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Full Length Research Paper

Volatile compounds in Ikivunde and Inyange, two Burundian cassava products

Nzigamasabo Aloys

Université du Burundi, Institut Supérieur d'Agriculture, Département de Technologie des Industries Agro-Alimentaires, BP 35 Gitega, Burundi.

E mail : nzigama@yahoo.com: Tel: +257 79 478 534

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The formation of volatile compounds in cassava roots, in non-fermented flour, in Ikivunde and in Inyange was investigate. Aldehydes flavor compounds were numerous in dried Ikivunde than in other cassava products. Non-fermented cassava flour had numerous acids, followed by dried Inyange, and then dried Ikivunde. Undried Inyange had numerous esters than any other cassava products, however, many of these esters are not found in dried Inyange. 1,3-butanediol, 2-butanol, acetone, 2-butanone and acetic acid were relatively more abundant than other components in fresh cassava. 2-3 butanediol, benzeneethanol, nonanal, hexanal, acetoin and acetic acid were abundant in non-fermented cassava flour. 2-butanol, 1-hexanol, ethanol, hexanal, 2-butanone and acetic acid predominated in Ikivunde after fermentation.1-pentanol, 1-hexanol, ethanol, nonanal, hexanal, decanal, octanal, 2-octenal and acetic acid dominate in Ikivunde after drying. The major compounds in Inyange after fermentation were 3-methyl-1-butanol, L-linalool, benzeneethanol, isopropyl alcohol, 1-hexanol, acetoin, 2-methoxy ethyl acetate, methyl isovalerate, methyl-3- methyl-2-butanoate, p-menth-8-en-1-ol acetate, isopropyl tiglate, p-menth-1-en-8-ol-acetate and acetic acid. In dried Inyange, 2,3-butanediol, benzeneethanol, nonanal, hexanal, acetoin and acetic acid were the major volatile compounds. The results indicated that processing cassava roots by soaking, heap fermentation and drying gave cassava products with different flavor compounds. This was due to different microorganisms present in their processing.

Keywords: Ikivunde, Inyange, cassava roots, non –fermented flour, flavours compounds.

INTRODUCTION

Cassava (*Manihot esculenta,* Crantz) is the staple food in tropical countries (Achi and Akomas, 2006). It is consumed as fresh vegetable, but a large proportion of the crop is processed into dried products. Cassava farming populations have empirically developed several processing methods for stabilizing cassava and reducing its toxicity (Lancaster et al., 1982; Coursey, 1973;Cooke and Coursey, 1981).

The usually used processing methods are sun drying and fermentation; however, the latter is by far the most used processing method. Fermentation is widely used to transform and preserve it because of its low technology and energy requirements and the unique organoleptic qualities of the final products (Daeschel et al., 1987;Onyango et al., 2004.). During that fermentation, cassava roots are softened and organoleptic qualities are developed. The fermentation process is initiated as a result of chance inoculation by microorganisms from the environment. The presence of unspecified microorganisms complicates the control of fermentation process and lead to the production of different flavors, which have been overlooked by investigators in the field of cassava and its food products.

Ikivunde and Inyange are eaten as paste and are also used in infant foods formulations and composite foods. In spite of the importance of these foods in Burundian diets, very few scientific studies were carried out on them and there are no reports of their flavoring compounds during their processing. The aim of this paper was to study the flavoring constituents of Ikivunde and Inyange.

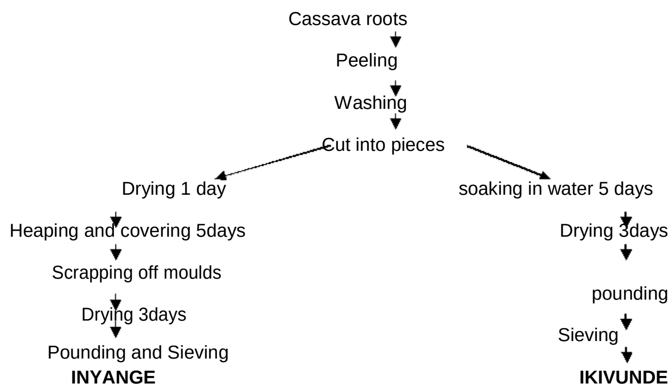

Figure 1. Flow diagram for processing Inyange and Ikivunde.

