité *et al.* (2008) on the defatting *citrullus lanatas* and Serrem *et al.* (2011) on the delipidation of soybeans. Sorghum flour is less rich in protein (13.54%) compared to DMF (65.41%). Sorghum flour has a carbohydrate content of 73.30% greater than that of DMF (13.89%). Fortification at different rates of sorghum flour by DMF changes the biochemical composition of mixed flours. Biscuits test also show an increase in their ash and cellulose contents. Biscuits test has a slight fat content due to the defatting of *Macrotemes subhyalinus* flour. However, the level of carbohydrate in biscuits test significantly decreased with the increase of DMF.

Biscuits fortified with DMF have new characteristics. Humidity increased with the incorporation of DMF.

This increase can be attributed to proteins that facilitates the retention of water in the pasta (Talati *et al.,* 2004; Tyagi *et al.,* 2007; Njintang *et al.,* 2007, Kumar *et al.,* 2010). The protein content of biscuits increased significantly compared to the control. This improvement is the consequence of the high content of protein in DMF, and the values observed are of the same order as those describeb by Serrem *et al.* (2011) for sorghum biscuits supplemented with legumes. According to Olaoye *et al.* (2007) biscuits are an important source of protein.

Fat biscuits significantly increased compared to the fat of the initial flours because of addition of butter and sunflower oil during production. This fat is an energy source for the biscuits (Olaoye *et al.,* 2007), contributes to their appearance, improves the flavor and gives a good feeling in the mouth (Pareyt and Delcour, 2008; Odoemelam, 2005, Zoulias *et al.,* 2002).

The carbohydrate content down because DMF is not a major source of carbohydrate. This decrease was highlighted by the work of Mohsen *et al.* (2009); Serem *et al.* (2011) and Islam *et al.* (2012). The ash content in biscuits increased due to a high content of ash in DMF.

All biscuits tests have a low acidity. This is most likely due to a departure of volatile acidity and organic compounds during cooking. The pH is an important parameter in the formulation of biscuits. An acidic pH is associated with the development of a pleasant taste (Ogunjobi and Ogunwolu, 2010). Sugar content (reducing sugar, non-reducing sugars and total sugar) is important and consequential to the addition of sucrose in the preparation of biscuits. The biscuits starch content decreased with the incorporation of DMF. This is due to a lack of starch in DMF.

The nutritional density in a nutrient is the amount of that nutrient per 100 kcal made from the food. Protein density in biscuits increased with the incorporation of DMF. These values reached 4.66 g/100kcal for biscuit BS25. A lower protein density of 5.5 g / 100kcal is recommended for this type of product (FAO/WHO, 2006). Lipid density is higher for sorghum biscuits but remained constant. These values reached 4.10 g/100 kcal for BS25 and biscuits does not lie in the interval (2.1-3.3) g/100 kcal for processed cereal for infants (FAO/ WHO, 2006).

The mineral composition of sorghum biscuit improve with the gradual incorporation of DMF. *Macrotemes subhyalinus* flour is an important source of minerals (Niaba *et al.,* 2011). The macronutrients (sodium, calcium, phosphorus, potassium and magnesium) have a high rate in the biscuits as well as the micronutrients (iron, copper and zinc).

Biscuits have physical characteristics that evolve according to the degree of DMF incorporation. The diameter increases as the thickness decreases with the increase of the DMF. According to Baljeet *et al.,* (2010), these two parameters are still evolving in reverse. The spread ratio is the ratio between the diameter and the thickness and this parameter is important to assess the quality of the biscuits (Bose and Shams-Ud-Din, 2010). Biscuits with high spread ratio values are better (Eissa *et al.,* 2007). The quality of biscuits is also evaluated by its specific volume which is a technological parameter that can adequately inform on the textural properties of the dry biscuits (Igrejas *et al.,* 2002; Manoharr *et al.,* 2002; Pedersen *et al.* 2004 Fustier *et al.,* 2007). Control biscuits have a specific volume greater than the other biscuits. Specific volume of biscuits test decreases with the incorporation of DMF. According to Bartolucci (1997) a high specific volume corresponds to a light biscuit.

