Effects of Air Drying Conditions on the Chemical, Pasting and Sensory Properties of *Fufu*, a Fermented Cassava Product

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ABSTRACT

The effect of air drying conditions on the acidity, volatile compounds, pasting and sensory properties of *fufu* was investigated using Response Surface Methodology. *Fufu* samples were dried at various temperatures (45-65°C), air velocities (2-4 m/s) and relative humidities (40-80%). The identified volatile compounds of fresh *fufu* were butanol, dimethyl-N-N-formamide, acetic acid, propionic acid, 2-ethyl-1-hexanol and butanoic acid. The optimum conditions for drying of *fufu* were 65°C, 4 m/s and 60%RH. These conditions reduced the concentrations of butanoic acid but increased the concentrations of other identified volatile constituents of wet *fufu*. The *fufu* with most acceptable organoleptic properties was that dried at temperature of 65°C, air velocity of 2m/s and relative humidity of 60%. The implications of these findings to cassava processors and consumers in West Africa are discussed.

INTRODUCTION

Fufu is a fermented wet-paste processed from cassava (*Manihot esculenta* Crantz) that is very common in Nigeria (Sanni *et al.* 1998). It is traditionally sold in the wet form (moisture content about 50%) which renders it highly perishable. One approach to improving the shelf life and marketability of *fufu* is to produce a dried product.

Okpokiri *et al.* (1985) reported that a good quality dried product was produced when wet *fufu* was dried in the oven at 55°C for the first 8 hours, thereafter increasing the drying temperature to 80°C. Drying of *fufu* in an oven at 60°C for 48 hours reduced its strong odour but the product was sticky, bland and unacceptable compared to the fresh product (Akingbala *et al.* 1991). A system of controlled drying that would retain the desirable qualities of *fufu* is required.

This paper summaries studies to optimise drying variables, such as temperature, air velocity and air moisture content, using as indices desirable *fufu* quality parameters.

MATERIALS AND METHODS

Raw materials and location of experiments

Waxed imported cassava from Costa Rica was used in drying experiments that were conducted in the laboratories of NRI in the UK. Dried *fufu* from this cassava was compared with fresh *fufu* prepared in Nigeria in sensory evaluation studies.

Preparation of dried *fufu*

Wet *fufu* was produced according to the method of Sanni *et al.* (1998). The wet *fufu* was divided into 19 lots and packed into stomacher bags (MS805, Seward, England) and stored at 4°C prior to drying. The effect of drying was included as a factor in the statistical analysis. The *fufu* lots were dried in an experimental air-drying rig (Cox 1993) under combinations of the following conditions: air temperature 45, 55, and 65°C; relative humidity 40, 60, and 80%; and air velocity 2, 3, and 4 m/s. Instead of 27 (3^3) possible experiments, these treatments were reduced to 12 combinations with three replications of the centre points using half fractional response surface experimental design (King and Lin 1995).

Analyses

The following analyses were carried out on fresh wet *fufu* and on the dried product: total titratable acidity and pH values (Oyewole and Odunfa 1992); volatile gases (Sanni 1999); pasting properties (Mazurs *et al.* 1957); and sensory characteristics (Sanni and Akingbala 2000). The data were statistically analysed using Genstat 5 release 3.1 (IBM-PC 80386 /DOS) and Systat 5.0 (SYSTAT INC).

RESULTS AND DISCUSSION

Influence of drying conditions on the acidity and volatile components of *fufu*

Data for the volatile components and acidity of wet *fufu* and the same product dried under different conditions are shown in Tables 1 and 2 respectively. The drying process caused a reduction in acidity (0.28 - 0.48 g/kg lactic acid) that was reflected in increased pH values.

In wet *fufu* butanoic acid was present at the highest concentration (46.56 μg/g dry matter of *fufu)* whereas ethyl hexanol was present at the lowest concentration (0.03 μg/g dry matter of *fufu*). There may however have been other volatile components present at concentrations less than the limit of detection.

Drying generally resulted in major losses of volatile gases (Table 2). For example, butanoic acid reduced from 46.61μg/g dry matter of *fufu* to between <0.01 and 0.12 μg/g dry matter of *fufu* at the end of the drying process. This is a desirable effect, as butanoic acid, propionic acid and acetic acid are thought to be responsible for the offensive odour in wet *fufu* (Ohochuku 1985).