Materials and methods

MATERIALS

The cassava roots were washed with water to remove all dirts, peeled and cut into pieces, which were mixed. The cassava samples were then divided into two portions and submitted to different processing methods after which they were ground and sieved through a 60-mesh sieve to yield Kivunde, and Inyange as depicted in the following

METHODS

Headspace solid-phase micro extraction.

A SPME holder (Supelco, Shanghai, China) for manual sampling combined with GC-MS (Finnigan TRACE MASS 2000) was used to perform the experiments. A fused silica fiber (PDMS) was chosen to extract the volatile components from cassava samples. Before initial use, the fiber was conditioned for 2 hrs at 250^{o}C.The fiber was held at 225^{o}C for 25 min prior to each extraction and allowed to come to room temperature for 10 min. The HS sampling techniques was used as follows: Selected sample vials were placed into a water bath at 50^{o}C. In each extraction, the sample was kept for 1hr in deposal to achieve the partition equilibration between the sample and the HS. After that time, the SPME fiber was exposed to the HS 1 cm above the solution surface to absorb the analytes. After 5 min, the fiber was withdrawn from the needle, and then introduced into a heated chromatograph injector for desorption and analysis.

Instrumental and Data analysis.

GC-MS Finnigan TRACE MASS was used to perform the analysis. Volatiles were separated using a capillary column (OV1701, 30m x 0.25 mm id,1.0mm film thickness). The carrier gas was ultra-purified helium at a flow rate of 1ml/min. Thermal desorption of the compounds from the fiber coating took place in the GC injector at 250^{O}C in a splitless mode for 1 min. The temperature program was isothermal for 2 min at 40^{O}C and raised at a rate of 5^{O}C/min to 80^{O}C at first, then raised at a rate of 8^{O}C/min to 180^{O}C, finally at a rate of 15^{O}C/min to 240^{O}C and held at this temperature for 8 min. Interface temperature was 250^{O}C. The mass spectra were acquired with a source temperature of 200^{O}C under a 70eV ionization potential. The ionization mode was EI+, emission current was 150µA and detector voltage was 350V. Identification of volatile components was confirmed by comparing their mass spectra with those contained in mass spectral database libraries (Willey, REPLIB, NISTDEMO and MAINLIB).

RESULTS AND DISCUSSION

Table 1 summarizes GC-MS data obtained from the analysis of volatile compounds from cassava roots, non-fermented flour, Ikivunde and Inyange after fermentation and drying.

The microbial fermentation produce volatile compounds and it is reasonable to presume that this is the result directly or indirectly of the metabolic activities of microorganisms or from chemical reactions (Leejeerajumnean et al., 2001; Zhao et al., 2006; Maarsehenk, 1991). Microorganisms produce extracellular and intra cellular enzymes, which contribute to flavour and aroma-generating reactions such as those, occur during cheese maturation (Maarse, 1991;Lindsay, 1996;Dakwa et al.,2005).

Alcohols, aldehydes, ketones, esters, acids, alkane, alkene, furan, phenols, nitrogen compouns, aromatic compounds were found to be responsible of the flavor in these cassava products. The origin of alcohols may be a chemical degradation of hydroperoxides of unsaturated

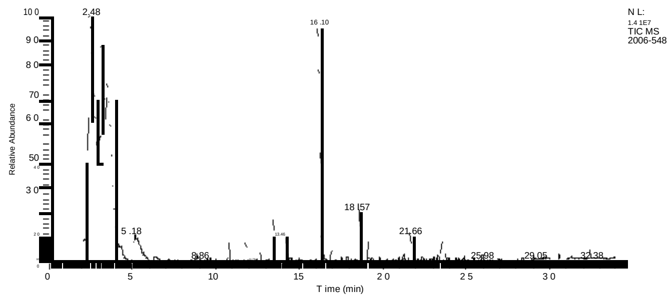

Figure 1. Chromatogram profiles of flavoring compounds in fresh cassava.