Sensory evaluation of biscuits highlighted their sensory characteristics. Regarding to color, sorghum biscuits are brown. The incorporation of DMF has no influence on the color of biscuits. However, all the biscuits were accepted according to the panelists. Siddiqui *et al.* (2003) found that the decrease in biscuits color was related to the high level of proteins. The amino acids of proteins react with reducing sugars during baking in the Maillard reaction. Biscuits color becomes darker with increasing of proteins (Dhingra and Jood, 2001; Iwe, 2007; Ubbor and Akobundu, 2009; Mohsen *et al.,* 2009). Color is an important parameter to correctly assess the baked biscuits (Hussain *et al.,* 2006). In terms of flavor, sorghum biscuits do not undergo significant change with the incorporation of DMF. This could be explained by the defatting of *Macrotermes subhyalinus*. In fact, the fat is responsible for the flavor in foods. Sorghum biscuits have a rough texture.

According to Gomez *et al.,* 2003; Bakke and Vickers, 2007; Akhtar *et al.,* 2008; Serrem *et al.,* 2011, the cooking conditions, the amount of components such as fiber, starch and water absorbed during kneading of the pasta, contribute to the final texture of the product. Taste is the main factor that determines the acceptability of a product, which has the most impact in measuring the success of the product on the market (Banureka and Mahendran, 2009). Sorghum biscuits have a good taste as suggested by the panelists. The incorporation of DMF did not improve the taste. Termites keep their taste during cooking (Oningbinde and Ekpo, 2007). Sorghum biscuits have a beautiful appearance. In sum, all the sorghum biscuits were accepted to a maximum content of 25% DMF.

Conclusion

The incorporation of DMF in sorghum flour significantly improves the protein content of mixed flours of sorghum and DMF. Biscuits from these flours are rich in nutrients. Protein content has increased enormously as well as mineral content. Sensory analysis showed that the addition of *Macrotermes subhyalinus* has been accepted by the panelists for a maximum content of 25% DMF incorporation. Given the richness in nutrients of termites, the presentation of these insects in forms food like biscuits could serve as food for young children.

References

Akhtar S, Anjum F, Rehman S, Sheikh M, Farzena K. 2008. Effect of fortification on the physico-chemical and microbiological stability of whole wheat flour. Food Chem. **112**, 156-163.

Allotey J, Mpuchane S. 2003. Utilization of useful insects as a food source. Afr. J. of Food Agr. Nutr. and Dev. **3,** 2.

AOAC. 1995. Official methods of Analysis of AOAC International, 16th ed. AOAC International Arlington, VA, p. 250.

AOAC. 1990. Association of Official Analytical Chemists. Official methods of analysis chemists, 15th ed (AOAC Arlington) Virginia, USA.

AOAC. 2000. Official methods of Analysis, Association of Official Analytical.

Atwater WO, Benedict FG. 1902. Experiments on the metabolism of matter and energy in the human body, 1898–1900. United States. Office of experiment stations. Bulletin No. **109**. Government Printing Office, Washington, DC.

Bakke A, Vickers Z. 2007. Consumer liking of refined and whole wheat breads. J. Food Sci. **72**, S473-S480.

Baljeet SY, Ritika BY, Roshan LY. 2010. Studies on functional properties and incorporation of buckwheat flour for biscuit making International Food Research Journal **17**, 1067-1076

Banjo AD, Lawal OA, Songonuga EA. 2006. The nutritional value of fourteen species of edible insects in southwestern Nigeria. African Journal of Biotechnology **5(3)**. 298-301.

Banureka VD, Mahendran T. 2009. Formulation of wheat - soybean biscuits and their quality characteristics, Tropical Agricultural Research and Extension **12(2)**.

Bartolucci JC. 1997. Comportement rhéologique des pâtes et qualité des farines de blés tendres Français en panification et en biscuiterie. Thèse de doctorat. Ecole nationale supérieure des industries agricoles et alimentaires, Massy, France. p. 300.

Bernfeld P. 1955. Amylase α and β. Meyhod in enzymology. In: colowich, I.S.P and N.O. Kaplan.9th Edn, Academic Inc, New York,p. 154.

Bertrand G, Thomas P. 1910. Guide pour les manipulations de chimie biologie. Paris Dunod et Pinat, p. 468.

BIPEA . 1976. Recueil des méthodes d'analyse des communautés européennes. Bureau Interprofessionnel d'Études Analytiques, Gennevilliers. France p. 140.