The optimum drying conditions for each variable measured during *fufu* drying are presented in Table 3. Temperature had an important effect on pH while titratable acidity was affected by the three drying variables. Storage days of wet *fufu* before drying were also observed to have strong influence on the titratable acidity. There was very strong evidence of an interaction between temperature and velocity for butanoic acid (R^2 = 90.5 %), followed by dimethyl formamide (52.8%), and acetic acid (37.3%). For butanol, the response to temperature was not linear and it was affected by the level of air moisture (R^2 = 44.9 %) (Table 3).

Since the objective is to reduce the unpleasant smell of *fufu*, the best air drying conditions to achieve this area temperature of 65°C, an air velocity of 4m/s and relative humidity of 40%RH.

Influence of drying conditions on the pasting characteristics of *fufu*

The pasting characteristics of wet *fufu,* and of dried *fufu* prepared under selected drying conditions, are presented in Table 4. Dried *fufu* exhibited higher peak viscosity (500-950 BU) compared to wet *fufu* (280 BU), showing higher starch granular disruption by drying. The viscosity at 50°C of dried *fufu* ranged between 630 and 860 BU compared to 900 BU for wet *fufu*. This is an indication of high retrogradation tendencies for some dried samples compared to the wet product. The wet *fufu* exhibited a good level of cold paste stability when held at 50°C for 30 minutes. Similar degrees of paste stabilities were obtained for samples dried at 65°C, 3m/s or 4m/s and relative humidities of 80% or 60%. *Fufu* dried under other drying combinations had a much lower level of cold paste stability and this would result in a less firm product, which is likely not to appeal to consumers.

As shown in Table 5, the percentage of association for peak viscosity was very low at 28.7%. The three-dimensional diagram for the peak viscosity against drying conditions of dried *fufu* (Figure 1) highlights the stronger influence of relative humidity compared to other conditions.

There is strong evidence ($p < 0.05$) that temperature, air moisture and storage period before drying affected the value of viscosity at 50°C ($R^2 = 80.3$ %). There was evidence that only temperature and storage period affected viscosity at 50°C for 30 minutes.

Retaining the firmness of cooked dried *fufu,* which desirable to consumers, as measured by viscosity on cooling at 50°C, requires control of air drying temperature and relative humidity of the dryer, and of course, the freshness of wet *fufu* before drying.

Sensory evaluation of dried *fufu*

Based on the findings from chemical and pasting results above, sensory analyses were conducted on selected dried *fufu* samples. Wet *fufu* made in Nigeria from a low-cyanogen cassava was assessed along with selected *fufu* samples made in UK. The mean sensory scores of wet and dried *fufu* products in the form of paste are presented in Table 6. Generally, there were significant differences between wet and dried *fufu* samples in terms of the sensory qualities assessed ($P<0.05$). Panellists preferred dried *fufu* samples to the wet *fufu* sample. Reasons for these differences may be due to differences in drying conditions or differences in the raw material. However, informal discussions with panellists indicated that this was due to the reduction in the level of offensive odour in the dried product. This was corroborated by the instrumental results that indicated a reduction in volatiles.

There were also significant differences among the dried *fufu* samples. From the results, *fufu* samples dried at temperature of 65°C, air velocity of 2 m/s and relative humidity of 60% had the highest mean scores for all the sensory attributes except texture.

There is a good relationship between the sensory characteristics and the other variables measured for dried *fufu*. For instance, as there was a significant difference in the sensory texture of dried *fufu* (Table 6), there are also variations in viscosities of *fufu* cooled to 50°C and viscosities at 50°C after holding for 30 minutes (Table 4).

CONCLUSIONS

For titratable acidity, volatile components and pasting properties, the optimum drying conditions for *fufu* are a temperature of 65°C, air velocity of 4 m/s, and relative humidity of 80%. However *fufu* dried at 65°C, 2 m/s air velocity and 60% relative humidity was more acceptable in sensory studies. The factors that make a food acceptable to a consumer are complex, but from the results presented in this paper it is clear that reducing the levels of volatiles and maintaining values of viscosity on cooling are important for improving the acceptability of the product.