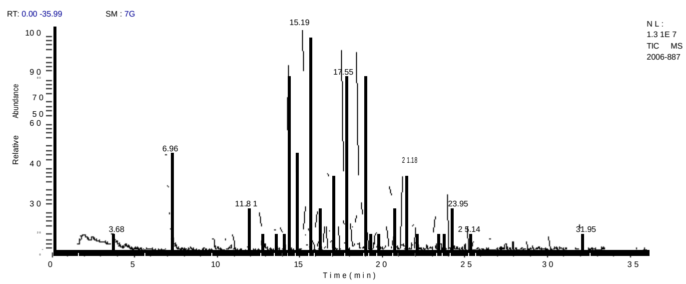

Figure 2. Chromatogram profiles of flavoring compounds in Ikivunde after drying.

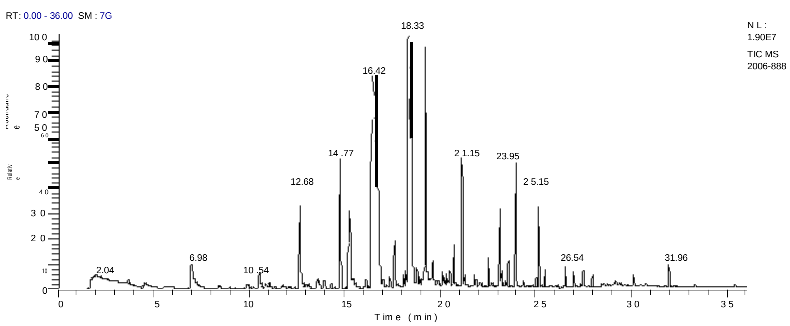

Figure 3. Chromatogram profiles of flavoring compounds in Inyange after drying.

fatty acids or may result from the microbial activity (Sanchez-silava et al., 2005). The presence of alcohol in unfermented cassava means that these compounds are native to cassava.

Aldehydes, ketones and carboxylic acids result from a degradative reaction of oxidation enzymatically catalyzed by lipoxygenase and hydroperoxidases (Sanchez-silvaet al., 2005; Sabio et al., 1998). Aldehydes flavor compounds are numerous in dried Ikivunde than in other cassava products. Both unfermented cassava, dried Ikivunde and dried Inyange had the same number of ketones. Non-fermented cassava flour had numerous acids, followed by dried Inyange, and then dried Ikivunde.

The esters, many of which have attractive aromas, are presumably the consequence of chemical reactions between microbial acidic and alcoholic metabolites, though it is also possible that the reactions may be catalyzed by microbial esterases (Eskin, 1990). Undried Inyange had numerous esters than any other cassava products, however, many of these esters are not found in dried inyange.

Figure 1, 2 and 3 provide the representative chromatograms for non-fermented flour, Ikivunde and Inyange after drying.

Alkane and alkene are readily formed from lipid hydroperoxides by the β-scission of alkoxy radicals to give alkyl radicals (Grosch, 1982).Alkane and alkene were very few in these cassava products and were of minor importance along with phenols, amides, aromatic compounds, terpenes and lactones.

1,3-butanediol, 2-butanol, acetone, 2-butanone and acetic acid were relatively more abundant than other components in fresh cassava. 2-3 butanediol, benzeneethanol, nonanal, hexanal, acetoin and acetic acid were abundant in non-fermented cassava flour. 2-butanol, 1-hexanol, ethanol, hexanal, 2-butanone and

Table 1. Volatile components in Ikivunde, Inyange and in non-fermented cassava flour.