Bose D, Shams-Ud-Din M. 2010. The effect of chickpea (*Cicer arietinim*) husk on the properties of cracker biscuits. J. Bangladesh Agril. Univ. **8(1),** 147–152, ISSN 1810-3030.

Dhingra S, Jood S. 2001. Organoleptic and nutritional evaluation of wheat breads supplemented with soybean and barley flour. Food Chem. **77**, 479-488.

Dubois M, Gilles FK, Hamilton JK, Rebers PA, Smith F. 1956. Anal.Chem. **280**, 350-356.

Eissa HA, Hussein AS, Mostafa BE. 2007. Rheological properties and quality evaluation of Egyptian balady bread and biscuits supplemented with flours of ungerminated and germinated legume seeds or mushroom. Pol. J. Food Nutr. Sci. **57**, 487–496.

Ekpo KE, Onigbinde AO. 2007. Characterization of Lipids in Winged Reproductives of the Termite *Macrotermis bellicosus*. Pakistan Journal of Nutrition. **6(3),** 247-251.

FAO/OMS. 2006. Codex Alimentarius : programme mixte FAO/OMS sur les normes alimentaires. Rapport de la vingt-septième session du comité du codex sur la nutrition et les aliments diététiques ou de régime. FAO/OMS. ALINORM 06/29/26. p. 105.

Favier JC, Ireland-ripert J, Toque C. 1995. Répertoire Général des Aliments – Table de composition. CNEVA-CIQUAL-INRA. Lavoisier Tec et Doc. Paris. p. 897.

Fustier P, Castaigne F, Turgeonb SL, Biliaderis CG. 2007. Semi-sweet biscuit making potential of soft wheat flour paten middle-cut and clear mill streams made with native and reconstituted flours. Journal of Cereal Science **46,** 119-131.

Gomez M, Ronda F, Blanco, Caballero P, Apesteguía A. 2003. Effect of dietary fibre on dough rheology and bread quality. Eur. Food Res.Technol. **216**, 51-56.

Hussain S, Anjum FM, Butt MS, Khan M I, Ashaghar A. 2006. Physical andSensory Attributes of Flaxseed Flour Supplemented Cookies. Turk Journal of Biol. **30,** 87-92

Igrejas G, Martinant JP, Bouguenne A, Villain AC, Saulnier L, Popineau Y, Gerard BG. 2002. Genetical, Biochemical and Technological Parameters Associated with Biscuit Quality. I. Prediction Using Grain Hardness and Water Extractable Arabinoxylans. Journal of Cereal Science **36**, 115-124.

Islam T, Chowdhury A, Islam M, Islam S. 2007. Standardization of Bread Preparation from Soy Flour. Int. J. Sustain. Crop Prod. **2(6),** 15-20.

Iwe MO. 2007. Current Trends in Sensory Evaluation of Foods. Rejoint Communication Services, Uwani Enugu, Nigeria.

Kinyuru JN, Kenji GM, Njoroge MS. 2009. Process development, nutrition and sensory qualities of wheat buns enriched with edible termites (*macrotermes subhylanus)* from lake victoria region,Kenya. African journal of food Agriculture Nutrition and Development **9**, 5374.

Kumar S, Rekha, Sinha LK. 2010. Evaluation of Quality Characteristics of Soy Based Millet Biscuits, Advances in Applied Science Research **1(3),** 187-196.

Manoharr S, Rao PH. 2002. Interrelationship between rheological characteristics of dough and quality of biscuits; use of elastic recovery of dough to predict biscuit quality. Food Research International. **35**, 807-813.

Meité A, Kouame KG, Amani NG, Kati-Coulibaly, Offoumou A. 2008. Caractéristiques physico-chimiques et sensorielles des pains fortifiés avec les farines de graines de *citrullus lanatus*. J. Sci. Pharm. Biol. **9,** 32-43.

Mohsen MS, Fadel HM, Bekhit MA, Edris AE, Ahmed YS. 2009. Effect of substitution of soy protein isolate on aroma volatiles, chemical composition and sensory quality of wheat cookies. International Journal of Food Science and Technology **44,** 1705–1712.