The use of a higher temperature for drying (65°C being better in this case than lower temperatures tested) and higher levels of humidity (60-80% rather than 40%) would appear to give a more acceptable product. The use of higher temperatures may cause problems because of the gelatinisation temperature of the starch.

If *fufu* processing is to be commercialised through the production of a dried product, then it is clearly necessary to gain a greater understanding of the kinetics of the process. The general principles that have been established in this paper together with specific equations may assist processing operations to predict the properties of their end products.

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Table 1. Volatile compounds and acidity of wet *fufu.*

Volatile component	Retention time (min.)	Concentration (μg/g dry matter *fufu*)
1-butanol	8.56	1.12 ± 0.1
Dimethyl [N,N] formamide	12.63	8.04 ± 1.4
Acetic acid	17.60	2.24 ± 0.1
2-ethyl-1-hexanol	18.98	0.03 ± 0.0
propionic acid	20.75	0.08 ± 0.0
butanoic acid	23.71	46.56 ± 0.0
pH	n.a.	3.64 ± 0.0
Titratable acidity (Lactic acid, g/Kg)	n.a.	0.65 ± 0.0

± Standard deviations (duplicate determinations). n.a., not applicable

Table 2. Effect of drying conditions on acidity and volatile compounds of dried *fufu*

Drying conditions	Acidity		Volatile Components (μg/g dry matter *fufu* weight)					
	pH	TTA	A	B	C	D	E	F
65°C 3m/s 80%RH	3.9	0.4	0.08	1.1	0.04	0.08	0.01	0.02
65°C 4m/s 60%RH	3.8	0.5	0.13	1.2	0.03	<0.01	<0.01	0.01
65°C 2m/s 60%RH	3.8	0.4	0.06	1.03	0.05	0.1	<0.01	0.1
65°C 3m/s 40%RH	3.9	0.4	0.07	1.17	0.06	<0.01	<0.01	<0.01
55°C 4m/s 80%RH	4.3	0.4	0.07	1.16	0.06	0.01	<0.01	0.01
55°C 4m/s 40%RH	4.3	0.3	0.06	1.04	0.06	<0.01	<0.01	0.01
55°C 2m/s 80%RH	4.2	0.4	0.06	1.11	0.05	0.01	<0.01	0.02
55°C 2m/s 40%RH	4.3	0.3	0.06	1.14	0.05	0.01	<0.01	<0.01
45°C 3m/s 80%RH	4.5	0.3	0.05	1.03	0.09	0.01	<0.01	0.04
45°C 2m/s 60%RH	4.2	0.4	0.07	1.15	0.05	<0.01	<0.01	0.01
45°C 4m/s 60%RH	5.4	0.3	0.09	1.08	0.05	0.01	<0.01	0.12
45°C 3m/s 60%RH	4.0	0.4	0.13	1.20	0.07	0.01	0.01	0.01
55°C 3m/s 60%RH	3.9	0.4	0.08	1.17	0.07	0.01	0.01	0.06

TTA, Titratable acidity (g/kg lactic acid). A, Butanol; B, Dimethyl formamide; C, Acetic acid; D, 2-ethyl-1-hexanol; E, Propionic acid; F, Butanoic acid.

Table 3. Optimum drying conditions for acidity and volatile components of *fufu*.

Variable	Relationships to drying conditions	Coefficient of determinations R^2	Optimum drying conditions		
			Temp (°C)	Air velocity (m/s)	Rel. Humid. (%)
PH	= 6.109 - 0.0353 (T)	37.0%	65		
Titratable acidity	= 2.185- 0.04647(T) + 0.0472(S) – 00058(S^2) – 143.3 (RH) +2.447 (T)(RH) – 0.2082 (V) + 0.003696(T) (V)	90.4%	65	4	8
Butanol	= 23.83 + 0.241(V) -0.619(T) + 0.0037 (T^2) – 723 (RH)+ 12.37 (T)(RH)	44.9%	45 (Minimised)	4	40
DMF	= 2.3 - 0.285(T) + 4144 (RH) – 124800(RH^2) - 5.04 (V) + 0.0912 (T)(V)	37.3%	45	2	60
Acetic acid	=- 6.87 + 2.030 (V)- 0.342 (V^2) + 0.206 (T) - 0.00202 (T^2).	52.8%	51	3	
2-ethyl 1-hexanol	= 2.036 - 0.0401 (S).				
Butanoic acid	=- 9.79 + 1819 (RH) - 53063 (RH^2) - 0.333 (T) + 0.00539 (T^2) + 2.595 (V) + 0.409 (V^2) - 0.0913 (V)(T).	90.5%	65 (Minimised) 45 (Maximised)	4 4	40 49