No	Compounds	% of peak area Cassava	Nf	Ik^{af}	Ik^{ad}	In^{af}	In^{ad}
	Alcohol						
1	1,3-butanediol	2.97	-	-	-	-	-
2	1,2 –propanediol	0.36	-	-	-	-	-
3	2 –butanol	4.71	-	4.68	-	-	-
4	1-penten-3-ol	0.1	-	-	-	-	-
5	3-methyl,1-butanol	0.16	-	-	-	5.06	-
6	1-pentanol	0.7	-	-	2.28	-	-
7	2-penten-1-ol	0.33	-	-	-	-	-
8	1-hexanol	1.74	0.14	3.16	-	-	-
9	1-octen-3-ol	0.07	-	-	0.79	-	-
10	2-ethyl-1- hexanol	0.59	0.27	-	0.87	-	-
11	L-linalool	0.08	-	-	-	9.34	-
12	2,3-butanediol	0.55	6.19	1.34	-	1.82	15.01
13	2-octen-1-ol	0.1	-	-	-	-	-
14	2-nonen-1-ol	0.07	0.4	-	-	-	-
15	2-hexadecanol	0.18	0.37	-	-	-	0.39
16	L-alpha-terpineol	0.16	-	-	-	-	-
17	Benzyl alcohol	0.07	0.39	0.4	-	-	0.52
18	Phenylethyl alcohol	0.07	-	-	-	-	-
19	1-dodecanol	0.11	-	0.48	-	-	-
20	Ethanol	-	0.27	28.56	1.66	-	-
21	Nonadecanol	-	0.17	-	-	-	-
22	6-methyl-1-heptanol	-	0.23	-	-	-	-
23	3,5-octadien-2-ol	-	0.16	-	-	-	-
24	1-octanol	-	0.38	0.45	1.5	-	0.43
25	2-heptadecanol	-	0.15	-	-	-	-
26	1-nonanol	-	0.25	-	1.76	-	0.31
27	benzene ethanol	-	1.99	0.38	1.5	12.04	2.42
28	3-penten-1-ol	-	-	0.39	-	-	-
29	2-heptanol	-	-	0.47	-	-	-
30	3-penten-2-ol	-	-	0.3	-	-	-
31	3-hexen-1-ol	-	-	0.33	-	-	-
32	1-heptanol	-	-	0.28	0.84	-	-
33	2-ethyl hexanol	-	-	0.32	-	-	0.23
34	2-nonanol	-	-	0.37	-	-	-
35	2-dodecanol	-	-	0.48	-	-	-
36	Isopropyl alcohol,2-propanol 1-hexanol,hexylalcohol	-	-	-	-	6.49	-
37	p-menth-8-en-2-ol	-	-	-	7.17	3.91	0.15
38	5,9-dimethyl-1-decanol	-	-	-	-	0.81	-
39	Epoxylinalool	-	-	-	0.37	-	-
40	1-decanol,decylalcohol	-	-	-	0.69	-	-
41	oleyl alcohol	-	-	-	0.69	-	-
42	9,12-octadecadien-1-ol	-	-	-	-	--	0.5
43	***Aldehydes*** n-caproaldehyde,hexanal	-	-	-	-	-	0.26
44	Nonanal	0.54	-	-	-	-	-
45	hexanal,n hexanal	0.14	3.02	0.74	11.66	0.66	4
46	2,4 pentadienal	-	2.14	5	13.08	-	2.35
47	4-pentenal	-	0.13	-	-	-	-
48	Heptanal	-	0.17	-	0.44	-	-

Nf: Non-fermented flour, **Ik**: Ikivunde, **In**: Inyange, the superscripts **af** and **ad** respectively mean after fermentation and after drying