NIABA Koffi PV, Gbogouri Grodji A, BEUGRE Avit G, Ocho-Anin ATCHIBRI AL, GNAKRI Dago. 2011. Potentialités nutritionnelles du reproducteur ailé du termite *Macrotermes subhyalinus* capturé à Abobo-doumé, Côte d'Ivoire. J. App. Biosc. **40,** 2706 – 2714.

Njintang YN, Mbofung CM, Balaam F, Kitissou P, Scher J. 2007. Effect of Taro (*Colocasia esculenta*) Flour Addition on The Functional and Alveographic Properties of Wheat Flour and Dough. Journal of the Science of Food and Agriculture **88(2),** 273-279.

Obiri-Danso K, Ellis WO, Simpon BK, Smith JP. 1997. Suitability of high lysine maize, obatanga for kenkey + production. Food Control **8,** 125-129.

Odoemelam SA. 2005. Functional Properties of Raw and Heat Processed Jackfruit *(Artocarpus heterophyllus*) Flour. Pakistan Journal of Nutrition **4(6),** 366-370.

Ogunjobi MAK, Ogunwola SO. 2010. Physicochemical and sensory properties of cassava flour biscuits supplemented with cashew apple powder. Journal of food technology **8 (1),** 24-29.

Olaoye OA, Onilude AA, Oladoye CO. 2007. Breadfruit Flour in BiscuitMaking: Effects on Product Quality. African Journal of Food Science 020-023.

Pareyt B. Delcour JA. 2008. The Role of Wheat Flour Constituents, Sugar, and Fat in Low Moisture Cereal Based Products: A Review on Sugar-Snap Cookies.

Pedersen L, Kaack K, Bergsoem N, Adler-Nissen J. 2004. Rheological properties of biscuit dough from different cultivars, and relationship to baking characteristic. Journal of Cereal Science **39,** 37-46.

Charlotte Serrem, Henriette L, de Kock, John Taylor. 2011. Nutritional quality, sensory quality and consumer acceptability of sorghum and bread wheat biscuits fortified with defatted soy flour. International Journal of Food Science and Technology **46**, 74–83.

Siddiqui NR, Hassan M, Raza S, Hameed L, Khalil S. 2003: Sensory and physical evaluation of biscuits supplemented with soy flour. Pakistan J Food Sci. **13(1-2),** 45- 48.

Sodjinou E, Biaou G, Codjia JC. 2002. Caractérisation du marché des escargots géants africains (achatines) dans les départements de l'Atlantique et du littoral au Sud-Bénin. Tropicultura **20(2),** 83- 88.

Srivastava Y, Semwal AD, Kumar GS, Singh AB. 2010. Effect of Virgin Coconut Meal (VCM) on the Textural, Thermal and Physico Chemical Properties of Biscuits. Food and Nutrition Sciences, **2**, 38-44.

Sutton MQ. 1988. Insects as food: aboriginal entomophagy in the Great Basin. Ballena. Press Anthropology Papers, 33, 115.

Talati JG, Patel KV, Patel BK. 2004. Biochemical Composition, *In vitro* Protein Digestibility, Antinutritional Factors and Functional Properties of Mustard Seed, Meal and Protein Isolate. Journal of Food Science and Technology, Vol. 41, No. 4, July/August, p. 608-612.

Tharrault JF. 1997. Qualité biscuitière des farines de blé tender: des blés biscuitiers pour une bonne maîtrise de la texture des biscuits. *In*, GODON B. et LOISEL W. Guide pratique d'analyse dans les industries des céréales. Lavoisier. Tec. et doc. Paris. p. 819.

Tyagi SK, Manikantan MR, Oberoi HS, Kaur G. 2007. Effect of Mustard Flour Incorporation on Nutrition, Textural and Organoleptic Characteristics of Biscuits. Journal of Food Engineering **80(4),** 1043-1050.

Ubbor SC, Akobundu ENT. 2009. Quality Characteristics of Cookies from Composite Flours of Watermelon Seed, Cassava and Wheat, Pakistan Journal of Nutrition **8 (7),** 1097-1102.

Zoulias EI, Oreopoulou V, Kounalaki E. 2002. Effect of Fat and Sugar Replacement on Cookie Properties. Journal of the Science of Food and Agriculture **82,** 1637–1644.