T, Temperature; V, Velocity; RH, Relative humidity; S, Storage days before drying.

Table 4. Effect of drying conditions on the pasting properties of *fufu*.

Drying conditions	Pasting temp (°C)	Peak Viscosity (BU)	Viscosity at 95°C (BU)	Viscosity at 95°C for 20 min (BU)	Viscosity at 50°C (BU)	Viscosity at 50°C for 30 minutes (BU)
Fresh	71 (0.0)*	280 (21.2)	260 (21.2)	350 (0.0)	900 (63.6)	880 (28.3)
65°C 3m/s 80%RH	70 (0.0)	785 (63.6)	750 (14.1)	565 (35.4)	630 (42.4)	595 (35.4)
65°C 4m/s 60%RH	76 (1.4)	740 (28.3)	740 (28.3)	585 (7.1)	655 (7.1)	620 (0.0)
65°C 2m/s 60%RH	70 (0.0)	770 (42.4)	770 (42.4)	615 (35.4)	700 (14.1)	650 (14.1)
65°C 3m/s 40%RH	70 (0.4)	950 (70.7)	950 (70.7)	690 (14.1)	770 (14.1)	710 (14.1)
55°C 4m/s 80%RH	71 (0.2)	810 (14.1)	810 (14.1)	680 (0.0)	800 (0.0)	740 (0.0)
55°C 4m/s 40%RH	81 (0.0)	780 (0.0)	780 (0.0)	640 (0.0)	780 (0.0	700 (28.3)
55°C 2m/s 80%RH	69 (2.0)	890 (14.1)	890 (14.1)	730 (14.1)	860 (0.0)	730 (14.1)
55°C 2m/s 40%RH	70 (0.4)	860 (0.0)	860 (0.0)	745 (7.1)	820 (0.0)	720 (0.0)
45°C 3m/s 80%RH	71 (0.9)	755 (7.1)	755 (7.1)	700 (0.0)	830 (14.1)	700 (0.0)
45°C 2m/s 60%RH	71 (1.3)	800 (0.0)	800 (0.0)	720 (0.0)	790 (14.1)	695 (7.1)
45°C 4m/s 60%RH	80 (0.3)	500 (0.0)	500 (0.0)	480 (0.0)	700 (0.0)	635 (7.1)
45°C 3m/s 60%RH	70 (0.0)	810 (14.1)	810 (14.1)	710 (14.1)	770 (14.1)	690 (14.1)
55°C 3m/s 60%RH	70 (0.0)	820 (0.0)	820 (0.0)	700 (28.3)	770 (14.1)	700 (0.0)

* Mean (Standard Deviation).

BU, Brabender Units.

Table 5. Optimum drying conditions for each pasting property measured in dried *fufu*.

Pasting property	**Relationships to drying conditions**	**Coefficient of determinations** R^2	**Optimum drying conditions**		
			Temp (°C)	**Vel (m/s)**	**Rel Hum (%)**
Pasting temperature (°C)	$= 59.8 - 4.72 (V) + 3.56 (V^2) + 1892(RH) - 789 (RH)(V)$.	76.8 %		4 m / s	40%
Peak viscosity (BU)	$= 4243 - 61.2 (V) - 391088 (RH) + 11500000 (RH^2)$.	28.7 %		2 m / s	40%
Viscosity at 95°C	$= 947 - 61.2 (V)$	16.0 %		2 m / s	
Viscosity at 95°C for 20 minutes holding (BU)	$= -264 - 342 (V) + 58.6 (T) - 0.694 (T^2) + 5.25 (T)(V)$	56.9 %	45°C	2 m / s	
Viscosity at 50°C	$= 904 + 5.80 (T) - 298681 (RH) + 9372292 (RH^2) + 80.4 (S) - 0.828 (S^2)$	80.3 %	65°C		80%
Viscosity at 50°C holding for 30 min (BU)	$= -1354 + 51.8 (T) - 0.470 (T^2) + 29.5 (S) - 0.330 (S^2)$	57.4 %	55.1°C		

T, Temperature; V, Velocity; RH, Relative humidity; S, Storage days before drying.