Table 1 Continue

49	Heptenal	-	0.21	-	1.07	-	0.14
49	Octenal	-	0.26	-	-	-	-
50	Decanal	-	0.27	-	-	-	1.7
51	Benzaldehyde	-	1.58	-	10.38	-	-
52	2-decenal	-	0.43	0.42	1.1	1.34	0.5
53	benzene acetaldehyde	-	0.14	-	1.15	-	0.39
54	hexadecenal,palmitic aldehyde	-	0.23	-	0.26	-	0.27
55	9,12-octadecadienal	-	0.91	-	0.57	-	-
	Octanal						
56	pentanal,valeraldehyde	-	0.15	-	-	-	-
57	2-hexenal	-	-	0.31	2.47	-	-
58	2-octenal	-	-	-	0.73	-	0.2
59	2-nonenal	-	-	-	0.31	-	0.34
60	trans-2-undecenal	-	-	-	1.96	-	-
61	2-heptenal	-	-	-	0.75	-	-
62	6-nonenal	-	-	-	0.76	-	0.67
63	Tetradecanal	-	-	-	-	-	0.24
64	9-octadecenal	-	-	-	-	-	-
65	9,17-octadecadienal	-	-	-	-	-	1.38
66	Furfural	-	-	-	-	-	0.28
67	Ketones	-	-	-	-	-	0.24
68	Acetone	-	-	-	-	-	0.14
	2-butanone						
69	Acetoin	6.19	-	-	-	0.81	-
70	2-nonanone	25.07	-	2.06	-	-	-
71	Diacetyl	0.61	2.25	-	0.54	2.77	3.05
72	3,5-octadien-2-one	0.1	-	-	-	0.73	-
73	isoamyl metyl ketone	-	0.51	-	-	-	-
74	6-methyl-5-hepten-2-one	-	0.2	-	-	-	-
75	3-octen-2-one	-	-	0.35	-	-	-
76	3,5-octadien-2-one	-	-	-	1.04	-	0.31
	2-pentanone						
77	***Esters***	-	-	-	0.8	-	-
78	12,15-octadecadiynoic acid, methyl	-	-	-	1.49	-	0.49
79	Ester	-	-	-	-	-	0.55
	Beta-terpinyl acetate						
80	Metyl caproate	0.08	-	-	-	-	-
	Ethyl isoallocholate						
81	Isobutyl phthalate	0.17	-	0.44	-	-	-
82	Dibutyl phtalate	0.07	-	-	-	-	-
83	Isoamylacetate	0.08	-	-	-	-	-
84	Ethyl acetate	0.1	-	-	0.31	0.78	0.19
85	Linalyl acetate	0.2	0.45	-	0.79	1.54	0.5
86	Alpha-terpinyl acetate	-	0.14	1.19	-	-	-
87	Methyl salicyalte	-	-	0.65	-	-	-
88	2-methoxyethyl acetate	-	-	1.17	-	-	-
89	methyl butyrate	-	-	1.78	-	-	-
90	methyl isovalerate	-	-	-	-	-	-
91	ocadecanoic acid phenylmethylester	-	-	-	-	2.29	-
92	eicosanoic acid,phenylmethyl ester	-	-	-	-	0.77	-
93	methyl-3-methyl-2-butanoate	-	-	-	-	7.53	-
94	p-menth-8-en-1-ol acetate	-	-	-	-	1-6	-
	methyl-2-pentenoate						
95	Isopropyltiglate	-	-	-	-	1.15	-
	p-menth-1-en-8-ol acetate						

Table continue

96	diethyl phthalate propanoic acid,-	-	-	-	-	8.92	-
	2 mthyl-2-ethyl,3						
97	hydrohexyl ester	-	-	-	-	4.21	-
	1-octylacetate						
98	***Acids***	-	-	-	-	1.04	-
99	Acetic acid	-	-	-	-	2.15	-
100	Pentanoic,valeric acid	-	-	-	-	6.67	-
	Hexanoic acid						
101	Pyruvic acid	-	-	-	-	0.72	-
102	Isobutyric acid	-	-	-	-	0.89	-
	Butyric acid						
	Caprylic acid						
103	Nonanoic acid	-	-	-	-	-	0.25
	Capric acid						
104	Benzoic acid	2.32	27.72	32.06	4.48	2.92	30.67
105	3-hydroxy dodecanoic acid	0.07	0.77	-	-	-	1.04
106	heptanoic acid	0.47	-	1.39	0.5	-	1.45
107	***Furan***	-	0.18	-	-	-	-
108	2-pentyl furan	-	0.31	-	-	-	0.39
109	***Alkane***	-	0.22	-	-	-	0.29
110	6-methyl octadecane	0.15	0.45	0.57	0.29	-	0.34
111	2,6,10trimethyltetradecane	-	0.22	0.37	0.32	-	0.37
112	6-phenyldodecane	-	0.16	-	-	-	-
113	Hexadecane	-	0.18	0.35	-	-	-
114	***Alken***	-	-	-	0.23	-	-
	3-ethyl,2-methyl ,1,3-hexadiene						
115	1-dodecene	-	-	-	0.42	-	-
	2,3,3 trimethyl-5-phenyl-1-penten						
156	***Nitrogen compounds***	0.1	-	-	0.96	-	0.22
	4-nitrophtalamide						
117	Lactamide	0.12	-	-	-	-	-
118	formamide	-	-	-	-	0.64	-
119		-	-	-	-	0.64	-
120	***Aromatic compounds***	-	-	-	-	-	0.22
	oxime						
121	o-cymene	0.1	-	-	-	-	-
122	naphthalene						
123	pyridine, azine	-	-	0.56	-	-	-
124	***Phenol***	-	-	-	-	-	0.2
	2-methoxy-4-methylphenol						
	Phenol						
125	o-trimethyl silyl phenol	-	-	-	0.39	0.75	-
126		-	0.43	-	-	-	-
127	***Terpenes***	-	0.5	-	-	-	0.66
	Neocurdione						
	L-limonene						
128							
129		0.1	-	-	-	-	-
130	***Lactone***	-	-	0.29	-	-	-
131	Butyrolactone	-	-	-	0.28	-	0.15
132		-	-	-	-	-	0.2
133		-					
134							
135		-	-	-	-	1.89	-
		-					
		-	0.16	-	-	1.25	0.2
136		-	-	0.49	-	-	-
137		-	-	-	-	1.72	-
138			-	1.07	-	-	-
			-	-	-	-	0.22

acetic acid predominated in Ikivunde after fermentation.1-pentanol, 1-hexanol, ethanol, nonanal, hexanal, decanal, octanal, 2-octenal and acetic acid dominate in Ikivunde after drying. The major compounds in Inyange after fermentation were 3-methyl-1-butanol, L-linalool, benzeneethanol, isopropyl alcohol, 1-hexanol, acetoin, 2-methoxy ethyl acetate, methyl isovalerate, methyl-3-methyl-2-butanoate, p-menth-8-en-1-ol acetate, isopropyl tiglate, p-menth-1-en-8-ol-acetate and acetic acid. In dried Inyange, 2,3-butanediol, benzeneethanol, nonanal, hexanal, acetoin and acetic acid were the major volatile compounds.

These flavor compounds contribute significantly to the flavor of these cassava products whereas the other compounds investigated are of minor importance. Benzeneethanol, nonanal, benzaldehyde and acetic acid were detected in both cassava products.

Generally, in analyzing the flavor compounds in this work, one of either trend could be observed. Firstly, some aroma present at the start of fermentation were no longer detectable as the fermentation progressed suggesting that they had been broken down or converted to other compounds through microbial activity or chemical reactions. Secondly, some compounds not present at the start of fermentation were built up during fermentation with usually a steady increase in the concentration. These also could be attributed to microbial activity and chemical reaction with other compounds. Third, after drying, some compounds were lost, formed or were found to be higher in the dried samples. Their higher concentrations were the consequence of continuing microbial metabolic or enzymic activities during drying.

CONCLUSION

The results indicated that processing cassava roots by soaking, heap fermentation and drying gave cassava products with different flavor compounds. This was due to different microorganisms present in their processing. The predominant flavor compounds in non-fermented cassava flour and in dried Inyange were the same but differed from those in dried Ikivunde. The increase in concentration of existing flavor compounds and the formation of new ones in dried Ikivunde and Inyange demonstrated that the microbial activities continue during drying.

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