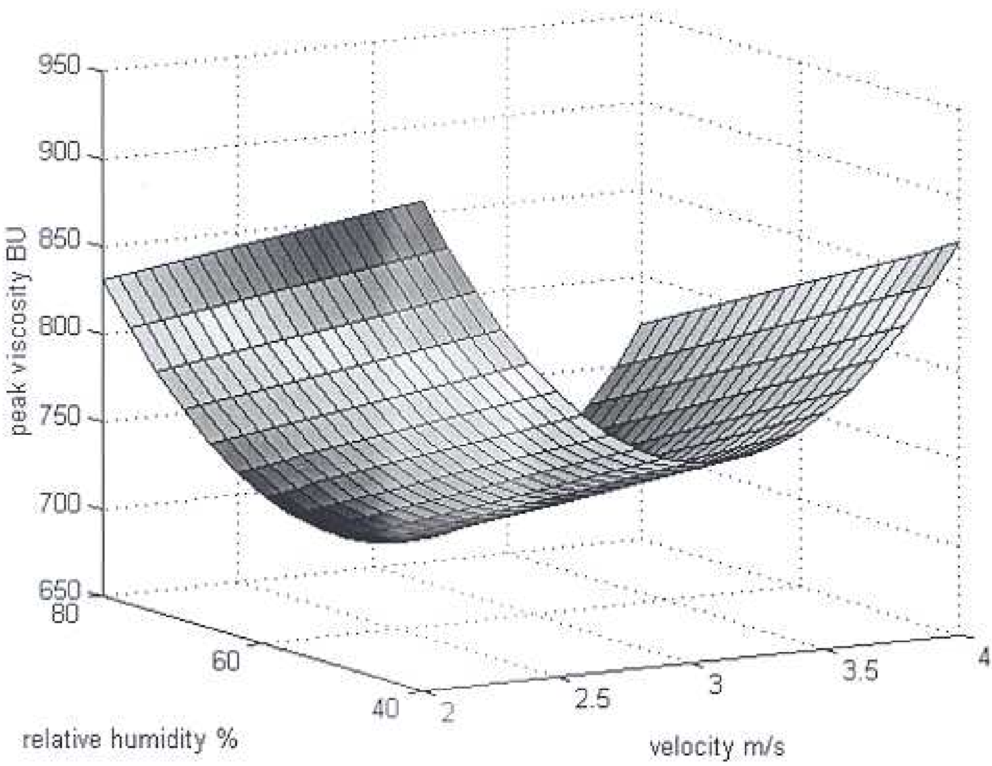

Figure 1. Three-dimensional diagram showing the peak viscosity (BU) as a function of relative humidity and velocity for dried *fufu*.

Table 6. Mean sensory evaluation scores for samples of fufu dried under different conditions.

Drying Treatment	Mean sensory evaluation score*				
	Colour	Taste	Odour	Texture	Acceptability
65°C 4 m/s 60%RH	5.89b	5.33c	5.78b	5.89b	5.22b
65°C 2 m/s 60%RH	7.22a	6.44a	6.89a	6.56a	7.22a
55°C 3 m/s 60%RH	6.56b	5.11b	5.78b	6.78a	6.67b
55°C 2 m/s80%RH	5.67b	4.89c	5.33b	5.33b	5.89b
45°C 4 m/s 60%RH	5.56b	6.00a	5.67b	5.44b	5.78b
45°C 2 m/s 60%RH	5.11b	6.11a	5.56b	6.44a	5.44b
Control (wet *fufu*)	3.89c	4.33c	4.67c	4.67c	4.11c

Mean scores followed by the same letters are not significantly different ($P < 0.05$).

* Values ranged from 0 (low acceptability) to 10 (high acceptability).